Common Structural Rules for Double Hull Oil Tankers, July 2010

Rule Change Notice 1

(1 July 2010 consolidated edition)

Notes:

(1) These Rule Changes enter into force on 1st July 2012.

(2) The Rule amendments in this document are applicable to the Common Structural Rules for Double Hull Oil Tankers, July 2010.

COMMON STRUCTURAL RULES FOR DOUBLE HULL OIL TANKERS, JULY 2010

RULE CHANGE NOTICE 1

This notice contains amendments within the following Sections of the Common Structural Rules for Double Hull Oil Tankers, July 2010. The amendments are effective on the dates shown:

Section	Paragraph/Figure/Table	Effective Date
Section 4	2.6.3.6	1 July 2012
Section 4	3.2.5.1	1 July 2012
Section 4	3.4.1.4	1 July 2012
Section 6	1.2.3.1	1 July 2012
Section 6	Table 6.1.3	1 July 2012
Section 6	2.1.1.2	1 July 2012
Section 6	Figure 6.3.1	1 July 2012
Section 6	4.1.2.3	1 July 2012
Section 7	Table 7.6.1	1 July 2012
Section 8	1.1.2.2	1 July 2012
Section 8	1.2.2.2	1 July 2012
Section 8	1.3.2.2	1 July 2012
Section 8	1.3.4.1	1 July 2012
Section 8	1.6.3.1	1 July 2012
Section 8	2.5.7.9	1 July 2012
Section 8	Table 8.2.3	1 July 2012
Section 8	6.3.7.5	1 July 2012
Section 8	6.4.5.1	1 July 2012
Section 8	6.4.7.5	1 July 2012
Section 9	1.1.1.2	1 July 2012
Section 9	2.3.1.1	1 July 2012
Section 9	2.4.5.5	1 July 2012
Section 10	1.1.1.4	1 July 2012
Section 11	Table 11.1.6	1 July 2012
Section 11	Figure 11.1.3	1 July 2012
Section 11	4.1.1.1	1 July 2012
Section 11	5.1.5.1	1 July 2012
Section 11	Table 11.5.1	1 July 2012
Appendix A	Miscellaneous paragraphs	1 July 2012
Appendix B	2.4.7.7 and 2.4.7.9	1 July 2012

Section	Paragraph/Figure/Table	Effective Date
Appendix B	2.5.1.2	1 July 2012
Appendix B	2.5.2.1	1 July 2012
Appendix B	2.5.3.2	1 July 2012
Appendix C	1.4.4.20	1 July 2012

This notice contains editorial amendments within the following Sections of the Common Structural Rules for Double Hull Oil Tankers, July 2010.

Section	Paragraph/Figure/Table	Type
Section 6	Figure 6.3.1	Editorial

For technical background for Rule Changes in this present document, reference is made to separate document Technical Background for Rule Change Notice 1.

SECTION 4 - BASIC INFORMATION

2.6 Geometrical Properties of the Hull Girder Cross-Section

2.6.3 Effective area for calculation of hull girder moment of inertia and section modulus

2.6.3.6 When several openings are located in or adjacent to the same cross-section, the total equivalent breadth of the combined openings, Σb_{ded}, is to be deducted, see *2.6.3.7* to ~~*2.3.6.8*~~ *2.6.3.8* and *Figure 4.2.18*.

3.2.5 Sniped ends

3.2.5.1 Stiffeners with sniped ends may be used where dynamic loads are small and where the incidence of vibration is considered to be small, i.e. structure not in the stern area and structure not in the vicinity of engines or generators, provided the net thickness of plating supported by the stiffener, $t_{p\text{-}net}$, is not less than:

$$t_{p-net} = c_1 \sqrt{\left(1000l - \frac{s}{2}\right)\frac{sPk}{10^6}}$$

Where:

l stiffener span, in m

s stiffener spacing, in mm, as defined in *2.2*

P design pressure for the stiffener for the design load set being considered, in kN/m². The design load sets and method to derive the design pressure are to be taken in accordance with the following criteria, which define the acceptance criteria set to be used:

a) Table 8.2.5 in the cargo tank region

b) Section 8/3.9.2.2 in the area forward of the forward cargo tank, and in the aft end

c) Section 8/4.8.1.2 in the machinery space

d) Section 8/6.2.4.1 and 6.2.5.3 as applicable for the particular structure under consideration

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

c_1 coefficient for the design load set being considered, to be taken as:

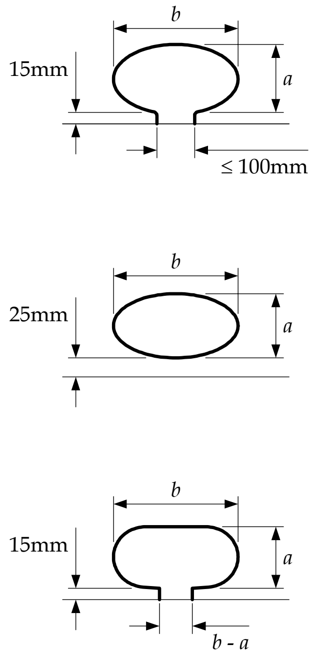
=1.2 for acceptance criteria set AC1 and sloshing design load

=1.1 for acceptance criteria set AC2

3.2.6 Air and drain holes and scallops

3.2.6.1 Air~~,~~ and drain holes~~,~~ and scallops ~~and block fabrication butts~~ are to be kept at least 200mm clear of the toes of end brackets, end connections and other areas of high stress concentration measured along the length of the stiffener toward the mid-span and 50mm measured along the length in the opposite direction. See *Figure 4.3.2(b)*. Openings that have been fitted with closing plates, such as scallops, may be permitted in way of block fabrication butts. In areas where the shear stress is less than 60 percent of the allowable limit, alternative arrangements may be accepted. Openings are to be well-rounded. *Figure 4.3.2(a)* shows some examples of air and drain holes and scallops. In general, the ratio of a/b, as defined in *Figure 4.3.2(a)*, is to be between 0.5 and 1.0. In fatigue sensitive areas further consideration may be required with respect to the details and arrangements of openings and scallops.

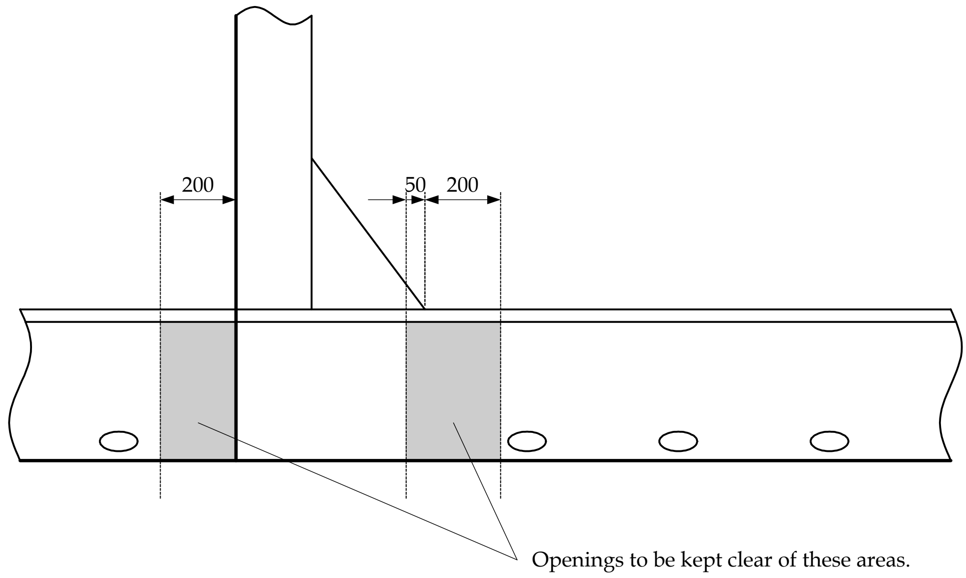
Figure 4.3.2(a)
Examples of Air and Drain Holes and Scallops



Note

The details shown in this figure are for guidance and illustration only.

Figure 4.3.2(b)
Location of Air and Drain Holes



3.4 Intersections of Continuous Local Support Members and Primary Support Members

3.4.1 General

3.4.1.4 When, in the following locations, the calculated direct stress, σ_w, in the primary support member web stiffener according to *3.4.3.5* exceeds 80% of the permissible values a soft heel is to be provided in way of the heel of primary support member web stiffeners:

(a) connection to shell envelope longitudinals below the scantling draught, T_{sc}

(b) connection to inner bottom longitudinals.

A soft heel is not required at the intersection with watertight bulkheads <u>and primary support members</u>, where a back bracket is fitted or where the primary support member web is welded to the stiffener face plate. The soft heel is to have a keyhole, similar to that shown in *Figure 4.3.6(c)*.

SECTION 6 - MATERIALS AND WELDING

1 STEEL GRADES

1.2 Application of Steel Materials

1.2.3 Operation in areas with low air temperature

1.2.3.1 For ships intended to operate for long periods in areas with a ~~lowest daily mean air temperature~~ lowest mean daily average temperature below –10 degrees C (i.e. regular service during winter to Arctic or Antarctic waters) the materials in exposed structures will be specially considered.

Table 6.1.3
Material Class or Grade of Structural Members

Structural member category	**Material Class or Grade**	
	Within 0.4*L* Amidships	**Outside 0.4*L***
Secondary Longitudinal bulkhead strakes, other than those belonging to primary category Deck plating exposed to weather other than that belonging to primary or special category Side plating	Class I	Grade A(8)/AH
Primary Bottom plating including keel plate Strength deck plating, excluding that belonging to the special category (10) (11) Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings (11) Uppermost strake in longitudinal bulkheads (10) Vertical strake (hatch side girder) and upper sloped strake in top wing tank	Class II	Grade A(8) /AH
Special Sheer strake at strength deck (1)(2)(3)(10) (11) Stringer plate in strength deck (1)(2)(3)(10) (11) Deck strake at longitudinal bulkhead, excluding deck plating in way of inner hull longitudinal bulkhead (2)(4)(10) (11) Strength deck plating at outboard corners of cargo hatch openings (11) Bilge strake (2)(6) Continuous longitudinal hatch coamings (11)	Class III	Class II (Class I outside 0.6*L* amidships)
Other Categories Plating for stern frames, rudder horns and shaft brackets	–	Class II
Longitudinal strength members of strength deck plating for ships with single strength deck (11)	Grade B / AH	-
Strength members not referred to in above categories (9)	Grade A(8) / AH	Grade A(8) /AH

Note

1. Not to be less than E/EH within 0.4*L* amidships in vessels with length, *L*, exceeding 250m.
2. Single strakes required to be of material class III or E/EH are, within 0.4*L* amidships, to have breadths not less than 800 + 5*L* mm, but need not be greater than 1800mm.
3. A radius gunwale plate may be considered to meet the requirements for both the stringer plate and the sheer strake, provided it extends generally 600mm inboard and vertically.
4. For tankers having a breadth, *B*, exceeding 70m, the centreline strake and the strakes in way of the longitudinal bulkheads port and starboard, are to be class III.
5. (void)
6. To be not lower than D/DH within 0.6*L* amidships of vessels with length, *L*, exceeding 250m.
7. (void)
8. Grade B/AH to be used for plate thickness more than 40 mm. For engine foundation heavy plates, Grade B/AH to be used for plate thickness more than 30mm. However, engine foundation heavy plates outside 0.6*L* amidships may be of Grade A/AH.
9. The material class used for reinforcement and the quality of material (i.e. whether normal or higher strength steel) used for welded attachments, such as spill protection bars and bilge keel, is to be similar to that of the hull envelope plating in way. Where attachments are made to round gunwale plates, special consideration will be given to the required grade of steel, taking account of the intended structural arrangements and attachment details.
10. The material class for deck plating, sheer strake and upper strake of longitudinal bulkhead within 0.4*L* amidships is also to be applied at structural breaks of the superstructure, irrespective of position.
11. To be not lower than B/AH within 0.4*L* amidships for ships with single strength deck.

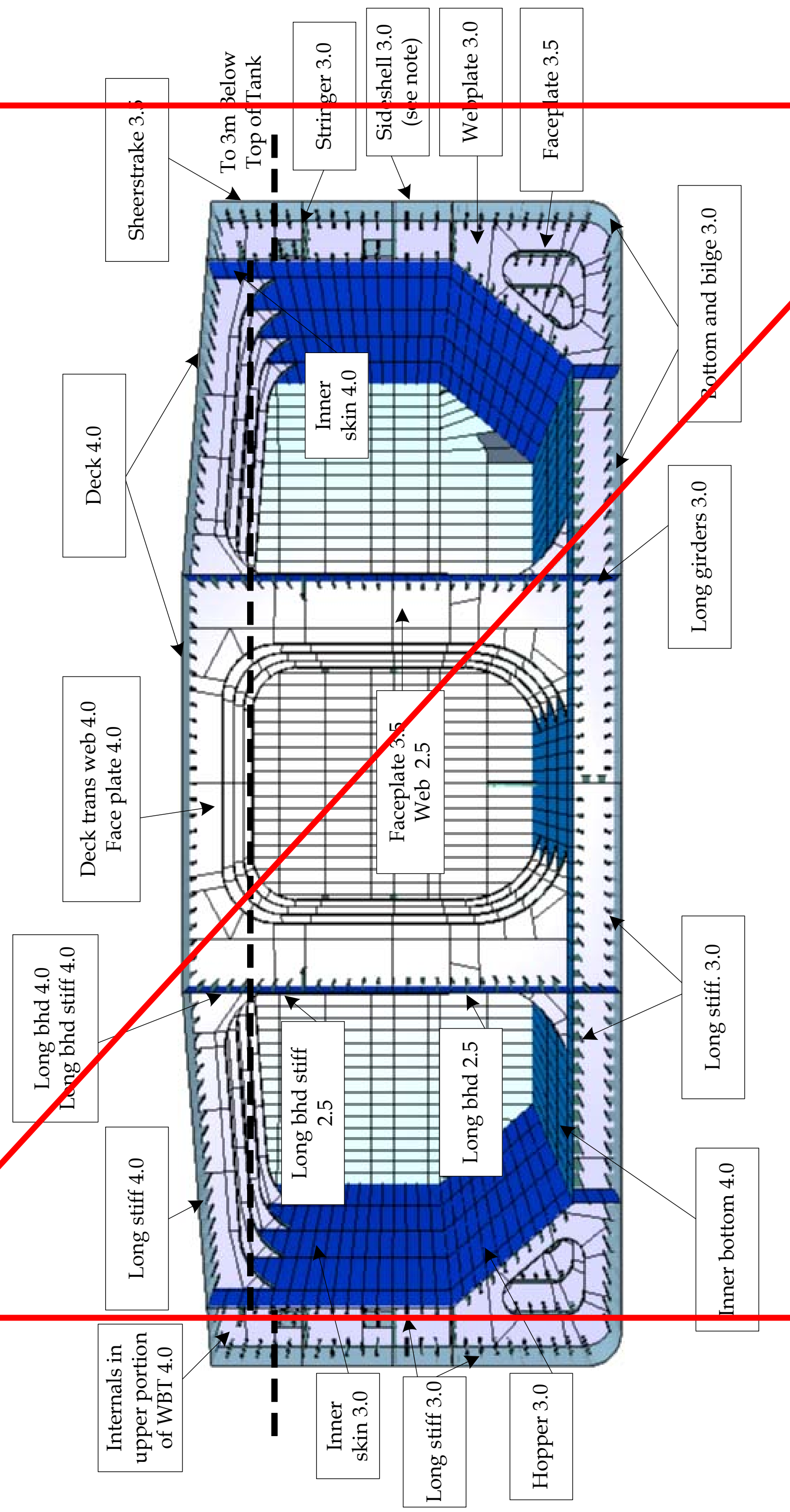
2.1 Hull Protection

2.1.1.2 For ships contracted for construction on or after 8 December 2006, the date of IMO adoption of the amended SOLAS Regulation II-1/3-2, by which an IMO "Performance standard for protective coatings for ballast tanks and void spaces" will be made mandatory, the coatings of internal spaces subject to the amended SOLAS Regulation are to satisfy the requirements of the IMO performance standard. For ships contracted for construction on or after 1 July 2012, the IMO performance standard is to be applied as interpreted by IACS UI SC 223 and UI SC 227. In applying IACS UI SC 223, "Administration" is to be read to be the "Classification Society".

3 CORROSION ADDITIONS

Figure 6.3.1

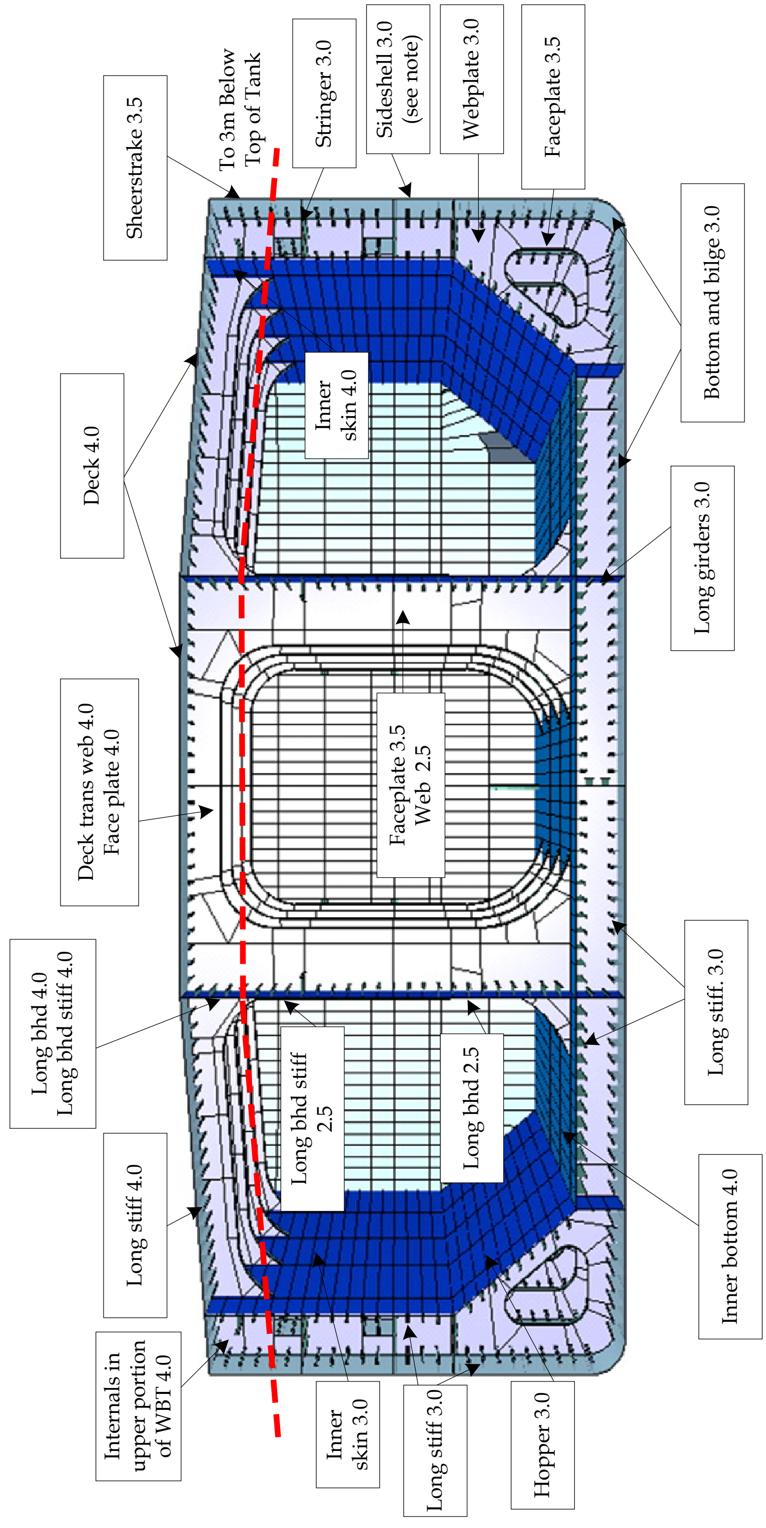
Corrosion Addition, t_{corr}, for Typical Structural Elements Within the Cargo Tank



Note

1. Corrosion additions are given for a standard configuration and without heated cargo
2. 0.5mm to be added for side plating in the quay contact region defined in *Section 8/Figure 8.2.2*

Figure 6.3.1
Corrosion Addition, t_{corr}, for Typical Structural Elements Within the Cargo Tank



Note
1. Corrosion additions are given for a standard configuration and without heated cargo
2. 0.5mm to be added for side plating in the quay contact region defined in *Section 8/Figure 8.2.2*

New Note

3. The distance 3m below top of tank is to be measure parallel to the deck.

4 FABRICATION

4.1 General

4.1.2 Fabrication standard

4.1.2.3 The fabrication standard is to include information, to establish the range and the tolerance limits, for the items specified as follows:

(a) Cutting edge

- the slope of the cut edge and the roughness of the cut edges

(b) Flanged longitudinals and brackets and built-up sections

- the breadth of flange and depth of web, angle between flange and web, and straightness in plane of flange or at the top of face plate

(c) Pillars

- the straightness between decks, and cylindrical structure diameter

(d) Brackets and small stiffeners

- the distortion at the free edge line of tripping brackets and small stiffeners

(e) Sub-assembly stiffeners

- details of snipe end of secondary face plates and stiffeners

(f) Plate assembly

- for flat and curved blocks the dimensions (length and breadth), distortion and squareness, and the deviation of interior members from the plate

(g) Cubic assembly

- in addition to the criteria for plate assembly, twisting deviation between upper and lower plates, for flat and curved cubic blocks

(h) Special assembly

- the distance between upper and lower gudgeons, distance between aft edge of propeller boss and aft peak bulkhead, twist of stern frame assembly, deviation of rudder from shaft centreline, twist of rudder plate, and flatness, breadth and length of top plate of main engine bed. Where ~~The final~~ boring out of the propeller boss and stern frame, skeg or solepiece is carried out at a late stage of construction, it is to be carried out after completing the major part of the welding of the aft part of the ship. Where block boring is used, the shaft alignment is to be carried out using a method and sequence submitted to and recognized by the Classification Society. ~~, and t~~The fit-up and alignment of the rudder, pintles and axles, are to be carried out after completing the major part of the welding of the aft part of the ship. The contacts between the conical surfaces of pintles, rudder stocks and rudder axles are to be checked before the final mounting.

(i) Butt joints in plating

- alignment of butt joint in plating

(j) Cruciform joints

- alignment measured on the median line and measured on the heel line of cruciform joints

(k) Alignment of interior members

- alignments of flange of T longitudinals, alignment of panel stiffeners, gaps in T joints and lap joints, and distance between scallop and cut outs for continuous stiffeners in assembly and in erection joints

(l) Keel and bottom sighting

- deflections for whole length of the ship, and for the distance between two adjacent bulkheads, cocking-up of fore body and of aft body, and rise of floor amidships

(m) Dimensions

- dimensions of length between perpendiculars, moulded breadth and depth at midship, and length between aft edge of propeller boss and main engine

(n) Fairness of plating between frames

- deflections between frames of shell, tank top, bulkhead, upper deck, superstructure deck, deck house deck and wall plating

(o) Fairness of plating in way of frames

- deflections of shell, tank top, bulkhead, strength deck plating and other structures measured in way of frames

SECTION 7 - LOADS

6 COMBINATION OF LOADS

6.2 Design Load Combination

6.2.1 General

6.2.1.1 The design load combinations are given in *Table 7.6.1*.

Table 7.6.1
Design Load Combinations

Load components \ Design Load Combination		S	S + D	A
$M_{v\text{-}total}$		$M_{sw\text{-}harb}$	$M_{sw\text{-}sea} + M_{wv}$	-
$M_{h\text{-}total}$		-	M_h	-
Q		$Q_{sw\text{-}harb}$	$Q_{sw\text{-}sea} + Q_{wv}$	-
P_{ex}	**Weather Deck**	-	$P_{wdk\text{-}dyn}$	-
	Hull envelope	P_{hys}	$P_{hys} + P_{wv\text{-}dyn}$	-
P_{in}	**Ballast tanks (BWE with sequential filling method)**	the greater of a) $P_{in\text{-}test}$ b) $P_{in\text{-}air} + P_{drop}$	$P_{in\text{-}tk} + P_{in\text{-}dyn}$	$P_{in\text{-}flood}$
	Ballast tanks (BWE with flow-through method)	the greater of a) $P_{in\text{-}test}$ b) $P_{in\text{-}air} + P_{drop}$	$P_{in\text{-}air} + P_{drop} + P_{in\text{-}dyn}$	$P_{in\text{-}flood}$
	Cargo tanks including cargo tanks designed for filling with water ballast	the greater of a) $P_{in\text{-}test}$ b) $P_{in\text{-}tk} + P_{valve}$	~~$P_{in\text{-}tk} + P_{in\text{-}dyn}$~~ $P_{in\text{-}tk} + P_{valve} - 25 + P_{in\text{-}dyn}$	-
	Other tanks with liquid filling	the greater of a) $P_{in\text{-}test}$ b) $P_{in\text{-}air}$	$P_{in\text{-}tk} + P_{in\text{-}dyn}$	$P_{in\text{-}flood}$
	Watertight boundaries	-	-	$P_{in\text{-}flood}$
P_{dk}	**Internal decks for dry spaces**	P_{stat}	$P_{stat} + P_{dk\text{-}dyn}$	-
	Decks for heavy units	F_{stat}	$F_{stat} + F_{dk\text{-}dyn}$	-

Table 7.6.1 (Continued)
Design Load Combinations

Note:

1. Separate load requirements may be specified in strength assessment (FEM) and scantling requirements.

Where:

$M_{v\text{-}total}$	design vertical bending moment, in kNm	
$M_{sw\text{-}perm\text{-}harb}$	permissible hull girder hogging and sagging still water bending moment envelopes for harbour/sheltered water operation, in kNm	see *2.1.1*
$M_{sw\text{-}perm\text{-}sea}$	permissible hull girder hogging and sagging still water bending moment envelopes for seagoing operation, in kNm	see *2.1.1*
M_{wv}	vertical wave bending moment for a considered dynamic load case, in kNm	see *6.3.2.1*
$M_{h\text{-}total}$	design horizontal bending moment, in kNm	
M_h	horizontal wave bending moment for a considered dynamic load case, in kNm	see *6.3.3.1*
Q	design vertical shear force, in kN	
$Q_{sw\text{-}perm\text{-}harb}$	permissible hull girder positive and negative still water shear force limits for harbour/sheltered water operation, in kN	see *2.1.3*
$Q_{sw\text{-}perm\text{-}sea}$	permissible hull girder positive and negative still water shear force limits for seagoing operation, in kN	see *2.1.3*
Q_{wv}	vertical wave shear force for a considered dynamic load case, in kN	see *6.3.4.1*
P_{ex}	design sea pressure, in kN/m^2	
P_{hys}	static sea pressure at considered draught, in kN/m^2	see *2.2.2.1*
$P_{wv\text{-}dyn}$	dynamic wave pressure for a considered dynamic load case, in kN/m^2	see *6.3.5*
$P_{wdk\text{-}dyn}$	green sea load for a considered dynamic load case, in kN/m^2	see *6.3.6*
P_{in}	design tank pressure, in kN/m^2	
$P_{in\text{-}test}$	tank testing pressure, in kN/m^2	see *2.2.3.5*
$P_{in\text{-}air}$	static tank pressure in the case of overfilling or filling during flow through ballast water exchange, in kN/m^2	see *2.2.3.2*
P_{drop}	added overpressure due to liquid flow through air pipe or overflow pipe, in kN/m^2	see *2.2.3.3*
P_{valve}	setting of pressure relief valve, in kN/m^2	see *2.2.3.5*
$P_{in\text{-}tk}$	static tank pressure, in kN/m^2	see *2.2.3.1*
$P_{in\text{-}dyn}$	dynamic tank pressure for a considered dynamic load case, in kN/m^2	see *6.3.7*
$P_{in\text{-}flood}$	pressure in compartments and tanks in flooded or damaged condition, in kN/m^2	see *2.2.3.4*
P_{stat}	static pressure on decks and inner bottom, in kN/m^2	see *2.2.4.1*
P_{dk}	design deck pressure, in kN/m^2	
$P_{dk\text{-}dyn}$	dynamic deck pressure on decks, inner bottom and hatch covers for a considered dynamic load case, in kN/m^2	see *6.3.8.1*
F_{stat}	load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, in kN	see *2.2.5.1*
$F_{dk\text{-}dyn}$	dynamic load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, in kN	see *6.3.8.2*

SECTION 8 - SCANTLING REQUIREMENTS

1 LONGITUDINAL STRENGTH

1.1 Loading Guidance

1.1.2 Loading Manual

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 at departure condition)
- 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 0.015*L*, where *L* is as defined in *Section 4/1.1.1*
- a heavy ballast condition where:
  - the draught at the forward perpendicular is not to be less than that for the normal ballast condition
  - ballast tanks in the cargo tank region or 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
  - the fore peak water ballast tank is to be full. If upper and lower fore peak tanks are fitted, the lower is required to be full. The upper fore peak tank may be full, partially full or empty.
  - 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
  - the trim is to be by the stern and is not to exceed 0.015*L*, where *L* is as defined in *Section 4/1.1.1*
- 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 with the calculations of the intermediate conditions just before and just after ballasting and/or deballasting any ballast tank

(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.

Guidance Note
The design condition specified in (c) is for assessment of hull strength and is not intended for ship operation. This condition will also be covered by the *IMO 73/78 SBT* condition provided the corresponding condition in the Loading Manual only includes ballast in segregated ballast tanks in the cargo tank region.

1.2.2 Minimum requirements

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

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

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~~ 1.1.9.1* but is not to be taken as less than 0.70

1.3 Assessment of hull girder shear strength

1.3.2 Hull Girder Shear Strength

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

$$Q_{sw-perm} \leq Q_{v-net50} - Q_{wv-pos} \quad \text{kN}$$

for maximum permissible positive shear force

$$Q_{sw-perm} \geq -Q_{v-net50} - Q_{wv-neg} \quad \text{kN}$$

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

$$= \frac{\tau_{ij-perm} t_{ij-net50}}{1000 q_v} \quad \text{kN}$$

$\tau_{ij-perm}$ 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. Where direct calculation of the unit shear flow is not available, the unit shear flow may be taken equal to:

$$= f_i \left(\frac{q_{1-net50}}{I_{v-net50}} \right) \cdot 10^{-9} \quad \text{mm}^{-1}$$

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 *Figure 8.1.2*

$q_{1-net50}$ first moment of area, in ~~cm^2~~ cm^3 ,about the horizontal neutral axis of the effective longitudinal members between the vertical level at which the shear stress is being determined and the vertical extremity, taken at the section being considered. 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*

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 *Figure 8.1.6*, the equivalent net thickness of plate used for calculation of the hull girder shear strength, t_{str-k}, where the index k refers to the identification number of the stringer, is not to be taken greater than:

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

Where:

$t_{sfc-net50}$ 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

$\tau_{ij-perm}$ permissible hull girder shear stress, τ_{perm}, for plate ij
$= 120/k_{ij}$ N/mm²

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

τ_{str} $= \dfrac{Q_{str-k}}{l_{str} t_{sfc-net50}}$ N/mm²

l_{str} connection length of stringer, in m, see *Figure 8.1.5*

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

$$\cancel{= 0.8F_{str-k}\left(1 - \frac{z_{str} - h_{db}}{h_{bhd}}\right)} \; \underline{= 0.8F_{str-k}\left(1 - \frac{z_{str} - h_{db}}{h_{blk}}\right)} \quad \text{kN}$$

F_{str-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 *Figure 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 *Figure 8.1.6*

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

1.6 Tapering and Structural Continuity of Longitudinal Hull Girder Elements

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 *Figure 8.1.10*.

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

$$z_{hts} = z_1\left(1 - \frac{\sigma_{perm}}{\sigma_1}\right) \quad m$$

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/mm²

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

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

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

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

σ_{perm} permissible hull girder bending stress as given in Table 8.1.3 for design load combination S+D, in N/mm²

$M_{sw-perm-sea}$ 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 m⁴, as defined in *Section 4/2.6.1.1*

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

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

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

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

2 CARGO TANK REGION

2.5 Bulkheads

2.5.7 Vertically corrugated bulkheads

2.5.7.9 For ships with a moulded depth, see *Section 4/1.1.4*, less than 16m, the lower stool may be eliminated provided the following requirements, in addition to the requirements of *2.5.7.6*, 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 *Figure 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 inner bottom and hopper tank in way of the corrugation is to be of at least the same material yield strength as the attached corrugation, and 'Z' grade steels as given in Section 6/1.1.5 are to be used unless plate through thickness properties are documented for approval.

(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 yield 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 *Figure 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 yield 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.

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}~~ 0.65C_{m1}
Longitudinal Bulkhead	C_3	C_{m3}	0.65C_{m3}

Where:

C_1	$= a_1 + b_1\sqrt{\frac{A_{dt}}{b_{dk}}}$	but is not to be taken as less than 0.60
	$= a_1 - b_1\sqrt{\frac{A_{dt}}{b_{dk}}}$	for transverse bulkhead with no lower stool, but is not to be taken as less than 0.55
a_1	$= 0.95 - \frac{0.41}{R_{bt}}$	
	= ~~0.6~~ 1.0	for transverse bulkhead with no lower stool
b_1	$= -0.20 + \frac{0.078}{R_{bt}}$	
	= 0.13	for transverse bulkhead with no lower stool
C_{m1}	$= a_{m1} + b_{m1}\sqrt{\frac{A_{dt}}{b_{dk}}}$	but is not to be taken as less than 0.55
	$= a_{m1} - b_{m1}\sqrt{\frac{A_{dt}}{b_{dk}}}$	for transverse bulkhead with no lower stool, but is not to be taken as less than 0.60
a_{m1}	$= 0.63 + \frac{0.25}{R_{bt}}$	
	= ~~0.96~~ 0.85	for transverse bulkhead with no lower stool
b_{m1}	$= -0.25 - \frac{0.11}{R_{bt}}$	
	= 0.34	for transverse bulkhead with no lower stool
C_3	$= a_3 + b_3\sqrt{\frac{A_{dl}}{l_{dk}}}$	but is not to be taken as less than 0.60
	$= a_3 - b_3\sqrt{\frac{A_{dl}}{l_{dk}}}$	for longitudinal bulkhead with no lower stool, but is not to be taken as less than 0.55
a_3	$= 0.86 - \frac{0.35}{R_{bl}}$	
	= ~~0.6~~ 1.0	for longitudinal bulkhead with no lower stool

Table 8.2.3 (Continued)
Values of C_i

b_3	$= -0.17 + \dfrac{0.10}{R_{bl}}$	
	= 0.13	for longitudinal bulkhead with no lower stool
C_{m3}	$= a_{m3} + b_{m3}\sqrt{\dfrac{A_{dl}}{l_{dk}}}$	but is not to be taken as less than 0.55
	$= a_{m3} - b_{m3}\sqrt{\dfrac{A_{dl}}{l_{dk}}}$	for longitudinal bulkhead with no lower stool, but is not to be taken as less than 0.60
a_{m3}	$= 0.32 + \dfrac{0.24}{R_{bl}}$	
	= ~~0.9~~ 0.85	for longitudinal bulkhead with no lower stool
b_{m3}	$= -0.12 - \dfrac{0.10}{R_{bl}}$	
	= 0.19	for longitudinal bulkhead with no lower stool
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 *Figure 8.2.3*	
b_{av-l}	average width of longitudinal bulkhead lower stool, in m. See *Figure 8.2.3*	
h_{st}	height of transverse bulkhead lower stool, in m. See *Figure 8.2.3*	
h_{sl}	height of longitudinal bulkhead lower stool, in m. See *Figure 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 *Figure 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 *Figure 8.2.3*	
l_{ib}	length of cargo tank at the inner bottom level between transverse lower stools, in m. See *Figure 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 *Figure 8.2.3*	

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 (void)

6 EVALUATION OF STRUCTURE FOR SLOSHING AND IMPACT LOADS

6.3 Bottom Slamming

6.3.7 Primary support members

6.3.7.5 The net web thickness, t_{w-net}, of primary support members adjacent to the shell is not to be less than:

$$\cancel{t_{w-net} = \frac{s}{70}\sqrt{\frac{\sigma_{yd}}{235}}} \quad \underline{t_{w-net} = \frac{s_w}{70}\sqrt{\frac{\sigma_{yd}}{235}}} \text{ mm}$$

Where:

s_w plate breadth, in mm, taken as the spacing between the web stiffening

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.4 Bow Impact

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:

$$Z_{pl-net} = \frac{P_{im}\, s l_{bdg}^{\ 2}}{f_{bdg}\, C_s\, \sigma_{yd}} \quad \text{cm}^3$$

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/m²

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~~ 6.4.3.2 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/mm²

6.4.7 Primary support members

6.4.7.5 The net section modulus of each primary support member, Z_{net50}, is not to be less than:

$$Z_{net50} = 1000 \frac{f_{bdg-pt} P_{im} \, b_{slm} f_{slm} \, l_{bdg}^{\ 2}}{f_{bdg} C_s \sigma_{yd}} \quad \text{cm}^3$$

Where:

f_{bdg-pt} correction factor for the bending moment at the ends and considering the patch load

$= 3 f_{slm}^{\ 3} - 8 f_{slm}^{\ 2} + 6 f_{slm}$

f_{slm} patch load modification factor

$= \dfrac{l_{slm}}{l_{bdg}}$

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~~ 5.3.1*, 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

SECTION 9 - DESIGN VERIFICATION

1 HULL GIRDER ULTIMATE STRENGTH

1.1 General

1.1.1 Application

1.1.1.2 The scantling requirements in this Sub-Section are to be applied ~~within 0.4L amidships~~ to any cross section along the entire vessel's length and are in addition to all other requirements within the rules.

2 STRENGTH ASSESSMENT (FEM)

2.3 Local Fine Mesh Structural Strength Analysis

2.3.1 Objective and scope

2.3.1.1 For tankers of conventional arrangements, as a minimum requirement, the following areas in the midship cargo region are to be investigated:

(a) main bracket toes and openings at critical locations and upper hopper knuckle joint of a typical transverse web frame located in the midship tank. Where a wash bulkhead is fitted, main bracket toes and openings at critical locations of transverse and vertical webs

(b) main bracket toes and openings at critical locations on a typical transverse web frame adjacent to a transverse bulkhead in way of the transverse bulkhead horizontal stringers

(c) main bracket toes, heels and openings at critical locations of horizontal stringers, connection of transverse bulkhead to double bottom girder or buttress of a typical transverse bulkhead

(d) connections of transverse and longitudinal corrugated bulkheads to bottom stool or inner bottom and double bottom supporting structure if a lower stool is not fitted. If a gusset plate is fitted the connection between the corrugation and the upper corners of the gusset are to be assessed

(e) end brackets and attached web stiffeners of typical longitudinal stiffeners of double bottom and deck, and adjoining vertical stiffener of transverse bulkhead. If longitudinal stiffeners are fitted above the deck then the connection in way of the transverse bulkhead are to be assessed.

2.3.1.2 The selection of critical locations on the structural members described in *2.3.1.1* to perform fine mesh analysis is to be in accordance with *Appendix B/3.1.*

2.3.1.3 Where the stress level in areas of stress concentration on structural members not specified in *2.3.1.1* exceeds the acceptance criteria of the cargo tank analysis, a fine mesh analysis is to be carried out to demonstrate satisfactory scantlings.

2.3.1.4 Where the geometry can not be adequately represented in the cargo tank finite element model, a fine mesh analysis may be used to demonstrate satisfactory scantlings. In such cases the average stress within an area equivalent to that specified in the cargo tank analysis (typically s by s) is to comply with the requirement given in *Table 9.2.1*. See also Note 1 of *Table 9.2.3*.

2.4.5 Application of scantlings to side shell, longitudinal bulkheads and inner hull longitudinal bulkheads

2.4.5.1 The scantlings of plating and longitudinal stiffeners of side shell, longitudinal bulkheads and inner longitudinal bulkheads within 0.15*D* from the deck are to be maintained longitudinally within 0.4*L* amidships. The scantlings of plating and longitudinal stiffener at a given height are not to be less than the maximum of that required for the corresponding vertical location along the length of the middle tanks of the cargo tank finite element model required by *Appendix B/1.1.1.5*. Outside 0.4*L* amidships, the scantlings of the plating and stiffeners within 0.15*D* from the deck may be tapered to that required by *Section 8* at the ends of the cargo tank region.

2.4.5.2 The plate thickness of side shell, longitudinal bulkheads and inner hull longitudinal bulkheads, including hopper plating, outside 0.15*D* from the deck may vary along the length and height of a tank. The plate thickness away from the transverse bulkheads is not to be less than that required for the corresponding location of the middle tanks of the cargo tank finite element model required by *Appendix B/1.1.1.5*. These scantlings are to be maintained for all tanks within the cargo region, other than the fore-most and aft-most cargo tanks. For the fore-most and aft-most cargo tanks, the minimum net thickness of the side shell, longitudinal bulkheads or inner hull longitudinal bulkheads (including hopper plating) plating outside 0.15*D* from the deck is given by:

$$t_{net} = t_{net-mid} \frac{s}{s_{mid}} \quad \text{mm}$$

Where:

$t_{net-mid}$ required net thickness for corresponding location in the midship tank, in mm

s spacing between longitudinal stiffeners at location under consideration, in mm

s_{mid} spacing between longitudinal stiffeners at corresponding location in midship tank, in mm

2.4.5.3 The plate thickness of side shell, longitudinal bulkheads and inner hull longitudinal bulkheads, including hopper plating, in way of transverse bulkheads required for strengthening against hull girder shear loads is not to be less than that required by *Appendix B/1.1.1.6, B/1.1.1.7* and *B/1.1.1.8*. Within 0.15*D* from the deck, the plate thicknesses in way of transverse bulkheads are not to be taken as less than that required by *2.4.5.1*. Outside 0.15*D* from the deck, the plate thicknesses in way of transverse bulkheads are not to be taken as less than that required by *2.4.5.2*.

2.4.5.4 The scantlings of longitudinal stiffeners of side shell, longitudinal bulkheads, inner longitudinal bulkheads and hopper plate at a given height, outside 0.15*D* from the deck, are not to be less than that required for the corresponding vertical location of the middle tanks of the cargo tank finite element model as required by *Appendix B/1.1.1.5*. These scantlings are to be maintained for all tanks within the cargo region.

2.4.5.5 The plate thickness required for strengthening against hull girder shear loads of the side shell, longitudinal bulkheads and inner hull longitudinal bulkheads in way of a transverse bulkhead is to be taken as the greater from the corresponding vertical location of the forward and aft transverse bulkhead of the middle tanks of the cargo tank finite element model as required by Appendix B/1.1.1.5. All relevant requirements in other sections of the Rules are also to be complied with.

SECTION 10 BUCKLING AND ULTIMATE STRENGTH

1 GENERAL

1.1 Strength Criteria

1.1.1 Scope

1.1.1.4 The strength criteria are to be based on the following assumptions and limitations in respect to buckling and ultimate strength control in design:

(a) the buckling strength of stiffeners is to be greater than the plate panels they support

(b) the primary support members supporting stiffeners are to have sufficient inertia to prevent out of plane buckling of the primary member, see *2.3.2.3*

(c) all stiffeners with their associated effective plate are to have moments of inertia to provide adequate lateral stability, see *2.2.2*

(d) the proportions of local support members and primary support members are to be such that local instability is prevented

(e) tripping of primary support members (e.g. torsional instability) is to be prevented by fitment of tripping brackets or equivalents, see in *2.3.3*

(f) the web plate of primary support members is to be such that elastic buckling of the plate between web stiffeners is prevented

(g) for plates with openings, the buckling strength of the areas surrounding the opening or cut out and any edge reinforcements are adequate, see ~~*3.4.2*~~*3.4.1* and *2.4.3*.

SECTION 11 GENERAL REQUIREMENT

1 HULL OPENINGS AND CLOSING ARRANGEMENTS

1.4 DECK HOUSES AND COMPANIONWAYS

1.4.10 Exposed bulkhead plating

1.4.10.1 The gross thickness of plating, $t_{blk\text{-}grs}$, is not to be less than that calculated from *1.4.10.2* and that given by:

$$t_{blk\text{-}grs} = 3s\sqrt{k\,h_{des}} \quad \text{mm}$$

Where:

s spacing of stiffeners, in m

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

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

h_{des} design head, in m:

$C_4[(C_5 f) - z]c$

but is not to be taken less than given below for the specified location:

$2.5 + L_1/100$ unprotected front bulkheads on the lowest tier

$1.25 + L_2/200$ elsewhere

L_1 rule length, L, as defined in *Section 4/1.1.1.1*, but is not to be taken greater than 250m

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

C_4 coefficient as given in *Table 11.1.6*

C_5 coefficient:

$$1.0 + \left[\frac{(x/L) - 0.45}{C_{b1} + 0.2}\right]^2 \quad \text{where } x/L \le 0.45$$

$$1.0 + 1.5\left[\frac{(x/L) - 0.45}{C_{b1} + 0.2}\right]^2 \quad \text{where } x/L > 0.45$$

C_{b1} block coefficient as defined in *Section 4/1.1.9.1*, but is not to be taken as less than 0.60 or greater than 0.80. For aft end bulkheads forward of amidships, C_{b1} may be taken as 0.80

x distance between the A.P. and the bulkhead being considered, in m. Deck house side bulkheads are to be divided into equal parts not exceeding 0.15L in length, and x is to be measured from the A.P. to the centre of each part considered

L rule length, as defined in *Section 4/1.1.1.1*

f	as defined in *Table 11.1.7*
z	vertical distance from the summer load waterline measured to the middle of the plate, in m
c	$0.3 + 0.7 b_{dh} / B_1$ but is not to be taken as less than 1.0 for exposed machinery casing bulkheads and in no case is b_{dh}/B_1 to be taken as less than 0.25
b_{dh}	breadth of deck house at the position being considered, in m
B_1	actual breadth of the vessel at the freeboard deck at the position being considered, in m

Table 11.1.6
Values of 'C_4'

Bulkhead location	**Value of 'C_4'**
Unprotected front, lowest tier	$2.0 + L_2/120$
Unprotected front, 2nd tier	$1.0 + L_2/120$
Unprotected front, 3rd tier and above	$0.5 + L_2/150$
Protected front, all tiers	$0.5 + L_2/150$
Sides, all tiers	$0.5 + L_2/150$
Aft ends, aft of amidships, all tiers	$0.7 + (L_2/1000) - 0.8x/L$
Aft ends, forward of amidships, all tiers	$0.5 + (L_2/1000) - 0.4x/L$

Table 11.1.7
Values of 'f'

L, in m	**f, in m**
90	6.00
100	6.61
120	7.68
140	8.65
160	9.39
180	9.88
200	10.27
220	10.57
240	10.78
260	10.93
280	11.01
≥ 300	11.03

Note
1. This Table is based on the equations given in *Table 11.1.8*

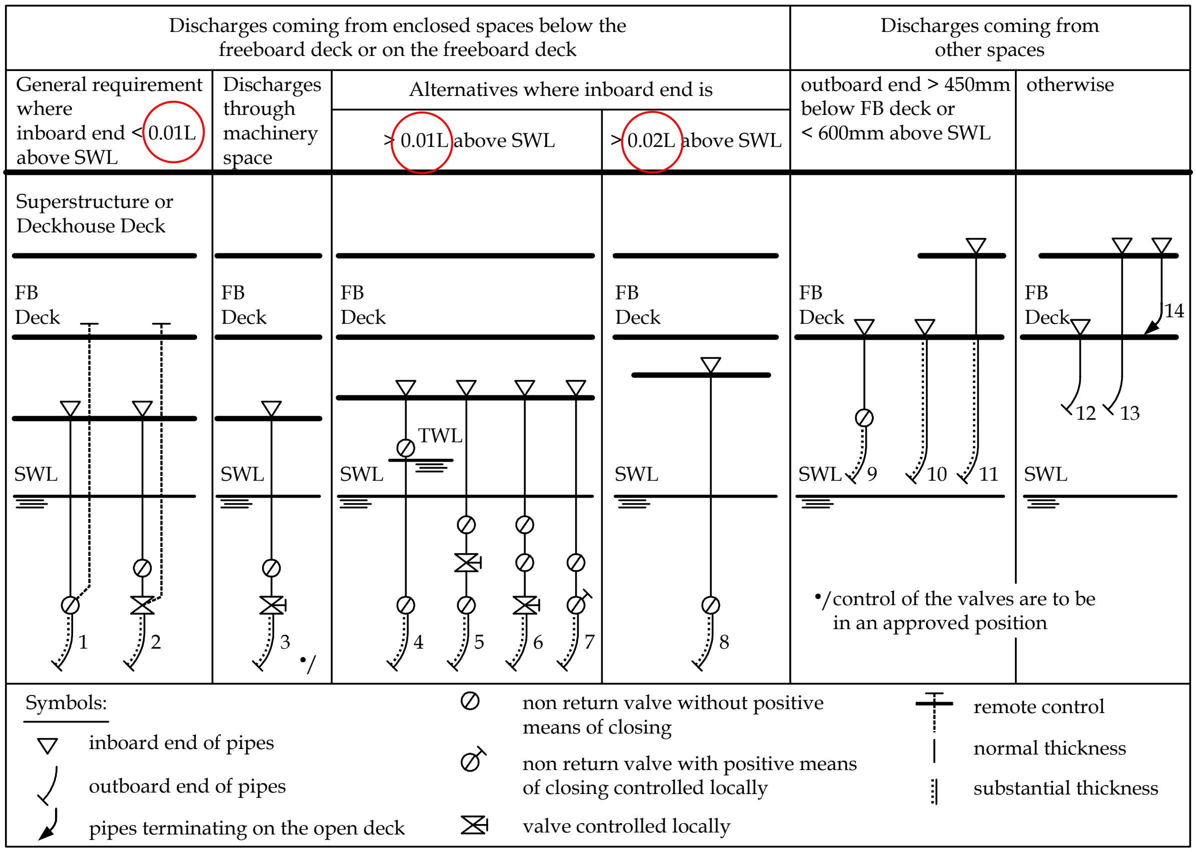
Table 11.1.8
Origin of 'f' Values

L, in m	**f, in m**
$L \le 150$	$(L/10)(e^{-L/300}) - [1 - (L/150)^2]$
$150 < L < 300$	$(L/10)(e^{-L/300})$
$L \ge 300$	11.03

1.5 Prevention of water passing inboard

1.5.3 For acceptable arrangements for discharges and scuppers, see *Figure 11.1.3*.

Figure 11.1.3
Diagrammatic Arrangement of Discharge and Scupper Systems



<u>"L" in *Figure 11.1.3* to be amended to "L_L"</u>

4 EQUIPMENT

4.1 Equipment Number Calculation

4.1.1 Requirements

4.1.1.1 Anchors and chains are to be in accordance with *Table 11.4.1* and the quantity, mass and sizes of these are to be determined by the equipment number (EN), given by:

$$EN = \Delta^{2/3} + 2Bh_{dk} + 0.1A$$

Where:

Δ	moulded displacement, in tonnes, as defined in *Section 4/1.1.7.1*
B	moulded breadth, in m, as defined in *Section 4/1.1.3.1*
h_{dk}	$h_{FB} + h_1 + h_2 + h_3 + \ldots$, as shown in *Figure 11.4.1*. In the calculation of h, sheer, camber and trim may be neglected
h_{FB}	freeboard from the summer load waterline amidships, in m
h_1, h_2, $h_3 \ldots h_n$	height on the centreline of each tier of houses having a breadth greater than $B/4$, in m.
A	profile area of the hull, superstructure and houses above the summer load waterline which are within the length L, in m^2. Superstructures or deck houses having a breadth equal to or less than $B/4$ at any point may be excluded. With regard to determining A, when a screen or bulwark is more than 1.5m high, the area shown in *Figure 11.4.2* as A_2 is to be included in A
L	rule length, as defined in *Section 4/1.1.1.1*

Notes

(a) Screens or bulwarks 1.5 m or more in height are to be regarded as parts of houses when determining h and A.

(b) If a house having a breadth greater than B/4 is above a house with a breadth of B/4 or less then the wide house is to be included but the narrow house ignored.

5 TESTING PROCEDURES

5.1 TANK TESTING

5.1.5 Leak testing

5.1.5.1 All boundary welds, erection joints, and penetrations including pipe connections, except welds made by automatic processes are to be examined in accordance with the approved procedure and under a pressure of at least 0.15bar with a leak indicating solution (e.g. soapy water solution). Pressures greater than 0.20bar are not recommended.

Table 11.5.1
Testing Requirements for Tanks and Boundaries

	Structures to be tested	Type of testing	Hydrostatic testing head or pressure	Remarks
1	Double Bottom Tanks	Structural(1)	The greater of - to the top of overflow, or - to the bulkhead deck	Tank boundaries tested from at least one side
2	Double Side Tanks	Structural(1)	The greater of - to the top of overflow, or - to 2.4m above top of tank(2)	Tank boundaries tested from at least one side
3	Cargo Tanks	Structural(1)	The greatest of - to the top of overflow, - to 2.4m above top of tank(2), or - to the top of tank(2) plus setting of any pressure relief valve	Tank boundaries tested from at least one side
	Fuel Oil Bunkers	Structural(1)		
4	Cofferdams	Structural(3)	The greater of - to the top of overflow, or - to 2.4m above top of cofferdam	
5a	Peak Tanks	Structural	The greater of - to the top of overflow, or - to 2.4m above top of tank(2)	Aft peak tank test to be carried out after installation of stern tube.
5b	Fore Peak not used as a tank	Refer to *SOLAS II.1 Reg.14*		
5c	Aft Peak not used as a tank	Leak		
6	Watertight Bulkheads in way of dry space	Hose(4)		Including steps and recesses
7	Watertight Doors below freeboard or bulkhead deck	Hose		For testing before installation(5)
8	(void)			
9	Watertight hatch covers of tanks on combination carriers	Structural testing	The greater of: - to 2.4m above the top of hatch cover, or - setting pressure of the pressure relief valve	At least every second hatch cover is to be tested
10	Weathertight Hatch Covers, Doors and other Closing Appliances	Hose(4)		
11	Shell plating in way of pump room	Visual examination		To be carefully examined with the vessel afloat

Table 11.5.1 (Continued)
Testing Requirements for Tanks and Boundaries

	Structures to be tested	Type of testing	Hydrostatic testing head or pressure	Remarks
12	Chain Locker (aft Collision Bulkhead)	Structural	To the top of chain locker spurling pipe	
13	Independent Tanks	Structural	The greater of - to the top of overflow, or - to 0.9 m above top of tank	
14	Ballast Ducts	Structural	Ballast pump maximum pressure or setting of any relief valve for the ballast duct if that is less	
15	Hawse Pipes	Hose		

Note

1. Leak or hydropneumatic testing may be accepted under the conditions specified in *5.1.5*, provided that at least one tank for each type is structurally tested, and selected in connection with the approval of the design. In general, the structural testing need not be repeated for subsequent vessels of a series of identical new buildings unless the Surveyor deems the repetition necessary. The structural testing of cargo space boundaries and tanks for segregated cargoes or pollutants on subsequent vessels of a series of identical new buildings are to be in accordance with the requirements of the individual Classification Society.
2. Top of tank is defined as the deck forming the top of the tank excluding hatchways.
3. Leak testing in accordance with *5.1.5* may be accepted, except that hydropneumatic testing may be required in consideration of the construction techniques and welding procedures employed.
4. Where hose testing is impractical due to the stage of outfitting (machinery, cables, switchboard, insulation etc.), it may be replaced at the individual Society's discretion, by a careful visual examination of all the crossings and welded joints. A dye penetrant test, leak test or ultrasonic leak test may be required.
5. Before installation (i.e. normally at manufacture) the watertight access doors or hatches are to be hydrostatically tested with a head of water equivalent to the bulkhead deck at centre, from the side which is most prone to leakage. The acceptance criteria are as follows:
   - no leakage for doors or hatches with gaskets
   - a maximum water leakage of one litre per minute for doors or hatches with metallic sealing.
6. If leak or hydropneumatic testing is carried out, arrangements are to be made to ensure that no pressure in excess of 0.30 bar is applied.

Appendix A – Hull Girder Ultimate Strength

2 CALCULATION OF HULL GIRDER ULTIMATE CAPACITY

2.2 Simplified Method Based on an Incremental-iterative Approach

2.2.2 Assumptions and modelling of the hull girder cross-section

2.2.2.1 In applying the procedure described in *2.2.1*, the following assumptions are to be made:

(a) The ultimate strength is calculated at a hull girder transverse section between two adjacent transverse webs.

(b) The hull girder transverse section remains plane during each curvature increment.

(c) The material properties of steel are assumed to be elastic, perfectly plastic.

(d) The hull girder transverse section can be divided into a set of elements which act independently of each other.

2.2.2.2 The elements making up the hull girder transverse section are:

(a) longitudinal stiffeners with attached plating, the structural behaviour is given in *2.3.1*

(b) transversely stiffened plate panels, the structural behaviour is given in *2.3.1*

(c) hard corners, as defined in *2.2.2.3*, the structural behaviour is given in *2.3.2*

2.2.2.3 The following structural areas are to be defined as hard corners:

(a) the plating area adjacent to intersecting plates

(b) the plating area adjacent to knuckles in the plating with an angle greater than 30 degrees.

(c) plating comprising rounded gunwales

An illustration of hard corner definition for girders on longitudinal bulkheads is given in *Figure A.2.3*. The hard corner size is defined in 2.2.2.4.

2.2.2.4 The size and modelling of hard corner elements is to be as follows:

(a) it is to be assumed that the hard corner extends up to $s/2$ from the plate intersection for longitudinally stiffened plate, where s is the stiffener spacing

(b) it is to be assumed that the hard corner extends up to $20t_{grs}$ from the plate intersection for transversely stiffened plates, where t_{grs} is the gross plate thickness.

<u>Note</u>

<u>(a)</u> For transversely stiffened plate, the effective breadth of plate for the load shortening portion of the stress-strain curve is to be taken as the full plate breadth, i.e. to the intersection of other plates – not from the end of the hard corner if any. The area on which the value of σ_{CR5} defined in 2.3.8.1 applies is to be taken as the breadth between the hard corners, i.e. excluding the end of the hard corner if any.

<u>(b) For longitudinally stiffened plate, the effective breadth of attached plate is equal to the mean spacing of the ordinary stiffener when the panels on both sides of the stiffener are longitudinally stiffened, or equal to the breadth of the longitudinally stiffened panel when the panel on one side of the stiffener is longitudinally stiffened and the other panel is of the transversely stiffened.</u>

2.2.2.5 Where the plate members are stiffened by non-continuous longitudinal stiffeners, the non-continuous stiffeners are considered only as dividing a plate into various elementary plate panels.

2.2.2.6 Openings are to be considered in accordance with Section 4/2.6.3.

2.2.2.7 Where attached plating is made of steels having different thicknesses and/or yield stresses, an average thickness and/or average yield stress obtained by the following formula are to be used for the calculation:

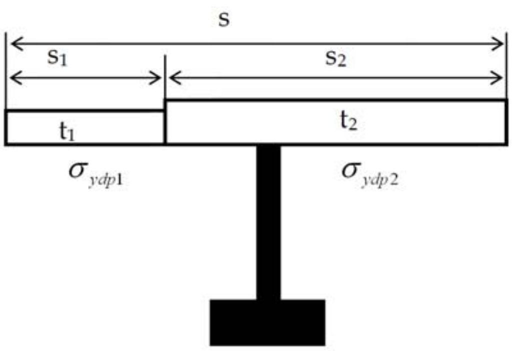
(a) $$t = \frac{t_1 s_1 + t_2 s_2}{s}$$

(b) $$\sigma_{ydp} = \frac{\sigma_{ydp1} t_1 s_1 + \sigma_{ydp2} t_2 s_2}{ts}$$

Where:

t_1, s_1, t_2, s_2, σ_{ydp1}, σ_{ydp2}, s, see Figure A.1.X.

Figure A.1.X
Definitions



2.3 Stress-strain Curves σ-ε (or Load-end Shortening Curves)

2.3.1 Plate panels and stiffeners

2.3.1.1 Plate panels and stiffeners are assumed to fail according to one of the modes of failure specified in *Table A.2.1*. The relevant stress-strain curve σ-ε is to be obtained for lengthening and shortening strains according to *Table A.2.1*.

2.3.1.2 Where the plate members are stiffened by non-continuous longitudinal stiffeners, the stress of the element is to be obtained in accordance with 2.3.3 to 2.3.7, taking into account the non-continuous longitudinal stiffener. In calculating the total forces for checking the hull girder ultimate strength, the area of non-continuous longitudinal stiffener is to be assumed as zero.

2.3.1.3 Where openings are provided in the plate panel, the considered area of the element is to be obtained by deducting the opening area from the plating in calculating the total force for checking the hull girder ultimate strength. Openings are to be considered in accordance with Section 4/2.6.3.

2.3.3 Elasto-plastic failure of structural elements

2.3.3.1 The equation describing the stress-strain curve σ-ε or the elasto-plastic failure of structural elements is to be obtained from the following formula, valid for both positive (compression or shortening) of hard corners and negative (tension or lengthening) strains of all elements (see *Figure A.2.4*):

$\cancel{\sigma = \Phi \sigma_{yd}}$

$\underline{\sigma = \Phi \sigma_{ydA}}$

Where:

Φ edge function:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 < \varepsilon < 1$

$\Phi = 1$ for $\varepsilon > 1$

ε relative strain:

$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_{yd}}$$

ε_E element strain

ε_{yd} strain corresponding to yield stress in the element:

$$\cancel{\varepsilon_{yd} = \frac{\sigma_{yd}}{E}}$$

$$\underline{\varepsilon_{yd} = \frac{\sigma_{ydA}}{E}}$$

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

$\underline{\sigma_{ydA}}$ <u>equivalent minimum yield stress of the considered element, in N/mm^2</u>

$$\underline{\sigma_{ydA} = \frac{\sigma_{ydp} A_{p-net50} + \sigma_{yds} A_{s-net50}}{A_{p-net50} + A_{s-net50}}}$$

$\underline{\sigma_{ydp}}$ <u>specified minimum yield stress of the material of the plate, in N/mm^2</u>

$\underline{\sigma_{yds}}$ <u>specified minimum yield stress of the material of the stiffener, in N/mm^2</u>

$\underline{A_{p-net50}}$ <u>net sectional area of attached plating, in cm^2</u>

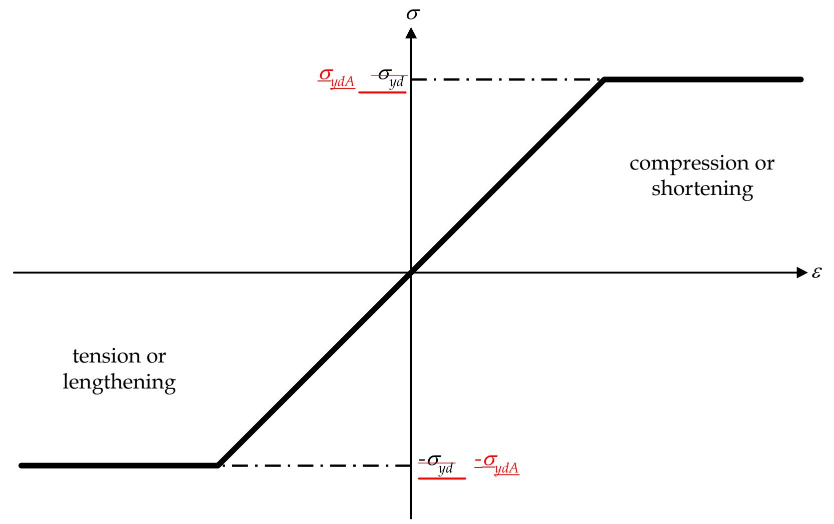
$\underline{A_{s-net50}}$ <u>net sectional area of the stiffener without attached plating, in cm^2</u>

<u>Note</u>

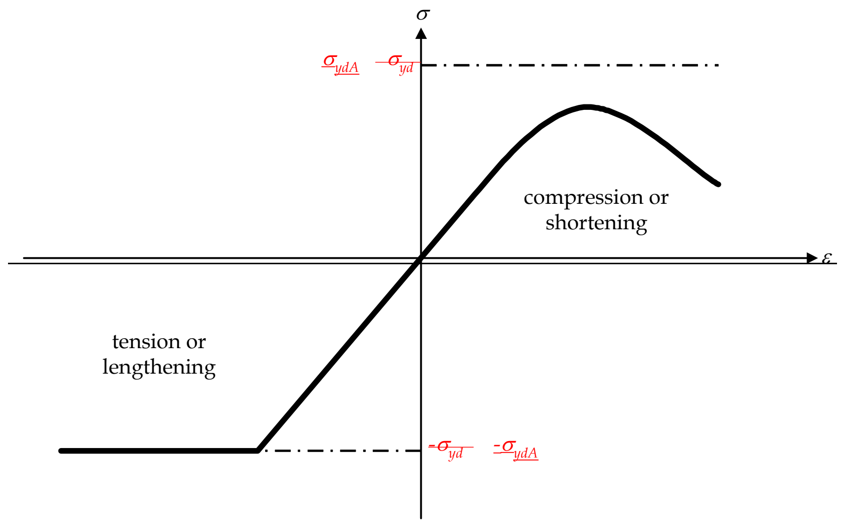
The signs of the stresses and strains in this Appendix are opposite to those in the rest of the Rules

Figure A.2.4
Example of Stress Strain Curves σ-ε

a) Stress strain curve σ-ε for elastic, perfectly plastic failure of a hard corner



b) Typical stress strain curve σ-ε for elasto-plastic failure of a stiffener



2.3.4 Beam column buckling

2.3.4.1 The equation describing the shortening portion of the stress strain curve σ_{CR1}-ε for the beam column buckling of stiffeners is to be obtained from the following formula:

$$\sigma_{CR1} = \Phi\sigma_{C1}\left(\frac{A_{s-net50} + 10^{-2} b_{eff-p} t_{net50}}{A_{s-net50} + 10^{-2} s t_{net50}}\right) \quad \text{N/mm}^2$$

Where:

Φ edge function defined in *2.3.3.1*

$A_{s\text{-}net50}$ net area of the stiffener, in cm^2, without attached plating

σ_{C1} critical stress, in N/mm^2:

$$\cancel{\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \quad for \quad \sigma_{E1} \le \frac{\sigma_{yd}}{2}\varepsilon}$$

$$\cancel{\sigma_{C1} = \sigma_{yd}\left(1 - \frac{\sigma_{yd}\varepsilon}{4\sigma_{E1}}\right) \quad for \quad \sigma_{E1} > \frac{\sigma_{yd}}{2}\varepsilon}$$

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \quad for \quad \sigma_{E1} \le \frac{\sigma_{ydB}}{2}\varepsilon$$

$$\sigma_{C1} = \sigma_{ydB}\left(1 - \frac{\sigma_{ydB}\varepsilon}{4\sigma_{E1}}\right) \quad for \quad \sigma_{E1} > \frac{\sigma_{ydB}}{2}\varepsilon$$

ε relative strain defined in *2.3.3.1*

σ_{E1} Euler column buckling stress, in N/mm^2:

$$\sigma_{E1} = \pi^2 E \frac{I_{E-net50}}{A_{E-net50} l_{stf}^2} 10^{-4}$$

E modulus of elasticity, 2.06 x 10^5 N/mm^2

$I_{E\text{-}net50}$ net moment of inertia of stiffeners, in cm^4, with attached plating of width $b_{eff\text{-}s}$

$b_{\text{eff-s}}$ effective width, in mm, of the attached plating for the stiffener:

$$b_{eff-s} = \frac{s}{\beta_p} \quad \text{for} \quad \beta_p > 1.0$$

$$b_{eff-s} = s \quad \text{for} \quad \beta_p \le 1.0$$

β_p

$$\cancel{= \frac{s}{t_{net50}}\sqrt{\frac{\varepsilon\sigma_{yd}}{E}}}$$

$$= \frac{s}{t_{net50}}\sqrt{\frac{\varepsilon\sigma_{ydp}}{E}}$$

s plate breadth, in mm, taken as the spacing between the stiffeners, as defined in *Section 4/2.2.1*

t_{net50} net thickness of attached plating, in mm

$A_{E\text{-}net50}$ net area, in cm^2, of stiffeners with attached plating of width $b_{eff\text{-}p}$

l_{stf} span of stiffener, in m, equal to spacing between primary support members

$b_{eff\text{-}p}$ effective width, in mm, of the plating:

$$b_{eff-p} = \left(\frac{2.25}{\beta_p} - \frac{1.25}{\beta_p^2}\right)s \qquad \text{for} \quad \beta_p > 1.25$$

$$b_{eff-p} = s \qquad \text{for} \quad \beta_p \le 1.25$$

σ_{ydB} equivalent minimum yield stress of the considered element, in N/mm^2

$$\sigma_{ydB} = \frac{\sigma_{ydp} A_{pE-net50} l_{pE} + \sigma_{yds} A_{s-net50} l_{sE}}{A_{pE-net50} l_{pE} + A_{s-net50} l_{sE}}$$

$A_{pE\text{-}net50}$ effective area, in cm^2

$$A_{pE-net50} = 10^{-2} b_{eff-s} t_{net50}$$

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

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

l_{pE} distance, in mm, measured from the neutral axis of the stiffener with attached plate of width, $b_{eff\text{-}s}$, to the bottom of the attached plate

l_{sE} distance, in mm, measured from the neutral axis of the stiffener with attached plate of width, $b_{eff\text{-}s}$, to the top of the stiffener

2.3.5 Torsional buckling of stiffeners

2.3.5.1 The equation describing the shortening portion of the stress-strain curve σ_{CR2}-ε for the lateral-flexural buckling of stiffeners is to be obtained according to the following formula:

$$\sigma_{CR2} = \Phi \frac{A_{s-net50}\sigma_{C2} + 10^{-2} s t_{net50} \sigma_{CP}}{A_{s-net50} + 10^{-2} s t_{net50}} \qquad N/mm^2$$

Where:

Φ edge function defined in *2.3.3.1*

$A_{s\text{-}net50}$ net area of the stiffener, in cm^2, without attached plating

σ_{C2} critical stress, in N/mm^2:

$$\cancel{\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \qquad \text{for} \quad \sigma_{E2} \le \frac{\sigma_{yd}}{2}\varepsilon}$$

$$\cancel{\sigma_{C2} = \sigma_{yd}\left(1 - \frac{\sigma_{yd}\varepsilon}{4\sigma_{E2}}\right) \qquad \text{for} \quad \sigma_{E2} > \frac{\sigma_{yd}}{2}\varepsilon}$$

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \qquad for \quad \sigma_{E2} \le \frac{\sigma_{yds}}{2}\varepsilon$$

$$\sigma_{C2} = \sigma_{yds}\left(1 - \frac{\sigma_{yds}\varepsilon}{4\sigma_{E2}}\right) \qquad for \quad \sigma_{E2} > \frac{\sigma_{yds}}{2}\varepsilon$$

σ_{E2} Euler torsional buckling stress, in N/mm^2

$\sigma_{E2} = \sigma_{ET}$

σ_{ET} reference stress for torsional buckling, in N/mm², defined in *Section 10/3.3.3.1*, calculated based on gross thickness minus the corrosion addition $0.5t_{corr}$.

ε relative strain defined in *2.3.3.1*

s plate breadth, in mm, taken as the spacing between the stiffeners, as defined in *Section 4/2.2.1*

t_{net50} net thickness of attached plating, in mm

σ_{CP} ultimate strength of the attached plating for the stiffener, in N/mm²:

$$\sigma_{CP} = \left(\frac{2.25}{\beta_p} - \frac{1.25}{\beta_p^2}\right)\sigma_{yd} \quad \text{for} \quad \beta_p > 1.25$$

$$\sigma_{CP} = \sigma_{yd} \quad \text{for} \quad \beta_p \le 1.25$$

$$\sigma_{CP} = \left(\frac{2.25}{\beta_p} - \frac{1.25}{\beta_p^2}\right)\sigma_{ydp} \quad \text{for} \quad \beta_p > 1.25$$

$$\sigma_{CP} = \sigma_{ydp} \quad \text{for} \quad \beta_p \le 1.25$$

β_p coefficient defined in *2.3.4*

σ_{ydp} specified minimum yield stress of the material of the plate, in N/mm²

σ_{yds} specified minimum yield stress of the material of the stiffener, in N/mm²

2.3.6 Web local buckling of stiffeners with flanged profiles

2.3.6.1 The equation describing the shortening portion of the stress strain curve σ_{CR3}-ε for the web local buckling of flanged stiffeners is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi\sigma_{yd}\left(\frac{b_{eff-p}t_{net50} + d_{w-eff}t_{w-net50} + b_f t_{f-net50}}{st_{net50} + d_w t_{w-net50} + b_f t_{f-net50}}\right) \quad \text{N/mm}^2$$

$$\sigma_{CR3} = \Phi\frac{b_{eff-p}t_{net50}\sigma_{ydp} + \left(d_{w-eff}t_{w-net50} + b_f t_{f-net50}\right)\sigma_{yds}}{st_{net50} + d_w t_{w-net50} + b_f t_{f-net50}} \quad \text{N/mm}^2$$

Where:

Φ edge function defined in *2.3.3.1*

b_{eff-p} effective width, in mm, of the plating, defined in *2.3.4*

t_{net50} net thickness of plate, in mm

d_w depth of the web, in mm

$t_{w-net50}$ net thickness of web, in mm

b_f breadth of the flange, in mm

$t_{f-net50}$ net thickness of flange, in mm

s plate breadth, in mm, taken as the spacing between the stiffeners, as defined in *Section 4/2.2.1*

$d_{w\text{-}eff}$ effective depth of the web, in mm:

$$d_{w-eff} = \left(\frac{2.25}{\beta_w} - \frac{1.25}{\beta_w^2}\right) d_w \quad \text{for} \quad \beta_w > 1.25$$

$$d_{w-eff} = d_w \quad \text{for} \quad \beta_w \le 1.25$$

β_w

$$\cancel{\frac{d_w}{t_{w-net50}}\sqrt{\frac{\varepsilon\sigma_{yd}}{E}}}$$

$$\frac{d_w}{t_{w-net50}}\sqrt{\frac{\varepsilon\sigma_{yds}}{E}}$$

ε relative strain defined in *2.3.3.1*

E modulus of elasticity, 2.06×10^5 N/mm^2

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

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

2.3.7 Web local buckling of flat bar stiffeners

2.3.7.1 The equation describing the shortening portion of the stress-strain curve σ_{CR4}-ε for the web local buckling of flat bar stiffeners is to be obtained from the following formula:

$$\sigma_{CR4} = \Phi\left(\frac{st_{net50}\sigma_{CP} + 10^{-2}A_{s-net50}\sigma_{C4}}{st_{net50} + 10^{-2}A_{s-net50}}\right)$$

Where:

Φ edge function defined in *2.3.3.1*

σ_{CP} ultimate strength of the attached plating, in N/mm^2, defined in *2.3.5*

σ_{C4} critical stress, in N/mm^2:

$$\cancel{\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \quad \text{for} \quad \sigma_{E4} \le \frac{\sigma_{yd}}{2}\varepsilon}$$

$$\cancel{\sigma_{C4} = \sigma_{yd}\left(1 - \frac{\sigma_{yd}\varepsilon}{4\sigma_{E4}}\right) \quad \text{for} \quad \sigma_{E4} > \frac{\sigma_{yd}}{2}\varepsilon}$$

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \quad for \quad \sigma_{E4} \le \frac{\sigma_{yds}}{2}\varepsilon$$

$$\sigma_{C4} = \sigma_{yds}\left(1 - \frac{\sigma_{yds}\varepsilon}{4\sigma_{E4}}\right) \quad for \quad \sigma_{E4} > \frac{\sigma_{yds}}{2}\varepsilon$$

σ_{E4} Euler buckling stress, in N/mm^2:

$$\sigma_{E4} = 160000\left(\frac{t_{w-net50}}{d_w}\right)^2$$

ε relative strain defined in *2.3.3.1*.

$A_{s\text{-}net50}$	net area of stiffener, in cm², *see* 2.3.5.1
$t_{w\text{-}net50}$	net thickness of web, in mm
d_w	depth of the web, in mm
s	plate breadth, in mm, taken as the spacing between the stiffeners, as defined in *Section 4/2.2.1*
t_{net50}	net thickness of attached plating, in mm
σ_{yds}	specified minimum yield stress of the material of the stiffener, in N/mm²

2.3.8 Buckling of transversely stiffened plate panels

2.3.8.1 The equation describing the shortening portion of the stress-strain curve σ_{CR5}-ε for the buckling of transversely stiffened panels is to be obtained from the following formula:

$$\sigma_{CR5} = \min\begin{cases} \Phi\sigma_{yd}\left[\dfrac{s}{1000 l_{stf}}\left(\dfrac{2.25}{\beta_p}-\dfrac{1.25}{\beta_p^2}\right)+0.1\left(1-\dfrac{s}{1000 l_{stf}}\right)\left(1+\dfrac{1}{\beta_p^2}\right)^2\right] \\ \sigma_{yd}\Phi \end{cases} \quad \text{N/mm}^2$$

$$\sigma_{CR5} = \min\begin{cases} \Phi\sigma_{ydp}\left[\dfrac{s}{1000 l_{stf}}\left(\dfrac{2.25}{\beta_p}-\dfrac{1.25}{\beta_p^2}\right)+0.1\left(1-\dfrac{s}{1000 l_{stf}}\right)\left(1+\dfrac{1}{\beta_p^2}\right)^2\right] \\ \sigma_{ydp}\Phi \end{cases} \quad \text{N/mm}^2$$

Where:

β_p	coefficient defined in *2.3.4.1*
Φ	edge function defined in *2.3.3.1*
s	plate breadth, in mm, taken as the spacing between the stiffeners, as defined in *Section 4/2.2.1*
l_{stf}	stiffener span, in m, equal to spacing between primary support members
~~σ_{yd}~~	~~specified minimum yield stress of the material, in N/mm²~~
σ_{ydp}	specified minimum yield stress of the material of the plate, in N/mm²

Appendix B – Structural Strength Assessment

2 CARGO TANK STRUCTURAL STRENGTH ANALYSIS

2.4 Application of Loads

2.4.7 Pressure in cargo and ballast tanks

2.4.7.7 The following are to be considered when calculating the static tank pressure in cargo tanks for harbour/tank testing load cases (design combination S) as required by *Section 7/Table 7.6.1*:

- ~~Maximum setting of pressure relief valve, P_{valve} as defined in *Section 7/2.2.3.5*, of all cargo tanks and, where applicable,~~ maximum h_{air}, as defined in *Section 7/2.2.3.2* and *Figure 7.2.3*, of all cargo tanks in the cargo region are to be considered in the calculation of $P_{in-test}$, see *Section 7/2.2.3.5*.

2.4.7.9 Maximum setting of pressure relief valve, P_{valve}, as defined in Section 7/2.2.3.5 are to be considered in design combination S and S+D as required by Section 7/Table 7.6.1.

2.5 Procedure to Adjust Hull Girder Shear Forces and Bending Moments

2.5.1 General

2.5.1.1 The procedure described in this section is to be applied to adjust the hull girder horizontal bending moment, vertical shear force and vertical bending moment distributions on the three cargo tanks FE model to achieve the required values.

2.5.1.2 Vertical distributed loads are applied to each frame position, together with a vertical bending moment applied to the model ends to produce the required value of vertical shear force at both the forward and aft bulkhead of the middle tank of the FE model, and the required value of vertical bending moment at a section within the length of the middle tank of the FE model. The required values are specified in *2.4.5*.

2.5.1.3 A horizontal bending moment is applied to the ends of the model to produce the required target value of horizontal bending moment at a section within the length of the middle tank of the FE model. The required values are specified in *2.4.6*.

2.5.2 Shear force and bending moment due to local loads

2.5.2.1 The vertical shear forces generated by the local loads are to be calculated at the transverse bulkhead positions of the middle tank of the FE model. The maximum absolute shear force at the bulkhead position of the middle tank of the FE model is to be used to obtain the required adjustment in shear forces at the transverse bulkhead, see *2.5.3*. The vertical bending moment distribution generated by the local loads is to be calculated along the length of the middle tank of the three cargo tank FE model. The FE model can be used to calculate the shear forces and bending moments. Alternatively, a simple beam model representing the length of the 3-tank FE model with simply supported ends may be used to determine the shear force and bending moment values.

2.5.2.2 For beam and oblique sea conditions, the horizontal bending moment distribution due to dynamic sea pressure and dynamic tank pressure is to be calculated along the length of the middle tank of the FE model.

2.5.2.3 The following local loads are to be applied for the calculation of hull girder shear forces and bending moments:

(a) ship structural weight distribution over the length of the 3-tank model (static loads). Where a simple beam model is used, the weight of the structure of each tank can be distributed evenly over the length of the cargo tank. The structural weight is to be calculated based on a thickness deduction of $0.5t_{corr}$, as used in the construction of the cargo tank FE model, see *2.2.1.5.*

(b) weight of cargo and ballast (static loads)

(c) static sea pressure, dynamic wave pressure and, where applicable, green sea load. For the Design Load Combination S (harbour/tank testing load cases), only static sea pressure needs to be applied

(d) dynamic tank pressure load for Design Load Combination S+D (seagoing load cases).

2.5.3 Procedure to adjust vertical shear force distribution

2.5.3.1 The required adjustment in shear forces at the transverse bulkhead positions (ΔQ_{aft} and ΔQ_{fwd} as shown in *Figure B.2.10*) are to be generated by applying vertical load at the frame positions as shown in *Figure B.2.11*. It is to be noted that vertical correction loads are not to be applied to any transverse tight bulkheads, any frames forward of the forward tank and any frames aft of the aft tank of the FE model. The sum of the total vertical correction loads applied is equal to zero.

2.5.3.2 The required adjustment in shear forces at the aft and forward transverse bulkheads of the middle tank of the FE model in order to generate the required shear forces at the bulkheads are given by:

$\Delta Q_{aft} = - Q_{targ} - Q_{aft}$

$\Delta Q_{fwd} = Q_{targ} - Q_{fwd}$

Where:

ΔQ_{aft} required adjustment in shear force at aft bulkhead of middle tank based on the maximum absolute shear force at the bulkhead

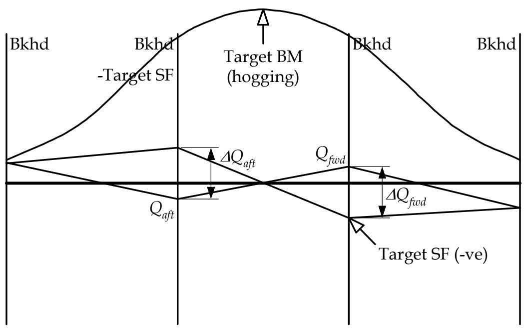
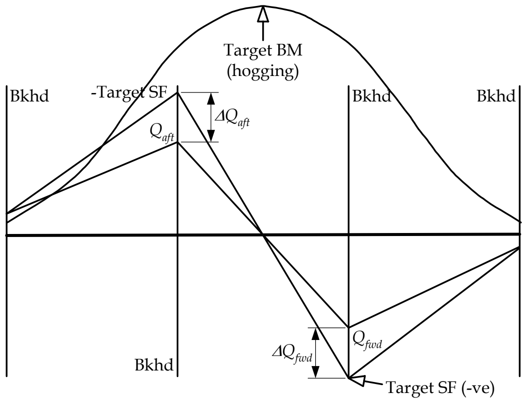
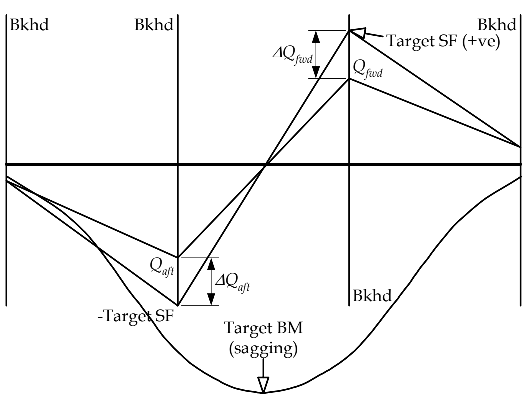
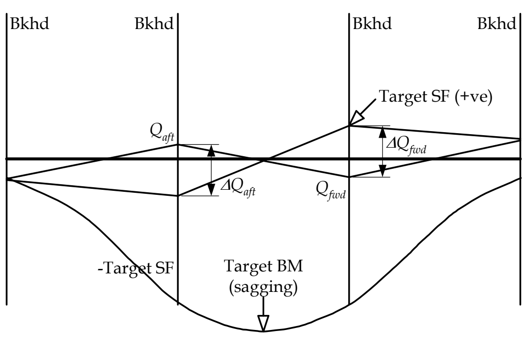
ΔQ_{fwd} required adjustment in shear force at fore bulkhead of the middle tank based on the maximum absolute shear force at the bulkhead

Q_{targ} required shear force value to be achieved at forward bulkhead of middle tank, see *2.4.5.*

Q_{aft} shear force due to local loads at aft bulkhead of middle tank, see *2.5.2*

Q_{fwd} shear force due to local loads at fore bulkhead of middle tank, see *2.5.2*

Figure B.2.10
Position of Target Shear Force and Required Shear Force Adjustment at Transverse Bulkhead Positions

Condition	Target			Aft Bkhd		Fore Bkhd	
	BM	**SF**	**Bkhd pos**	**SF**	**ΔQ_{aft}**	**SF**	**ΔQ_{fwd}**
	Hog	-ve	Fore	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (-ve)	$Q_{targ} - Q_{fwd}$
	Hog	-ve	Fore	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (-ve)	$Q_{targ} - Q_{fwd}$
	Sag	+ve	Fore	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (+ve)	$Q_{targ} - Q_{fwd}$
	Sag	+ve	Fore	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (+ve)	$Q_{targ} - Q_{fwd}$

Note

For definition of symbols, see *2.5.3.2*.

Appendix C – Fatigue Strength Assessment

1.4.4.20 The stress range combination factors, f_1, f_2, f_3 and f_4, which are to be applied to the following zones, are given in ~~Tables C.1.2 to C.1.4~~ Tables C.1.3 to C.1.5:

(a) Zone M: Midship region. This zone extends over the full length of all tanks where the tank LCG lies between 0.35L and 0.8L from AP.

(b) Zone A: Aft region. This zone starts at the middle of the tank immediately aft of Zone M and extends aftwards to include all the aftmost tanks.

(c) Zone F: Forward region. This zone starts at the middle of the tank immediately forward of Zone M and extends forwards to include all the foremost tanks.

(d) Zone AT: Aft transition region between Zone M and Zone A. The stress range combination factors are to be calculated by linear interpolation between the stress range combination factors for Zones M and A.

(e) Zone FT: Forward transition region between Zone M and Zone F. The stress range combination factors are to be calculated by linear interpolation between the stress range combination factors for Zones M and F.

Note

Where ballast tanks, centre and wing cargo tanks do not have the same lengths e.g. if slop tank is present, the middle position is to be taken at the middle of the longer tank.

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