Requirements concerning STRENGTH OF SHIPS

CONTENTS

S1
(1971)
(Rev. 1
1981)
(Rev.2
1983)
(Rev.3
1995)
Rev. 4
1997)
(Rev.5
June
2001)
(Rev.6
July
2004)

Requirements for Loading Conditions, Loading Manuals and Loading Instruments

IACS considers that this Requirement satisfies Regulation 10(1) of the International Convention on Load Lines, 1966.

S1.1 - General

S1.1.1 - Application

These requirements* apply to all classed sea-going ships of 65m in length and above which are contracted for construction on or after 1st July 1998, and contain minimum requirements for loading guidance information.

S1.1.2 - Definitions

Loading Manual:

A Loading Manual is a document which describes:

- the loading conditions on which the design of the ship has been based, including permissible limits of still water bending moment and shear force
- the results of the calculations of still water bending moments, shear forces and where applicable, limitations due to torsional and lateral loads
- the allowable local loading for the structure (hatch covers, decks, double bottom, etc.)

Loading Instrument

A loading instrument is an instrument, which is either analog or digital, by means of which it can be easily and quickly ascertained that, at specified read-out points, the still water bending moments, shear forces, and the still water torsional moments and lateral loads, where applicable, in any load or ballast condition will not exceed the specified permissible values.

An operational manual is always to be provided for the loading instrument.

Single point loading instruments are not acceptable.

Category I Ships

- Ships with large deck openings where combined stresses due to vertical and horizontal hull girder bending and torsional and lateral loads have to be considered;

- Ships liable to carry non-homogeneous loadings, where the cargo and/or ballast may be unevenly distributed. Ships less than 120 metres in length, when their design takes into account uneven distribution of cargo or ballast, belong to Category II;

- Chemical tankers and gas carriers.

Notes

* For ships which were contracted for construction before 1st July 1998, the relevant prior revisions of this Unified Requirement as well as Members' reservations to those revisions of this Unified Requirement apply. Certain additional requirements of Unified Requirement S1A also apply to bulk carriers, ore carriers and combination carriers (see UR Z11), of 150m length and above.

* The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.

Category II Ships

- Ships with arrangement giving small possibilities for variation in the distribution of cargo and ballast, and ships on regular and fixed trading pattern where the Loading Manual gives sufficient guidance, and in addition the exception given under Category I.

S1.1.3 - Annual and Special Survey

At each Annual and Special Survey, it is to be checked that the approved loading guidance information is available on board.

The loading instrument is to be checked for accuracy at regular intervals by the ship's Master by applying test loading conditions.

At each Special Survey this checking is to be done in the presence of the Surveyor.

S1.2 - Loading Conditions, Loading Manuals and Loading Instruments

S1.2.1 - General

An approved loading manual is to be supplied for all ships except those of Category II with length less than 90m in which the deadweight does not exceed 30% of the displacement at the summer loadline draft.

In addition, an approved loading instrument is to be supplied for all ships of Category I of 100 m in length and above.

S1.2.2 - Conditions of Approval of Loading Manuals

The approved Loading Manual is to be based on the final data of the ship. The Manual is to include the design loading and ballast conditions upon which the approval of the hull scantlings is based.

Annex 1 contains, as guidance only, a list of the loading conditions which normally should be included in the Loading Manual.

In case of modifications resulting in changes to the main data of the ship, a new approved Loading Manual is to be issued.

The Loading Manual must be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

S1.2.3 - Condition of Approval of Loading Instruments

The loading instrument is subject to approval, which is to include:

- verification of type approval, if any
- verification that the final data of the ship has been used
- acceptance of number and position of read-out points
- acceptance of relevant limits for all read-out points
- checking of proper installation and operation of the instrument on board, in accordance with agreed test conditions, and that a copy of the operation manual is available.

Recommendations on the approval of Loading instruments are given in the IACS document "Recommendations on loading instruments".

S1
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In case of modifications implying changes in the main data of the ship, the loading instrument is to be modified accordingly and approved.

The operation manual and the instrument output must be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

The operation of the loading instrument is to be verified upon installation. It is to be checked that the agreed test conditions and the operation manual for the instrument is available on board.

S1
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ANNEX 1 TO REQUIREMENT S1

GUIDANCE ON CONDITIONS

1. The Loading Manual should contain the design loading and ballast conditions, subdivided into departure and arrival conditions, and ballast exchange at sea conditions, where applicable, upon which the approval of the hull scantlings is based.

2. In particular the following loading conditions should be included:

2.1 Cargo Ships, Container Ships, Roll-on/Roll-off and Refrigerated Carriers, Ore Carriers and Bulk Carriers:

- Homogeneous loading conditions at maximum draught
- Ballast conditions
- Special loading conditions, e.g. container or light load conditions at less than the maximum draught, heavy cargo, empty holds or non-homogeneous cargo conditions deck cargo conditions, etc., where applicable
- Short voyage or harbour conditions, where applicable
- Docking condition afloat
- Loading and unloading transitory conditions, where applicable

2.2 Oil Tankers:

- Homogeneous loading conditions (excluding dry and clean ballast tanks) and ballast or part-loaded conditions for both departure and arrival
- Any specified non-uniform distribution of loading
- Mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions
- Docking condition afloat
- Loading and unloading transitory conditions

2.3 Chemical Tankers:

- Conditions as specified for oil tankers
- Conditions for high density or heated cargo and segregated cargo where these are included in the approved cargo list

2.4 Liquefied Gas Carriers

- Homogeneous loading conditions for all approved cargoes for both arrival and departure
- Ballast conditions for both arrival and departure
- Cargo condition where one or more tanks are empty or partially filled or where more than one type of cargo having significantly different densities is carried, for both arrival and departure
- Harbour condition for which an increased vapour pressure has been approved
- Docking condition afloat

2.5 Combination Carriers

- Conditions as specified in 2.1 and 2.2, above.

Annex 2 is deleted

END

S1A
(1997)
(Rev.1 April, 1998)
(Rev. 2 May, 1998)
(Rev.3 Sept. 2000)
(Rev.4 Nov.2001)
(Rev.5 July 2004)

Additional Requirements for Loading Conditions, Loading Manuals and Loading Instruments for Bulk Carriers, Ore Carriers and Combination Carriers

S1A.1 - Application

Bulk Carriers, Ore Carriers and Combination Carriers (see URZ11) of 150 m length and above, which are contracted for construction before 1st July 1998 are to be provided with an approved loading instrument of a type to the satisfaction of the Society not later than their entry into service or 1st January 1999, whichever occurs later.

In addition, Bulk Carriers of 150 m length and above where one or more cargo holds are bounded by the side shell only, which were contracted for construction before 1st July 1998 are to be provided, with an approved loading manual with typical loading sequences where the vessel is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions where applicable. Typical unloading sequences for these conditions shall also be included. Annex 1 contains, as guidance only, an example of a Loading Sequence Summary Form. Annex 2 contains guidance for loading and unloading sequences for existing bulk carriers.

Bulk Carriers, Ore Carriers and Combination Carriers of 150m length and above, which are contracted for construction on or after 1st July 1998, are to be provided with an approved Loading Manual and approved computer-based Loading Instrument, in accordance with S1A.2 , S1A.3 and S1A.4. Annex 3 contains guidance for loading and unloading sequences for new bulk carriers.

S1A.2 - Definitions

S1A.2.1 - Loading Manual

Loading Manual is a document which describes:

a) the loading conditions on which the design of the ship has been based, including permissible limits of still water bending moments and shear forces;
b) the results of the calculations of still water bending moments, shear forces and where applicable, limitations due to torsional loads;
c) for bulk carriers, envelope results and permissible limits of still water bending moments and shear forces in the hold flooded condition according to S17 as applicable;
d) the cargo hold(s) or combination of cargo holds that might be empty at full draught. If no cargo hold is allowed to be empty at full draught, this is to be clearly stated in the loading manual;
e) maximum allowable and minimum required mass of cargo and double bottom contents of each hold as a function of the draught at mid-hold position;
f) maximum allowable and minimum required mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds. This mean draught may be calculated by averaging the draught of the two mid-hold positions;
g) maximum allowable tank top loading together with specification of the nature of the cargo for cargoes other than bulk cargoes;
h) maximum allowable load on deck and hatch covers. If the vessel is not approved to carry load on deck or hatch covers, this is to be clearly stated in the loading manual;
i) the maximum rate of ballast change together with the advice that a load plan is to be agreed with the terminal on the basis of the achievable rates of change of ballast.

Notes: 1. The latest date for implementation for requirements in S1A.2.1(f) is 1st July 1999.
2. The latest date for implementation for requirements in S1A.2.2(b) is 1st July 1999.
3. The latest date for implementation for requirements in S1A.4(d) is 1st July 1999.
4. Changes introduced in Rev.3 are to be uniformly implemented by IACS Members and Associates from 1 July 2001.
5. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.

S1A
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S1A.2.2 - Loading Instrument

A loading instrument is an approved digital system as defined in S1. In addition to the requirements in S1, it shall ascertain as applicable that:

a) the mass of cargo and double bottom contents in way of each hold as a function of the draught at mid-hold position;
b) the mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds;
c) the still water bending moment and shear forces in the hold flooded conditions according to S17;

are within permissible values.

S1A.3 - Conditions of Approval of Loading Manuals

In addition to the requirements given in S1.2.2, the following conditions, subdivided into departure and arrival conditions as appropriate, are to be included in the Loading Manual:

a) alternate light and heavy cargo loading conditions at maximum draught, where applicable;
b) homogeneous light and heavy cargo loading conditions at maximum draught;
c) ballast conditions. For vessels having ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty;
d) short voyage conditions where the vessel is to be loaded to maximum draught but with limited amount of bunkers;
e) multiple port loading/unloading conditions;
f) deck cargo conditions, where applicable;
g) typical loading sequences where the vessel is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions where applicable. Typical unloading sequences for these conditions shall also be included. The typical loading/unloading sequences shall also be developed to not exceed applicable strength limitations. The typical loading sequences shall also be developed paying due attention to loading rate and the deballasting capability. Annex 1 contains, as guidance only, an example of a Loading Sequence Summary Form.
h) typical sequences for change of ballast at sea, where applicable.

S1A.4 - Condition of Approval of Loading Instruments

The loading instrument is subject to approval. In addition to the requirements given in S1.2.3, the approval is to include as applicable:

a) acceptance of hull girder bending moment limits for all read-out points
b) acceptance of hull girder shear force limits for all read-out points
c) acceptance of limits for mass of cargo and double bottom contents of each hold as a function of draught
d) acceptance of limits for mass of cargo and double bottom contents in any two adjacent holds as a function of draught.

S1A
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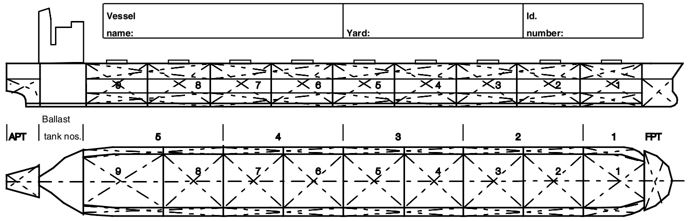
ANNEX 1
Guidance on Typical Loading Sequence Summary Form

ANNEX 3 TO REQUIREMENT S1
GUIDANCE ON TYPICAL LOADING SEQUENCE SUMMARY FORM

Vessel name:	Yard:	Id. number:



Port (specific or typical):	Condition at commencement of loading/discharging	
Total mass of cargo to be loaded/discharged:	Condition at end of loading/discharging	
Dock water Density (V.m3)	Maximum Loading/discharging rate:	Average Loading/discharging rate:
Number of loaders/dischargers:	Maximum Ballasting/Deballasting rate:	Average Ballasting/Deballasting rate:

Volume of Hold, Vh (m3)									
Heigth of hold,h (m)									

Note: **During each pour it has to be controlled that allowable limits for hull girder shear forces, bending moments and mass in holds are not exceeded.**
Loading/discarging operations may have to be paused to allow for ballasting/deballasting in order to keep actual values within limits.

	Hold content at commencement of loading/discharging								
Cargo mass									
Density (t/m3)									
Grade									

Ballast content at commencement of loading/discharging	APT	Ball. no. 5	Ball. no. 4	Hold no. 6	Ball. no. 3	Hold no. 4	Ball. no. 2	Ball. no.1	FPT
Wings or peaks									
Upper									
Lower/Peaks									

Commencement of loading/discharging (sea)				
T aft (m)	Trim (m)	T fwd (m)	Maximum S.F. (%)	Maximum B.M. (%)

CARGO OPERATIONS	Hold 9	Hold 8	Hold 7	Hold 6	Hold 5	Hold 4	Hold 3	Hold 2	Hold 1
Pour no. /grade									
1									
2									
3									
4									
5									
6									
7									
8									
..									
Draft Survey (for loading):	Total cargo onboard (t):				Remaining cargo to be loaded (t):				
n-1									
n									

BALLAST OPERATIONS		APT	Ballast tank no. 5	Ballast tank no.4	No.6 Ballast hold	Ballast tank no.3	No. 4 Ballast hold	Ballast tank no.2	Ballast tank no.1	FPT
1	Upper									
	Lower/Peak									
2	Upper									
	Lower/Peak									
3	Upper									
	Lower/Peak									
4	Upper									
	Lower/Peak									
5	Upper									
	Lower/Peak									
6	Upper									
	Lower/Peak									
7	Upper									
	Lower/Peak									
8	Upper									
	Lower/Peak									
..	Upper									
	Lower/Peak									
Draft Survey	Total amount of bunkers onboard (t):									
n-1	Upper									
	Lower/Peak									
n	Upper									
	Lower/Peak									

Values at end of pour (from harbour to sea)				
T fwd (m)	Trim (m)	T fwd (m)	Maximum S.F. (%)	Maximum B.M. (%)

	Hold content at end of loading/discharging								
Cargo mass									
	Total mass loaded/discharged (t)								

Ballast content at end of loading/discharging	APT	Ball. no. 5	Ball. no. 4	No. 6 hold	Ball. no. 3	No. 4 hold	Ball. no. 2	Ball. no.1	FPT
Wings or peaks									
Upper									
Lower/Peaks									

Values at end of loading/discharging (sea)				
T aft (m)	Trim (m)	T fwd (m)	Maximum S.F. (%)	Maximum B.M. (%)

	Maximum occuring values among all conditions above									
Net load on Double Bottom										tons/m2
Net load in two adjacent holds										tons

Net load on double bottom = (Mh/V) * h - T (t/m2)
- where: Mh = Mass in hold + mass in DB (t)
V = Total volume of hold (m3)
h = heigth of hold from inner bottom to top of coaming (m)
T = draught (m)

Approved by:

Place, date, stamp and sign

S1A
cont'd

ANNEX 2

EXISTING BULK CARRIERS
GUIDANCE FOR LOADING/UNLOADING SEQUENCES

1. UR S1A.1 requires that bulk carriers of 150m length and above, where one or more cargo holds are bounded by the side shell only, which were contracted for construction before 1st July 1998, are to be provided, with an approved loading manual with typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part loaded conditions and alternate conditions where applicable. Typical unloading sequences shall be included.

2. This requirement will necessitate shipowners and operators to prepare and submit for approval typical loading and unloading sequences.

3. The minimum acceptable number of typical sequences is:

- one homogeneous full load condition,
- one part load condition where relevant, such as block loading or two port unloading,
- one full load alternate hold condition, if the ship is approved for alternate hold loading.

4. The shipowner / operator should select actual loading / unloading sequences, where possible, which may be port specific or typical.

5. The sequence may be prepared using the onboard loading instrument. The selected loading conditions should be built up step by step from commencement of cargo loading to reaching full deadweight capacity. Each time the loading equipment changes position to a new hold defines a step. Each step is to be documented and submitted to the class society. The printout from the loading instrument is generally acceptable. This allows the actual bending moments and shear forces to be verified and prevent the permissible values being exceeded. In addition, the local strength of each hold may need to be considered during the loading.

6. For each loading condition a summary of all steps is to be included. This summary is to highlight the essential information for each step such as:

- How much cargo is filled in each hold during the different steps,
- How much ballast is discharged from each ballast tank during the different steps,
- The maximum still water bending moment and shear at the end of each step,
- The ship's trim and draught at the end of each step.

Blank summary sheets are attached for reference for typical 5, 7 and 9 hold bulk carriers.

7. The approved typical loading/unloading sequences, may be included in the approved loading manual or take the form of an addendum prepared for purposes of complying with class society requirements. A copy of the approved typical loading/unloading sequences is to be placed onboard the ship.

S1A
cont'd

ANNEX 3

NEW BULK CARRIERS
GUIDANCE FOR LOADING/UNLOADING SEQUENCES

1. UR S1A.1 requires that Bulk Carriers, Ore Carriers and Combination Carriers of 150m length and above, which are contracted for construction on or after 1st July 1998, are to be provided with an approved loading manual with typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part loaded conditions and alternate conditions where applicable. The typical unloading sequences shall be developed paying due attention to the loading rate, the deballasting capacity and the applicable strength limitations.

2. The shipbuilder will be required to prepare and submit for approval typical loading and unloading sequences.

3. The typical loading sequences as relevant should include::

- alternate light and heavy cargo load condition,
- homogeneous light and heavy cargo load condition,
- short voyage condition where the ship is loaded to maximum draught but with limited bunkers
- multiple port loading / unloading condition,
- deck cargo condition,
- block loading.

4. The loading / unloading sequences may be port specific or typical.

5. The sequence is to be built up step by step from commencement of cargo loading to reaching full deadweight capacity. Each time the loading equipment changes position to a new hold defines a step. Each step is to be documented and submitted to the class society. In addition to longitudinal srtength, the local strength of each hold is to be considered.

6. For each loading condition a summary of all steps is to be included. This summary is to highlight the essential information for each step such as:

- How much cargo is filled in each hold during the different steps,
- How much ballast is discharged from each ballast tank during the different steps,
- The maximum still water bending moment and shear at the end of each step,
- The ship's trim and draught at the end of each step.

END

S2 (1973) Definition of ship's length *L* and of block coefficient C_b

S2.1 Rule length *L*
The length of L is the distance, in metres, on the summer load waterline from the fore side of stem to the after side of the rudder post, or the centre of the rudder stock if there is no rudder post. *L* is not to be less than 96%, and need not be greater than 97%, of the extreme length on the summer load waterline. In ships with unusual stern and bow arrangement the length *L* will be specially considered.

S2.2 Block coefficient C_b
The block coefficient C_b is the moulded block coefficient at draught *d* corresponding to summer load waterline, based on rule length *L* and moulded breadth *B*:

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

◄◄

S3 (1973) Strength of end bulkheads of superstructures and deckhouses

S3.1 Scope

The following proposal applies to bulkheads forming the only protection for openings as per Regulation 18 of LLC 1966 and for accommodations. These requirements define minimum scantlings based upon local lateral loads and it may be required that they be increased in individual cases. Scantlings of tiers not specifically mentioned in this proposal are left to the discretion of individual Classification Societies.

S3.2 Design pressure head

$$p = \frac{a}{100}(bf - y)c$$

where p = design pressure in N/mm2 (MPa)

$a = 2{,}0 + \frac{L_1}{120}$ for lowest tier of unprotected fronts

The lowest tier is normally that tier which is directly situated above the uppermost continuous deck to which the rule depth *D* is to be measured. However, where the freeboard is excessive, it may be left to each individual Classification Society to define this tier as an upper tier. It is recommended that 'excessive freeboard' is that which exceeds the minimum tabular freeboard by more than one standard superstructure height.

$a = 1{,}0 + \frac{L_1}{120}$ for 2nd tier of unprotected fronts

$a = 0{,}5 + \frac{L_1}{150}$ { for 3rd tier of unprotected fronts; for sides and protected fronts

$a = 0{,}7 + \frac{L_1}{1000} - 0{,}8\frac{x}{L}$ for aft ends aft of amidships

$a = 0{,}5 + \frac{L_1}{1000} - 0{,}4\frac{x}{L}$ for aft ends forward of amidships

L, L_1 = length of ships in metres, L_1 need not be taken greater than 300 m

►

S3
cont'd

$b = 1{,}0 + \left(\frac{x/L - 0{,}45}{C_b + 0{,}2}\right)^2$ for $x/L > 0{,}45$

$b = 1{,}0 + 1{,}5\left(\frac{x/L - 0{,}45}{C_b + 0{,}2}\right)^2$ for $x/L > 0{,}45$

C_b = block coefficient, $0{,}60 < C_b < 0{,}80$

when determining aft ends forward of amidships, C_b need not be taken less than 0,80

x = distance in metres between bulkhead considered and AP
When determining sides of a deckhouse, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding 0,15*L* each and *x* is to be taken as the distance between AP and the centre of each part considered.

$f = \frac{L}{10} e^{-/L300} - \left[1 - \left(\frac{L}{150}\right)^2\right]$ for $L < 150$ m

$f = \frac{L}{10} e^{-/L300}$ for $150 \text{ m} < L < 300$ m

$f = 11{,}03$ for $L > 300$ m

y = vertical distance in metres from summer waterline to midpoint of stiffener span

$c = \left(0{,}3 + 0{,}7\frac{b'}{B'}\right)$

b' = breadth of deckhouse at the position considered

B' = actual maximum breadth of ship on the exposed weather deck at the position considered

For exposed parts of machinery casings *c* is not to be taken less than 1.0

The design pressure *p* is not to be taken less than the minimum values given in Table 1.

Table 1

L (m)	*p* (N/mm^2 or MPa)	
	Lowest tier of unprotected fronts	Elsewhere
$L \le 50$	0,03	0,015
$50 < L < 250$	$0{,}025 + 10^{-4}L$	$0{,}0125 + 0{,}5 \times 10^{-4}L$
$L \ge 250$	0,05	0,025

S3.3 Stiffener modulus

$W = 350 s l^2 p$

where W = stiffener modulus (cm^3)

s = spacing of stiffeners (m), measured along the plating

l = unsupported span (m), which is to be taken as the 'tween deck height $l_{min} = 2{,}0$ m

p = pressure in N/mm^2 (MPa) as defined above.
The section modulus of house side stiffeners need not be greater than that of side frames on the deck situated directly below taking account of spacing and span

These requirements assume the webs of lower tier stiffeners to be efficiently welded to the decks. Scantlings for other types of end connections may be specially considered.

S3.4 Thickness of plating

$t = 30s\sqrt{p}$

where t = thickness of plating (mm), not less than:
$5{,}0 + L_1/100$ for lowest tier
$4{,}0 + L_1/100$ for upper tiers, but not less than 5,0 mm

s and *p* are as defined above.

When determining *p*, *y* is to be measured to middle of the plate field.

◄◄

S4
(1973)
(Rev. 1
1974)

Criteria for the use of high tensile steel with yield points of 315 N/mm² and 355 N/mm² (with respect to longitudinal strength)

k = 0,78 for steel with Y = 315 N/mm²

k = 0,72 for steel with Y = 355 N/mm²

provided that the moment of inertia of the midship section is not less than:

$I_{min} = 3\, W_{min}\, L$ (cm⁴)

Y = minimum upper yield point

L = Rule length of ship (m)

W_{min} = minimum mild steel section modulus (cm²) as given for a new ship in S7. Any reduction for corrosion control is not to be taken account of.

◄◄

S5
(1975)

Calculation of midship section moduli for conventional ship for ship's scantlings

When calculating the midship section modulus within 0,4L amidships the sectional area of all continuous longitudinal strength members is to be taken into account.

Large openings, i.e. openings exceeding 2,5 m in length or 1,2 m in breadth and scallops, where scallop-welding is applied, are always to be deducted from the sectional areas used in the section modulus calculation.

Smaller openings (manholes, lightening holes, single scallops in way of seams, etc.) need not be deducted provided that the sum of their breadths or shadow area breadths in one transverse section does not reduce the section modulus at deck or bottom by more than 3% and provided that the height of lightening holes, draining holes and single scallops in longitudinals or longitudinal girders does not exceed 25% of the web depth, for scallops maximum 75 mm.

A deduction-free sum of smaller opening breadths in one transverse section in the bottom or deck area of 0,06 (B - Σb) (where B = breadth of ship, Σb = total breadth of large openings) may be considered equivalent to the above reduction in section modulus.

The shadow area will be obtained by drawing two tangent lines with an opening angle of 30°C.

The deck modulus is related to the moulded deck line at side.

The bottom modulus is related to the base line.

Continuous trunks and longitudinal hatch coamings are to be included in the longitudinal sectional area provided they are effectively supported by longitudinal bulkheads or deep girders. The deck modulus is then to be calculated by dividing the moment of inertia by the following distance, provided this is greater than the distance to the deck line at side:

$$y_t = y\left(0{,}9 + 0{,}2\,\frac{x}{B}\right)$$

y = distance from neutral axis to top of continuous strength member

x = distance from top of continuous strength member to centreline of the ship

x and y to be measured to the point giving the largest value of y_t.

Longitudinal girders between multi-hatchways will be considered by special calculations. ◄◄

S6
(1978)
(Rev. 1 1980)
(Rev. 2 1996)
(Rev.3 May 2002)
(Rev. 4 July 2003)

Use of steel grades for various hull members - ships of 90 m in length and above

S6.1 Ships in normal world wide service

Materials in the various strength members are not to be of lower grade than those corresponding to classes I, II and III. as given in Table 1, depending on the categories of structural members (SECONDARY, PRIMARY and SPECIAL).

Table 1 - Application of Material Classes and Grades

Structural member category	Material class – Within 0.4L amidships	Material class – Outside 0.4L amidships
SECONDARY: A1. Longitudinal bulkhead strakes, other than that belonging to the Primary category A2. Deck Plating exposed to weather, other than that belonging to the Primary or Special category A3. Side plating	I	A/AH
PRIMARY: B1. Bottom plating, including keel plate B2. Strength deck plating, excluding that belonging to the Special category B3. Continuous longitudinal members above strength deck, excluding hatch coamings B4. Uppermost strake in longitudinal bulkhead B5. Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	II	A/AH
SPECIAL: C1. Sheer strake at strength deck [1], [8] C2. Stringer plate in strength deck [1], [8] C3. Deck strake at longitudinal bulkhead [2], [8] C4. Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch openings configuration [3] C5. Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch openings configuration [4] C6. Bilge strake [5], [6], [8] C7. Longitudinal hatch coamings of length greater than 0.15 L. [7] C8. End brackets and deck house transition of longitudinal cargo hatch coamings [7]	III	II (I outside 0.6L amidships)

Notes:
[1] Not to be less than grade E/EH within 0.4L amidships in ships with length exceeding 250 metres.
[2] Excluding deck plating in way of inner-skin bulkhead of double hull ships.
[3] Not to be less than class III within the length of the cargo region.
[4] Not to be less than class III within 0.6L amidships and class II within the remaining length of the cargo region.
[5] May be of class II in ships with a double bottom over the full breadth and with length less than 150 metres.
[6] Not to be less than grade D/DH within 0.4L amidships in ships with length exceeding 250 metres.
[7] Not to be less than grade D/DH.
[8] Single strakes required to be of class III or of grade E/EH and within 0.4L amidships are to have breadths not less than 800+5xL mm, need not be greater than 1800 mm, unless limited by the geometry of the ship's design.

The material grade requirements for hull members of each class depending on thickness are defined in Table 2.

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Table 2 Material Grade Requirements for Classes I, II and III

Class	I		II		III	
Thickness , in mm	MS	HT	MS	HT	MS	HT
$t \leq 15$	A	AH	A	AH	A	AH
$15 < t \leq 20$	A	AH	A	AH	B	AH
$20 < t \leq 25$	A	AH	B	AH	D	DH
$25 < t \leq 30$	A	AH	D	DH	D	DH
$30 < t \leq 35$	B	AH	D	DH	E	EH
$35 < t \leq 40$	B	AH	D	DH	E	EH
$40 < t \leq 50$	D	DH	E	EH	E	EH

For strength members not mentioned in Table 1, grade A/AH may generally be used. The steel grade is to correspond to the as-built plate thickness when this is greater than the rule requirement.

Plating materials for sternframes, rudders, rudder horns and shaft brackets are in general not to be of lower grades than corresponding to class II. For rudder and rudder body plates subjected to stress concentrations (e.g. in way of lower support of semi-spade rudders or at upper part of spade rudders) class III is to be applied.

S6.2 - Structures exposed to low air temperatures

For ships intended to operate in areas with low air temperatures (below and including - 20ºC), e.g. regular service during winter seasons to Arctic or Antartic waters, the materials in exposed structures are to be selected based on the design temperature t_D, to be taken as defined in S6.3.

Materials in the various strength members above the lowest ballast water line (BWL) exposed to air are not to be of lower grades than those corresponding to classes I, II and III, as given in Table 3, depending on the categories of structural members (SECONDARY, PRIMARYand SPECIAL). For non-exposed structures and structures below the lowest ballast water line, see S6.1.

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Table 3 - Application of Material Classes and Grades - Structures Exposed at Low Temperatures

Structural member category	Material class	
	Within 0,4 L amidships	Outside 0,4 L amidships
SECONDARY: Deck plating exposed to weather, in general Side plating above BWL Transverse bulkheads above BWL	I	I
PRIMARY: Strength deck plating [1] Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings Longitudinal bulkhead above BWL Top wing tank bulkhead above BWL	II	I
SPECIAL: Sheer strake at strength deck [2] Stringer plate in strength deck [2] Deck strake at longitudinal bulkhead [3] Continuous longitudinal hatch coamings [4]	III	II

Notes:

[1] Plating at corners of large hatch openings to be specially considered. Class III or grade E/EH to be applied in positions where high local stresses may occur.
[2] Not to be less than grade E/EH within 0,4 L amidships in ships with length exceeding 250 metres.
[3] In ships with breadth exceeding 70 metres at least three deck strakes to be class III.
[4] Not to be less than grade D/DH.

The material grade requirements for hull members of each class depending on thickness and design temperature are defined in Table 4. For design temperatures t_D < -55ºC, materials are to be specially considered by each Classification Society.

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Table 4 - Material Grade Requirements for Classes, I, II and III at Low Temperatures

Class I

Plate thickness, in mm	-20/-25°C MS	HT	-26/-35°C MS	HT	-36/-45°C MS	HT	-46/-55°C MS	HT
t ≤ 10	A	AH	B	AH	D	DH	D	DH
10 < t ≤ 15	B	AH	D	DH	D	DH	D	DH
15 < t ≤ 20	B	AH	D	DH	D	DH	E	EH
20 < t ≤ 25	D	DH	D	DH	D	DH	E	EH
25 > t ≤ 30	D	DH	D	DH	E	EH	E	EH
30 < t ≤ 35	D	DH	D	DH	E	EH	E	EH
35 < t ≤ 45	D	DH	E	EH	E	EH	Ø	FH
45 < t ≤ 50	E	EH	E	EH	Ø	FH	Ø	FH

Ø = Not applicable

Class II

Plate thickness, in mm	-20/-25°C MS	HT	-26/-35°C MS	HT	-36/-45°C MS	HT	-46/-55°C MS	HT
t ≤ 10	B	AH	D	DH	D	DH	E	EH
10 < t ≤ 20	D	DH	D	DH	E	EH	E	EH
20 < t ≤ 30	D	DH	E	EH	E	EH	Ø	FH
30 < t ≤ 40	E	EH	E	EH	Ø	FH	Ø	FH
40 < t ≤ 45	E	EH	Ø	FH	Ø	FH	Ø	Ø
45 < t ≤ 50	E	EH	Ø	FH	Ø	FH	Ø	Ø

Ø = Not applicable

Class III

Plate thickness, in mm	-20/-25°C MS	HT	-26/-35°C MS	HT	-36/-45°C MS	HT	-46/-55°C MS	HT
t ≤ 10	D	DH	D	DH	E	EH	E	EH
10 < t ≤ 20	D	DH	E	EH	E	EH	Ø	FH
20 < t ≤ 25	E	EH	E	EH	Ø	FH	Ø	FH
25 < t ≤ 30	E	EH	E	EH	Ø	FH	Ø	FH
30 < t ≤ 35	E	EH	Ø	FH	Ø	FH	Ø	Ø
35 < t ≤ 40	E	EH	Ø	FH	Ø	FH	Ø	Ø
40 < t ≤ 50	Ø	FH	Ø	FH	Ø	Ø	Ø	Ø

Ø = Not applicable

Single strakes required to be of class III or of grade E/EH of FH are to have breadths not less than 800+ 5•L mm, maximum 1800 mm.

Plating materials for sternframes, rudder horns, rudders and shaft brackets are not to be of lower grades than those corresponding to the material classes given in 6.1.

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S6.3 Design temperature t_D

The design temperature t_D is to be taken as the lowest mean daily average air temperautre in the area of operation.

Mean: Statistical mean over observation period (at least 20 years).
Average: Average during one day and night.
Lowest: Lowest during year.

For seasonally restricted service the lowest value within the period of operation applies.

Fig. 1 illustrates the temperature definition.

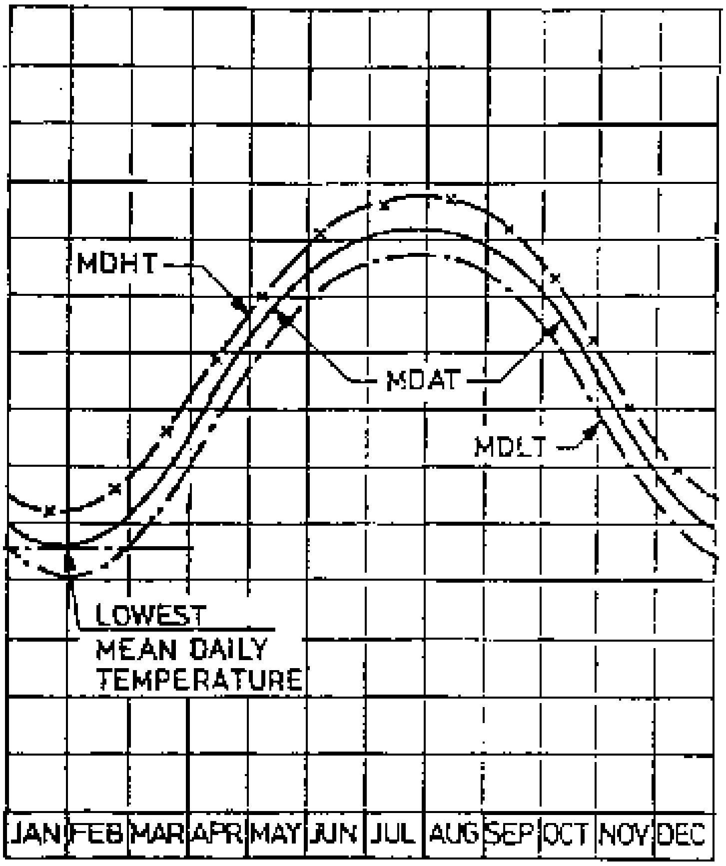

Fig. 1

Commonly used definitions of temperatures.

MDHT = Mean Daily High (or maximum) Temperature
MDAT = Mean Daily Average Temperature.
MDLT = Mean Daily Low (or minimum) Temperature.

◀◀

S7 Minimum longitudinal strength standards†

(1973)
(Rev. 1 1976)
(Rev. 2 1978)
(Rev. 3 1989)

S7.1 The minimum midship section modulus at deck and keel for ships 90 m ≤ L ≤ 500 m and made of hull structural steel is

$$W_{min} = cL^2B\,(C_b + 0{,}7)\,k \qquad (\text{cm}^3)$$

where L = Rule length (m)
B = Rule breadth (m)
C_b = Rule block coefficient; C_b is not to be taken less than 0,60
c = c_n for new ships
c = c_s for ships in service = 0,9 c_n

$$c_n = 10{,}75 - \left(\frac{300 - L}{100}\right)^{3/2} \quad \text{for } 90 \text{ m} \le L \le 300\text{m}$$

$$= 10{,}75 \quad \text{for } 300 \text{ m} < L < 350 \text{ m}$$

$$= 10{,}75 - \left(\frac{L - 350}{150}\right)^{3/2} \quad \text{for } 350 \text{ m} \le L \le 500 \text{ m}$$

k = material factor
k = 1,0 for ordinary hull structural steel,
k < 1,0 for higher tensile steel according to S4.

S7.2 Scantlings of all continuous longitudinal members of hull girder based on the section modulus requirement in S7.1 are to be maintained within 0,4 L amidships.
However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the end of the 0,4 L part, bearing in mind the desire not to inhibit the vessel's loading flexibility.

S7.3 In ships where part of the longitudinal strength material in the deck or bottom area are forming boundaries of tanks for oil cargoes or ballast water and such tanks are provided with an effective corrosion protection system, certain reductions in the scantlings of these boundaries are allowed. These reductions, however, should in no case reduce the minimum hull girder section modulus for a new ship by more than 5%.

NOTE
The above standard refers in unrestricted service with minimum midship section modulus only. However, it may not be applicable to ships of unusual type or design, e.g. for ships of unusual main proportions and/or weight distributions.

'New Ships' are ships in the stage directly after completion.

† This Requirement is subject to periodical updating.

S8 Bow doors and inner doors

(1982)
(Rev. 2 1995)
(Corr. 1997)
(Rev.3 Nov. 2003)

S8.1 General

S8.1.1 *Application*

S8.1.1a These requirements are for the arrangement, strength and securing of bow doors and inner doors leading to a complete or long forward enclosed superstructures, or to a long non-enclosed superstructure, where fitted to attain minimum bow height equivalence.

The requirements apply to all ro-ro passenger ships and ro-ro cargo ships engaged on international voyages and also to ro-ro passenger ships and ro-ro cargo ships engaged only in domestic (non-international) voyages, except where specifically indicated otherwise herein.

The requirements are not applicable to high speed, light displacement craft as defined in the IMO Code of Safety for High Speed Craft.

S8.1.1b Two types of bow door are provided for:

- **Visor doors** opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms,
- **Side-opening doors** opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the ship. It is anticipated that side-opening bow doors are arranged in pairs.

Other types of bow door will be specially considered in association with the applicable requirements of these rules.

S8.1.2 *Arrangement*

S8.1.2a Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck for the purpose of this requirement.

S8.1.2b An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door needs not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, refer to regulation II-1/10 or II-1/11 of the SOLAS Convention, as appropriate to the type of ship. A vehicle ramp may be arranged for this purpose, provided its position complies with regulation II-1/10 or II-1/11 of the SOLAS Convention, as appropriate to the type of ship. If this is not possible a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

S8.1.2c Bow doors are to be so fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

S8.1.2d Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in S8.1.2b.

S8.1.2e The requirements for inner doors are based on the assumption that vehicle are effectively lashed and secured against movement in stowed position.

S8.1.3 *Definitions*

Securing device - a device used to keep the door closed by preventing it from rotating about its hinges.

Supporting device - a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure.

Locking device - a device that locks a securing device in the closed position

Footnote: It was agreed by IACS Council in August 1995 that this UR S8 should be uniformly applied by IACS Members to new ships as soon as possible but not later than 1 July 1996 and, with immediate effect, when approving plans for bow arrangements on new ships, Members should strongly recommend that the requirements as set out in the revised UR S8 are complied in full. ▶

Ro-ro passenger ship	-a passenger ship with ro-ro spaces or special category spaces.
Ro-ro spaces	-are spaces not normally sub-divided in any way and normally extending to either a substantial length or the entire length of the ship, in which motor vehicles with fuel in their tanks for their own propulsion and/or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks or in or on similar stowage units or, other receptacles) can be loaded and unloaded normally in a horizontal direction.
Special category spaces	- are those enclosed vehicle spaces above or below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10m.

S8.2 Strength Criteria

S8..2.1 *Primary structure and Securing and Supporting devices*

S8.2.1a Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be determined to withstand the design loads defined in S8.3, using the following permissible stresses:

shear stress : $$\tau = \frac{80}{k} \text{ N/mm}^2$$

bending stress : $$\sigma = \frac{120}{k} \text{ N/mm}^2$$

equivalent stress : $$\sigma_c = \sqrt{\sigma^2 + 3\tau^2} = \frac{150}{k} \text{ N/mm}^2$$

where k is the material factor as given in S4, but is not to be taken less than 0.72 unless a direct fatigue analysis is carried out.

S8.2.1b The buckling strength of primary members is to be verified as being adequate.

S.8.2.1c For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed $0.8\sigma_F$,where σ_F is the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

S8.2.1d The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of bolts not carrying support forces is not to exceed :

$$\frac{125}{k} \text{ N/mm}^2$$

S8.3 Design loads

S8.3.1 *Bow doors*

S8.3.1a The design external pressure, in kN/m^2, to be considered for the scantlings of primary members, securing and supporting devices of bow doors is not to be less than the pressure normally used by the Society nor than:

$$P_e = 2.75\lambda C_H (0.22 + 0.15\tan\alpha)(0.4V\sin\beta + 0.6L^{0.5})^2$$

where:

V contractual ship's speed, in knots,

L ship's length, in m, but need not be taken greater than 200 metres,

λ coefficient depending on the area where the ship is intended to be operated:

- **λ**=1 for seagoing ships,
- **λ**=0.8 for ships operated in coastal waters,
- **λ**=0.5 for ships operated in sheltered waters,

▶

S8
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Note: Coastal waters and sheltered waters are defined according to the practice of each Classification Society. As an example, coastal waters may be defined as areas where significant wave heights do not exceed 4m for more than three hours a year and sheltered waters as areas where significant wave heights do not exceed 2m for more than three hours a year.

C_H = 0.0125 L for L < 80m
1 for L ≥ 80m

α flare angle at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating,

β entry angle at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane.

S8.3.1b The design external forces, in kN, considered for the scantlings of securing and supporting devices of bow doors are not to be less than:

$$F_x = P_e A_x$$

$$F_y = P_e A_y$$

$$F_z = P_e A_z$$

where:

A_x area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded.

A_y area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser.

A_z area, in m^2, of the horizontal projection of the door between the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser.

h height, in m, of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser,

ℓ length, in m, of the door at a height h/2 above the bottom of the door,

w breadth, in m, of the door at a height h/2 above the bottom of the door,

Pe external pressure, in kN/m^2, as given in S8.3.1a with angles **α** and **β** defined as follows:

α flare angle measured at the point on the bow door, $\ell/2$ aft of the stem line on the plane h/2 above the bottom of the door, as shown in Figure 1,

β entry angle measured at the same point as **α**.

For bow doors, including bulwark, of unusual form or proportions, e.g. ships with a rounded nose and large stem angles, the areas and angles used for determination of the design values of external forces may require to be specially considered.

S8.3.1c For visor doors the closing moment M_y under external loads, in kN·m, is to be taken as:

$$M_y = F_x a + 10Wc - F_z b$$

►

S8
cont'd

where:

W mass of the visor door, in t,

a vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Figure 2,

b horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Figure 2,

c horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Figure 2.

S8.3.1d Moreover, the lifting arms of a visor door and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1.5kN/m^2 is to be taken into account.

S8.3.2 *Inner doors*

S8.3.2a The design external pressure p_e, in kN/m^2, considered for the scantlings of primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of the following:

. p_e = 0.45 L,

. hydrostatic pressure p_h = 10h, where h is the distance, in m, from the load point to the top of the cargo space,

where L is the ship's length, as defined in S8.3.1a.

S8.3.2b The design internal pressure p_i, in kN/m^2, considered for the scantlings of securing devices of inner doors is not to be less than:

p_i = 25

S8.4 Scantlings of bow doors

S8.4.1 *General*

S8.4.1a The strength of bow doors is to be commensurate with that of the surrounding structure.

S8.4.1b Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the ship structure.

S8.4.2 *Plating and secondary stiffeners*

S8.4.2a The thickness of the bow door plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.

S8.4.2b The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and bow doors stiffeners.

S.8.4.2c The stiffener webs are to have a net sectional area, in cm^2, not less than:

$$A = \frac{Qk}{10}$$

▶

S8
cont'd

where:

Q shear force, in kN, in the stiffener calculated by using uniformly distributed external pressure p_e as given in S8.3.1a.

S8.4.3 *Primary structure*

S8.4.3a The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

S8.4.3b The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

S8.4.3c Scantlings of the primary members are generally to be supported by direct strength calculations in association with the external pressure given in S8.3.1a and permissible stresses given in S8.2.1a. Normally, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections.

S8.5 Scantlings of inner doors

S8.5.1 *General*

S8.5.1a Scantlings of the primary members are generally to be supported by direct strength calculations in association with the external pressure given in S8.3.2a and permissible stresses given in S8.2.1a. Normally, formulae for simple beam theory may be applied.

S8.5.1b Where inner doors also serve as a vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

S8.5.1c The distribution of the forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the structure and the actual position and stiffness of the supports.

S8.6 Securing and supporting of bow doors

S8.6.1 General

S8.6.1a Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is not generally to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

S8.6.1b Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide load compression of the packing material are not generally to be included in the calculations called for in S8.6.2e. The number of securing and supporting devices are generally to be the minimum practical whilst taking into account the requirements for redundant provision given in S8.6.2f and S8.6.2g and the available space for adequate support in the hull structure.

S8.6.1c For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self closing under external loads, that is M_y>0. Moreover, the closing moment M_y as given in S8.3.1c is to be not less than:

$$M_{yo} = 10Wc + 0.1\left(a^2 + b^2\right)^{0.5}\left(F_x^{\,2} + F_z^{\,2}\right)^{0.5}$$

▶

S8 cont'd

S8.6.2 *Scantlings*

S8.6.2a Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in S8.2.1a.

S8.6.2b For visor doors the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

i) case 1 F_x and F_z

ii) case 2 $0.7F_y$ acting on each side separately together with $0.7F_x$ and $0.7F_z$

where F_x, F_y and F_z are determined as indicated in S8.3.1b and applied at the centroid of projected areas.

S8.6.2c For side-opening doors the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

i) case 1 F_x, F_y and F_z acting on both doors

ii) case 2 $0.7\,F_x$ and $0.7F_z$ acting on both doors and $0.7F_y$ acting on each door separately,

where F_x, F_y and F_z are determined as indicated in S8.3.1b and applied at the centroid of projected areas.

S8.6.2d The support forces as determined according to S8.6.2b i) and S8.6.2c i) shall generally give rise to a zero moment about the transverse axis through the centroid of the area A_x. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

S8.6.2e The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

S8.6.2f The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable to withstand the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in S8.2.1.

S8.6.2g For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in S8.2.1a. The opening moment M_o, in kN·m, to be balanced by this reaction force, is not to be taken less than:

$$M_o = 10\,W\,d + 5A_x a$$

where:

d vertical distance, in m, from the hinge axis to the centre of gravity of the door, as shown in Figure 2,

a as defined in S8.3.1c.

S8.6.2.h For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force (F_z - 10W), in kN, within the permissible stresses given in S8.2.1a.

S8.6.2.i All load transmitting elements in the design load path, from door through securing and supporting devices into the ship structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets.

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S8
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S8.6.2j For side-opening doors, thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure (see example of Figure 3). Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangement serving the same purpose may be proposed.

S8.7 Securing and locking arrangement

S8.7.1 *Systems for operation*

S8.7.1a Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or to be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

S8.7.1b Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

- the closing and opening of the doors, and
- associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorized persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

S8.7.1c Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of the hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

S8.7.2 *Systems for indication/monitoring*

S8.7.2a Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It shall not be possible to turn off the indicator light.

S8.7.2b The indicator system is to be designed on the fail safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system for operating and closing doors is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply from the emergency source of power or other secure power supply e.g. UPS. The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

Note: The indicator system is considered designed on the fail - safe principal when:
1) The indication panel is provided with:
   - a power failure alarm
   - an earth failure alarm
   - a lamp test
   - separate indication for door closed, door locked, door not closed and door not locked.
2) Limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series).
3) Limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series).
4) Two electrical circuits (also in one multicore cable), one for the indication of door closed / not closed and the other for door locked / not locked.
5) In case of dislocation of limit switches, indication to show : not closed / not locked / securing arrangement not in place - as appropriate.

S8.7.2c The indication panel on the navigation bridge is to be equipped with a mode selection function "harbour/sea voyage", so arranged that audible alarm is given on the navigation bridge if the vessel leaves harbour with the bow door or inner door not closed or with any of the securing devices not in the correct position.

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S8.7.2d A water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

Note: The indicator system is considered designed on the fail - safe principal when:
1) The indication panel is provided with:
- a power failure alarm
- an earth failure alarm
- a lamp test
- separate indication for door closed, door locked, door not closed and door not locked.

2) Limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series).
3) Limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series).
4) Two electrical circuits (also in one multicore cable), one for the indication of door closed / not closed and the other for door locked / not locked.
5) In case of dislocation of limit switches, indication to show : not closed / not locked / securing arrangement not in place - as appropriate.

S8.7.2e Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to monitor the position of the doors and a sufficient number of their securing devices. Special consideration is to be given for the lighting and contrasting colour of objects under surveillance.

Note: The indicator system is considered designed on the fail - safe principal when:
1) The indication panel is provided with:
- a power failure alarm
- an earth failure alarm
- a lamp test
- separate indication for door closed, door locked, door not closed and door not locked.

2) Limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series).
3) Limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series).
4) Two electrical circuits (also in one multicore cable), one for the indication of door closed / not closed and the other for door locked / not locked.
5) In case of dislocation of limit switches, indication to show : not closed / not locked / securing arrangement not in place - as appropriate.

S8.7.2f A drainage system is to be arranged in the area between bow door and ramp, or where no ramp is fitted, between the bow door and inner door. The system is to be equipped with an audible alarm function to the navigation bridge being set off when the water levels in these areas exceed 0.5m or the high water level alarm, whichever is lesser.

Note: The indicator system is considered designed on the fail - safe principal when:
1) The indication panel is provided with:
- a power failure alarm
- an earth failure alarm
- a lamp test
- separate indication for door closed, door locked, door not closed and door not locked.

2) Limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series).
3) Limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series).
4) Two electrical circuits (also in one multicore cable), one for the indication of door closed / not closed and the other for door locked / not locked.
5) In case of dislocation of limit switches, indication to show : not closed / not locked / securing arrangement not in place - as appropriate.

S8.7.2.g For ro-ro passenger ships on international voyages, the special category spaces and ro-ro spaces are to be continuously patrolled or monitored by effective means, such as television suveillance, so that any movement of vehicles in adverse weather conditions or unauthorized access by passengers thereto, can be detected whilst the ship is underway.

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S8.8 Operating and Maintenance Manual

S8.8.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and is to contain necessary information on:

- main particulars and design drawings
  special safety precautions
  details of vessel, class, statutory certificates
  equipment and design loading (for ramps)
  key plan of equipment (doors and ramps)
  manufacturer's recommended testing for equipment
  description of equipment
    - bow doors
    - inner bow doors
    - bow ramp/doors
    - side doors
    - stern doors
    - central power pack
    - bridge panel
    - engine control room panel
- service conditions
  limiting heel and trim of ship for loading/unloading
  limiting heel and trim for door operations
  doors/ramps operating instructions
  doors/ramps emergency operating instructions
- maintenance
  schedule and extent of maintenance
  trouble shooting and acceptable clearances
  maufacturer's maintenance procedures
- register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This Manual is to be submitted for approval that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance / rejection criteria.

Note: It is recommended that recorded inspections of the door supporting and securing devices be carried out by the ship's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the shell doors. Any damages recorded during such inspections are to be reported to the Classification Society.

S8.8.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at appropriate place.

Fig. 1 Definition of α and β

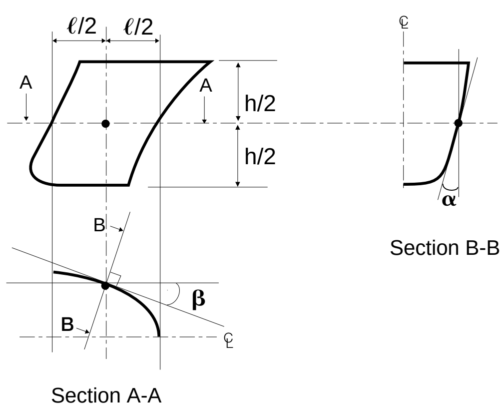

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Fig. 2 Bow Door of Visor Type

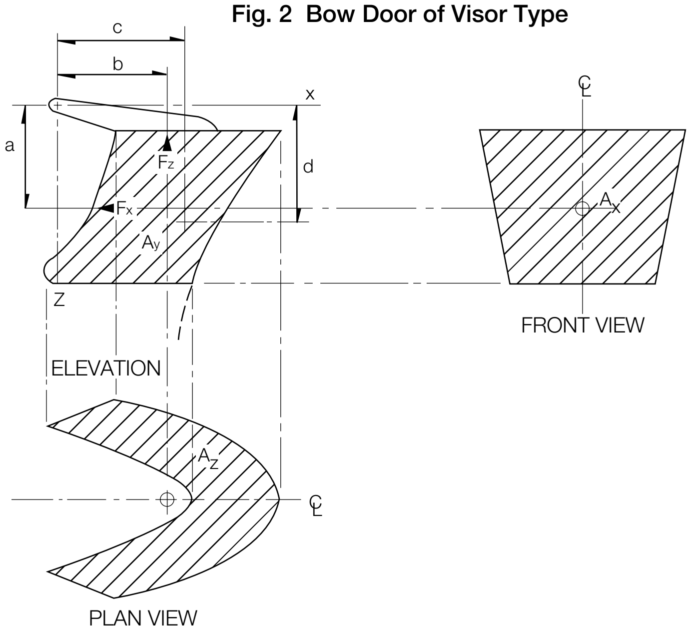
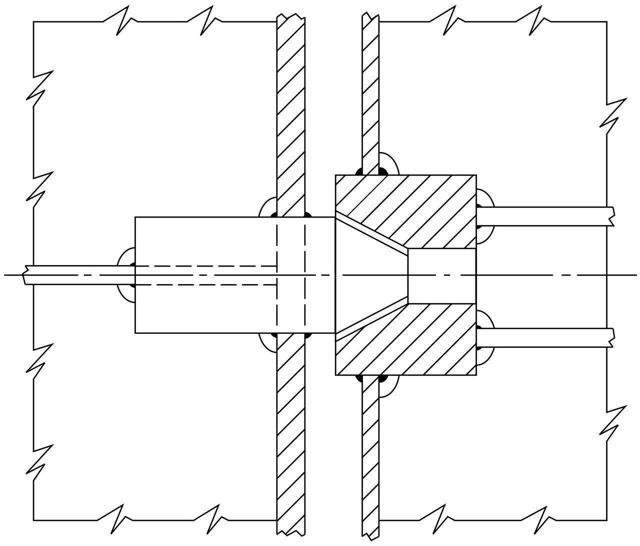


Fig. 3 Thrust Bearing



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S9 Side Shell Doors and Stern Doors

(1984)
(Rev. 1 1990)
(Rev. 2 1993)
(Rev. 3 1996)
(Rev. 4 1996)
(Rev.5 Nov. 2003)

S9.1 General

S9.1.1 *Application*

S9.1.1a These requirements are for the arrangement, strength and securing of side shell doors, abaft the collision bulkhead, and of stern doors leading to enclosed spaces.

The requirements apply to all ro-ro passenger ships and ro-ro cargo ships engaged on international voyages and also to ro-ro passenger ships and ro-ro cargo ships engaged only in domestic (non international) voyages, except where specifically indicated otherwise herein.
The requirements are not applicable to high speed, light displacement craft as defined in the IMO Code of Safety for High Speed Craft.

S9.1.2 *Arrangement*

S9.1.2a Stern doors for passenger vessels are to be situated above the freeboard deck. Stern doors for Ro-Ro cargo ships and side shell doors may be either below or above the freeboard deck.

S9.1.2b Side shell doors and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure.

S9.1.2c Where the sill of any side shell door is below the uppermost load line, the arrangement is to be specially considered (see IACS Interpretation LL 21).

S9.1.2d Doors should preferably open outwards.

S9.1.3 *Definitions*

Securing device	- a device used to keep the door closed by preventing it from rotating about its hinges or about pivotted attachments to the ship.
Supporting device	- a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure.
Locking device	-a device that locks a securing device in the closed position.
Ro-ro passenger ship	-a passenger ship with ro-ro spaces or special category spaces.
Ro-ro spaces	-are spaces not normally sub-divided in any way and extending to either a substantial length or the entire length of the ship, in which motor vehicles with fuel in their tanks for their own propulsion and/or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks or in or on similar stowage units or, other receptacles) can be loaded and unloaded normally in a horizontal direction.
Special category spaces	-are those enclosed vehicle spaces above or below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10m**.**

S9.2 Strength Criteria

S9.2.1 *Primary structure and Securing and Supporting devices*

S9.2.1a Scantlings of the primary members, securing and supporting devices of side shell doors and stern doors are to be determined to withstand the design loads defined in S9.3, using the following permissible stresses :

shear stress : $\tau = \frac{80}{k}$ N/mm^2

bending stress : $\sigma = \frac{120}{k}$ N/mm^2

equivalent stress : $\sigma_c = \sqrt{\sigma^2 + 3\tau^2} = \frac{150}{k}$ N/mm^2

where k is the material factor as given in S4, but is not to be taken less than 0.72 unless a direct strength analysis with regard to relevant modes of failures is carried out.

Note: Revision 4 of the UR is applicable to new ships for which the request for classification is received on or after 1 July 1997.

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S9.2.1b The buckling strength of primary members is to be verified as being adequate.

S9.2.1c For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 0.8 σ_F, where σ_F is the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.
S9.2.1d The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of bolts not carrying support forces is not to exceed 125/k N/mm^2, with k defined in S9.2.1a.

S9.3 Design loads

S9.3.1 The design forces, in kN, considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are to be not less than :

(i) Design forces for securing or supporting devices of doors opening inwards :

. external force : $F_e = A\ p_e + F_p$

. internal force : $F_i = F_o + 10\ W$

(ii) Design forces for securing or supporting devices of doors opening outwards :

. external force : $F_e = A\ p_e$

. internal force : $F_i = F_o + 10\ W + F_p$

(iii) Design forces for primary members :

. external force : $F_e = A\ p_e$

. internal force : $F\ i = F_o + 10\ W$

whichever is the greater,

where :
A area, in m^2, of the door opening,
W mass of the door, in t,
F_p total packing force in kN. Packing line pressure is normally not to be taken less than 5N/mm,
F_o the greater of F_c and 5 A (kN),
F_c accidental force, in kN, due to loose of cargo etc., to be uniformly distributed over the area A and not to be taken less than 300kN. For small doors such as bunker doors and pilot doors, the value of F_c may be appropriately reduced. However, the value of F_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes.
p_e external design pressure, in kN/m^2, determined at the centre of gravity of the door opening and not taken less than :

$10\ (T - Z_G) + 25$ for $Z_G < T$
25 for $Z_G \geq T$

Moreover, for stern doors of ships fitted with bow doors, pe is not to be taken less than :

$$P_e = 0.6\lambda C_H (0.8 + 0.6 L^{0.5})^2$$

λ coefficient depending on the area where the ship is intended to be operated:

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λ = 1 for sea going ships,

λ = 0.8 for ships operated in coastal waters,

λ = 0.5 for ships operated in sheltered waters.

Note : *Coastal waters and sheltered waters are defined according to the practice of each Classification Society. As an example, coastal waters may be defined as areas where significant wave heights do not exceed 4m for more than three hours a year and sheltered waters as areas where significant wave heights do not exceed 2m for more than three hours a year.*

CH = 0.0125 L for $L < 80m$
= 1 for $L \geq 80m$

L ship's length, in m, but need not be taken greater than 200 metres,
T draught, in m, at the highest subdivision load line,
Z_G height of the centre of area of the door, in m, above the baseline.

S9.4 Scantlings of side shell doors and stern doors

S9.4.1 ***General***

S9.4.1a The strength of side shell doors and stern doors is to be commensurate with that of the surrounding structure.

S9.4.1b Side shell doors and stern doors are to be adequately stiffened and means are to be provided to prevent any lateral or vertical movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship's structure.

S9.4.1c Where doors also serve as vehicle ramps, the design of the hinges should take into account the ship angle of trim and heel which may result in uneven loading on the hinges.

S9.4.1d Shell door openings are to have well-rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below.

S9.4.2 *Plating and secondary stiffeners*

S9.4.2a The thickness of the door plating is not to be less than the required thickness for the side shell plating, using the door stiffener spacing, but in no case less than the minimum required thickness of shell plating.

Where doors serve as vehicle ramps, the plating thickness is to be not less than required for vehicle decks.

S9.4.2b The section modulus of horizontal or vertical stiffeners is not to be less than that required for side framing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and door stiffeners.

Where doors serve as vehicle ramps, the stiffener scantlings are not to be less than required for vehicle decks.

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S9.4.3 ***Primary Structure***

S9.4.3a The secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

S9.4.3b The primary members and the hull structure in way are to have sufficient stiffness to ensure structural integrity of the boundary of the door.

S9.4.3c Scantlings of the primary members are generally to be supported by direct strength calculations in association with the design forces given in S9.3 and permissible stresses given in S9.2.1a. Normally, formulae for simple beam theory may be applied to determine the bending stresses. Members are to be considered to have simply supported end connections.

S9.5 Securing and Supporting of Doors

S9.5.1 ***General***

S9.5.1a Side shell doors and stern doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered.

Maximum design clearance between securing and supporting devices is not generally to exceed 3mm.

A means is to be provided for mechanically fixing the door in the open position.

S9.5.1b Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material are not generally to be included in the calculations called for in S9.5.2b. The number of securing and supporting devices are generally to be the minimum practical whilst taking into account the requirement for redundant provision given in S9.5.2c and the available space for adequate support in the hull structure.

S9.5.2 ***Scantlings***

S9.5.2a Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in S9.2.1a.

S9.5.2b The distribution of the reaction forces acting on the securing devices and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position of the supports.

S9.5.2c The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable to withstand the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in S9.2.1a.

S9.5.2d All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices. These elements include pins, support brackets and back-up brackets.

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S9.6 Securing and Locking Arrangement

S9.6.1 ***Systems for operation***

S9.6.1a Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or are to be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

S9.6.1b Doors which are locateeed partly or totally below the freeboard deck with a clear opening area greater than $6m^2$ are to be provided with an arrangement for remote control, from a position above the freeboard deck, of :

. the closing and opening of the doors,
. associated securing and locking devices.

For doors which are required to be equipped with a remote control arrangement, indication of the open/closed position of the door and the securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorized persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

S9.6.1c Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of the hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when closed position.

S9.6.2 ***Systems for indication/monitoring***

S9.6.2a The following requirements apply to doors in the boundary of special category spaces or ro-ro spaces, as defined in S9.1.3, through which such spaces may be flooded.
For cargo ships, where no part of the door is below the uppermost waterline and the area of the door opening is not greater than $6m^2$, then the requirements of this section need not be applied.

S9.6.2b Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It shall not be possible to turn off the indicator light.

S9.6.2c The indicator system is to be designed on the fail safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a backup power supply from the emergency source of power or secure power supply e.g. UPS.

Note: see 8.7.2b for fail safe principal design.

The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

S9.6.2d The indication panel on the navigation bridge is to be equipped with a mode selection function "harbour/sea voyage", so arranged that audible alarm is given on the navigation bridge if the vessel leaves harbour with any side shell or stern door not closed or with any of the securing devices not in the correct position.

S9.6.2e For passenger ships, a water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors.

For cargo ships, a water leakage detection system with audible alarm is to be arranged to provide an indication to the navigation bridge.

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S9.6.2.f For ro-ro passenger ships, on international voyages, the special category spaces and ro-ro spaces are to be continuously patrolled or monitored by effective means, such as television surveillance, so that any movement of vehicles in adverse weather conditions and unauthorized access by passengers thereto, can be detected whilst the ship is underway.

S9.7 Operating and Maintenance Manual

S9.7.1 An Operating and Maintenance Manual for the side shell doors and stern doors is to be provided on board and is to contain the necessary information on :

. main particulars and design drawings
  special safety precautions
  details of vessel, class, statutory certificates
  equipment and design loading (for ramps)
  key plan of equipment (doors and ramps)
  manufacturer's recommended testing for equipment
  description of equipment
    bow doors
    inner bow doors
    bow ramp/doors
    side doors
    stern doors
    central power pack
    bridge panel
    engine control room panel

. service conditions
  limiting heel and trim of ship for loading/unloading
  limiting heel and trim for door operations
  doors/ramps operating instructions
  doors/ramps emergency operating instructions

. maintenance
  schedule and extent of maintenance
  trouble shooting and acceptable clearances
  maufacturer's maintenance procedures

. register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This Manual is to be submitted for approval that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance / rejection criteria.

Note : It is recommended that recorded inspections of the door supporting and securing devices be carried out by the ship's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of side shell and stern doors. Any damage recorded during such inspections is to be reported to the Classification Society.

S9.7.2 Documented operating procedures for closing and securing side shell and stern doors are to be kept on board and posted at the appropriate places.

Explanatory Note

The external pressure applied on stern doors is derived from the formula considered in UR S8 for bow doors, assuming :

α = 0 degree
β = 90 degrees
V = 2 knots

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S10 Rudders, sole pieces and rudder horns

(1986)
(Rev. 1 1990)
(Corr. July 1999)
(Corr. July 2003)

S10.1 General

1.1 Basic assumptions

1.1.1 The following requirements apply to ordinary profile rudders, without any special arrangement for increasing the rudder force, such as fins, flaps, steering propellers, etc. Rudders not conforming with the ordinary types will be subject to special consideration.

1.2 Design considerations

1.2.1 Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

1.2.2 Suitable arrangements are to be provided to prevent the rudder from lifting.

1.2.3 In rudder trunks which are 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 and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.

1.3 Materials

1.3.1 Rudder stocks, pintles, coupling bolts, keys and cast parts of rudders are to be made of rolled, forged or cast carbon manganese steel in accordance with unified requirements W7, W8 and W11.

For rudder stocks, pintles, keys and bolts the minimum yield stress is not to be less than 200 N/mm^2. The following requirements are based on a material's yield stress of 235 N/mm^2. If material is used having a yield stress differing from 235 N/mm^2 the material factor is to be determined as follows:

$$K = \left(\frac{\sigma_F}{235}\right)^e$$

with

e = 0,75 for $\sigma_F > 235$ N/mm^2

e = 1,00 for $\sigma_F \leq 235$ N/mm^2

σ_F = yield stress (N/mm^2) of material used, and is not to be taken greater than $0{,}7\sigma_T$ or 450 N/mm^2, whichever is the smaller value

σ_T = tensile strength of material used

1.3.2 Before significant reductions in rudder stock diameter due to the application of steels with yield stresses exceeding 235 N/mm^2 are granted, the Society may require the evaluation of the rudder stock deformations. Large deformations should be avoided in order to avoid excessive edge pressures in way of bearings.

1.3.3 Welded parts of rudders are to be made of approved rolled hull materials. Required scantlings may be reduced when higher tensile steels are applied. The material factor according to UR S4 is to be used.

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S 10.2 Rudder force and rudder torque

2.1 Rudder blades without cut-outs (Fig. 1)

2.1.1 The rudder force upon which the rudder scantlings are to be based is to be determined from the following formula:

$$C_R = K_1 \bullet K_2 \bullet K_3 \bullet 132 \bullet A \bullet V^2 \bullet K_{th} \quad [N]$$

Where:

C_R = rudder force [N];

A = area of rudder blade [m²];

V = maximum service speed (knots) with the ship on summer load waterline. When the speed is less than 10 knots, V is to be replaced by the expression:

$V_{min} = (V + 20)/3$.

For the astern condition the maximum astern speed is to be used, however, in no case less than

$V_{astern} = 0,5\ V$.

K_1 = factor depending on the aspect ratio λ of the rudder area;

K_1 = $(\lambda + 2)/3$, with λ not to be taken greater than 2;

λ $= b^2/A_t$, where b = mean height of the rudder area [m]. Mean breadth and mean height of rudder are calculated acc. to the coordinate system in Fig. 1;

A_t = sum of rudder blade area A and area of rudder post or rudder horn, if any, within the height b [m²];

K_3 = 0,8 for rudders outside the propeller jet;

= 1,15 for rudders behind a fixed propeller nozzle;

= 1,0 otherwise;

K_{th} = $C_R (C_{th}) / C_R (C_{th} = 1.0)$, C_{th} = thrust coefficient;

K_{th} is usually equal to 1.0 for rudders behind propeller. For cases, where C_{th} is larger than one, it is left to the discretion of each individual society to consider the factor K_{th} with thrust coefficient C_{th} larger than 1.

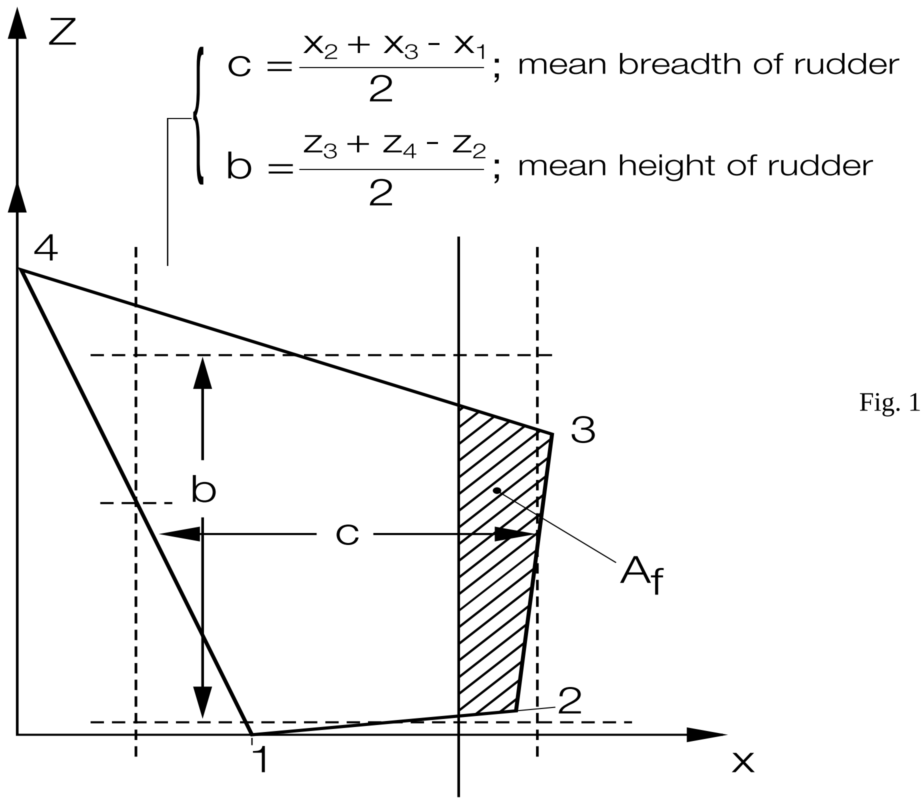

Fig. 1

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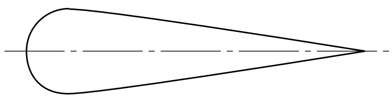
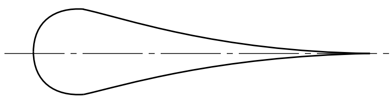
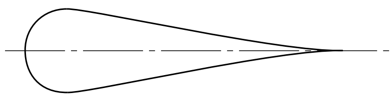
Table 1

Profile type	K_2 ahead condition	K_2 astern condition
NACA-00 Göttingen-profiles 	1,1	0,80
hollow profiles 	1,35	0,90
flat side profiles 	1,1	0,90

S10
cont'd

2.1.2 The rudder torque is to be calculated for both the ahead and astern condition according to the formula:

Q_R = CR · r [Nm]
r = c (α – k) [m]
c = mean breadth of rudder area [m], *see* Fig. 1
α = 0,33 for ahead condition
α = 0,66 for astern condition
k = balance factor as follows
k = A_f / A, where A_f = portion of the rudder blade area situated ahead of the centre line of the rudder stock
r_{min} = 0,1 · c[m] for ahead condition

2.2 Rudder blades with cut-outs (semi-spade rudders)

The total rudder force C_R is to be calculated according to S10.2.1.1. The pressure distribution over the rudder area, upon which the determination of rudder torque and rudder blade strength is to be based, is to be derived as follows:

The rudder area may be divided into two rectangular or trapezoidal parts with areas A_1 and A_2, so that $A = A_1 + A_2$ (*see* Fig. 2).

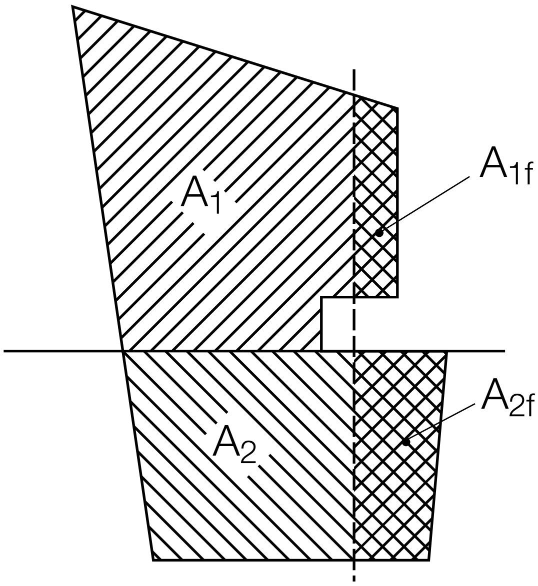


Fig. 2

The levers r_1 and r_2 are to be determined as follows:

$r_1 = c_1 (\alpha - k_1)$ [m]
$r_2 = c_2 (\alpha - k_2)$ [m]
c_1, c_2 = mean breadth of partial areas A_1, A_2, determined, where applicable, in accordance with Fig. 1 in S10.2.1.1

$$k_1 = \frac{A_{1f}}{A_1}$$

$$k_2 = \frac{A_{2f}}{A_2}$$

α = 0,33 for ahead condition
α = 0,66 for astern condition

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S10
cont'd

For parts of a rudder behind a fixed structure such as rudder horn

α = 0,25 for ahead condition
α = 0,55 for astern condition

The resulting force of each part may be taken as:

$$CR_1 = C_R \frac{A_1}{A} \quad [N]$$

$$CR_2 = C_R \frac{A_2}{A} \quad [N]$$

The resulting torque of each part may be taken as:

$$Q_{R1} = C_{R1} \cdot r_1 \quad [Nm]$$
$$Q_{R2} = C_{R2} \cdot r_2 \quad [Nm]$$

The total rudder torque is to be calculated for both the ahead and astern condition according to the formula:

$$Q_R = Q_{R1} + Q_{R2} \quad [Nm]$$

For ahead condition Q_R is not to be taken less than

$$Q_{R\,min} = 0{,}1 \cdot C_R \cdot \frac{A_1 \cdot c_1 + A_2 \cdot c_2}{A}$$

S10.3 Rudder stock scantlings in way of the tiller

The rudder stock diameter required for the transmission of the rudder torque is to be dimensioned such that the torsional stress will not exceed the following value:

$$\tau_t = 68 \cdot K$$

The rudder stock diameter for the transmission of the rudder torque is therefore not to be less than:

$$d_t = 4{,}2 \sqrt[3]{Q_R / K} \quad [mm]$$

Q_R = total rudder torque [Nm] as calculated in S10.2.1.2 and/or S10.2.2.

For the application of the material factor K see also S10.1.3.2.

S10.4 Rudder strength calculation

4.1 The rudder force and resulting rudder torque as given in 2 causes bending moments and shear forces in the rudder body, bending moments and torques in the rudder stock, supporting forces in pintle bearings and rudder stock bearings and bending moments, shear forces and torques in rudder horns and heel pieces. The rudder body is to be stiffened by horizontal and vertical webs enabling it to act as bending girder.

4.2 The bending moments, shear forces and torques as well as the reaction forces are to be determined by a direct calculation or by an approximate simplified method considered appropriate by each individual society. For rudders supported by sole pieces or rudder horns these structures are to be included in the calculation model in order to account for the elastic support of the rudder body. Guidelines for calculation of bending moment and shear force distribution are given in an annex to this requirement.

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4.3 Rudder stock scantlings due to combined loads

If the rudder stock is subjected to combined torque and bending the equivalent stress in the rudder stock is not to exceed 118/K.

The equivalent stress is to be determined by the formula:

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau_t^2} \qquad [N/mm^2]$$

Bending stress : $\sigma_b = 10.2 \ M/d_c^3$ [N/mm²]
Torsional stress: $\tau_t = 5.1 \ Q_R/d_c^3$ [N/mm²]

The rudder stock diameter is therefore not to be less than:

$$d_c = d_t \cdot \sqrt[6]{1 + 4/3 \text{ x } [M/Q_R]^2} \qquad [mm]$$

M = bending moment [Nm] at the station of the rudder stock considered

S10.5 Rudder blade scantlings

5.1 Permissible stresses

The section modulus and the web area of a horizontal section of the rudder blade made of ordinary hull structural steel are to be such that the following stresses will not be exceeded:

a) rudder blades without cut-outs (Fig. 1)
   (i) bending stress σ_b — 110 N/mm²
   (ii) shear stress τ — 50 N/mm²
   (iii) equivalent stress $\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}$ — 120 N/mm²

b) rudder blades with cut-outs (e.g. semi-spade rudders. Fig. 2 of S10)
   (i) bending stress σ_b — 75 N/mm²
   (ii) shear stress τ — 50 N/mm²
   in way of cut-outs
   (iii) equivalent stress $\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}$ — 100 N/mm²

5.2 Rudder plating

The thickness of the rudder side, top and bottom plating made of ordinary hull structural steel is not to be less than:

$$t = 5.5 \cdot s \cdot \beta \sqrt{d + C_R \ 10^{-4}/A} + 2.5 \qquad [mm]$$

d = summer loadline draught [m] of the ship;
CR = rudder force [N] according to S10.2.1.1;
A = rudder area [m²];

$$\beta = \sqrt{1.1 - 0.5\,[s/b]^2} \ ; \qquad \text{max. } 1.00 \text{ if } b/s \geq 2.5$$

s = smallest unsupported width of plating in [m];
b = greatest unsupported width of plating in [m].

The thickness of the nose plates may be increased to the discretion of each society. The thickness of web plates is not to be less than 70% of the rudder side plating, however, not less than 8 mm. For higher tensile steels the material factor according to UR S4 is to be used correspondingly.

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5.3 Single plate rudders

5.3.1 Mainpiece diameter

The mainpiece diameter is calculated according to S10.3 and S10.4.3 respectively. For spade rudders the lower third may taper down to 0.75 times stock diameter.

5.3.2 Blade thickness

The blade thickness is not to be less than:

t_b = 1.5 s V + 2.5 [mm]
s = spacing of stiffening arms in [m], not to exceed 1 m;
v = speed in knots, see S10.2.1.1.

5.3.3 Arms

The thickness of the arms is not to be less than the blade thickness

$t_a = t_b$.

The section modulus is not to be less than

Z_a = 0.5 s C_1^2 V^2 [cm^3];
C_1 = horizontal distance from the aft edge of the rudder to the centreline of the rudder stock, in meters

For higher tensile steels the material factor according to UR S4 is to be used correspondingly.

S10.6 Rudder stock couplings

6.1 Horizontal flange couplings

6.1.1 The diameter of the coupling bolts is not to be less than:

$d_b = 0.62 \sqrt{d^3 \; K_b / n \; e_m \; K_s}$ [mm]
d = stock diameter, the greater of the diameters d_t or d_c according to S10.3 and S10.4.3 [mm];
n = total number of bolts, which is not to be less than 6;
e_m = mean distance [mm] of the bolt axes from the centre of the bolt system;
K_s = material factor for the stock as given in S10.1.3.1;
K_b = material factor for the bolts as given in S10.1.3.1.

6.1.2 The thickness of the coupling flanges is not to be less than determined by the following formulæ:

$t_f = d_b \cdot \sqrt{K_f / K_b}$
K_f = material factor for flange as given in S10.1.3.1;
t_f min = $0.9 \cdot d_b$;
d_b = bolt diameter calculated for a number of bolts not exceeding 8.

6.1.3 The width of material outside the bolt holes is not to be less than 0.67 d_b.

6.2 Cone couplings

6.2.1 Cone couplings without hydraulic arrangements for mounting and dismounting the coupling should have a taper on diameter of 1:8-1:12 and be secured by a slugging nut.

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taper = $(d_o - d_u) / 1$

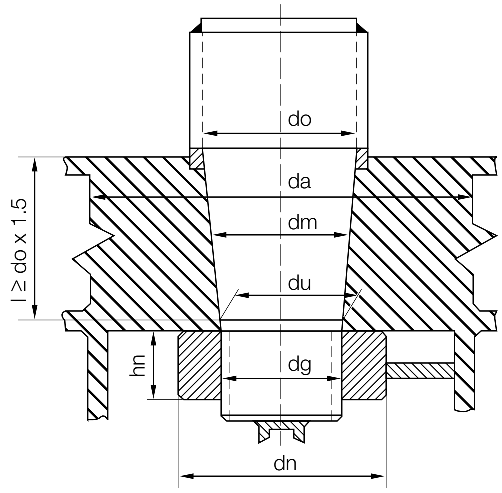

Fig. 4

The taper length (1) of rudder stocks fitted into the rudder blade and secured by a nut should generally not be less than 1.5 times the rudder stock diameter (d_o) at the top of the rudder.

For couplings between stock and rudder a key is to be provided. Determination of scantlings of the key is left to the discretion of each society.

6.2.2 The dimensions of the slugging nut are to be as follows (see Fig. 4):

external thread diameter: $d_g \geq 0.65 \cdot d_o$
length of nut: $h_n \geq 0.6 \cdot d_g$
outer diameter of nut: $d_n \geq 1.2 \cdot d_u$, or $1,5 \cdot d_g$ whichever is the greater.

6.2.3 Cone couplings with hydraulic arrangements for mounting and dismounting the coupling (mounting with oil injection and hydraulic nut) should have a taper on diameter of 1:12-1:20.

The push-up oil pressure and the push-up length are to be specially considered in each individual case based on a calculation to be submitted by the yard.

6.3 Vertical flange couplings

6.3.1 The diameter of the coupling bolts is not to be less than

$$d_b = 0.81\, d / \sqrt{n} \times \sqrt{k_b / k_s}$$

where

d = stock diameter;
n = total number of bolts, which is not to be less than 8;
k_b = material factor for bolts as given in S10.1.3.1;
k_s = material factor for stock as given in S10.1.3.1.

6.3.2 The first moment of area of the bolts about the centre of the coupling, m. must be at least:

$$m = 0.00043\, d^3.$$

6.3.3 The thickness of the coupling flanges must be at least equal to the bolt diameter, and the width of the flange material outside the bolt holes must be greater than or equal to 0.67 d_b.

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S10.7 Pintles

7.1 Pintles are to have a conical attachment to the gudgeons with a taper on diameter not greater than:

1:8 - 1:12 for keyed and other manually assembled pintles applying locking by slugging nut,
1:12 - 1:20 on diameter for pintles mounted with oil injection and hydraulic nut.

The length of the pintle housing in the gudgeon is not to be less than the maximum pintle diameter

$$d_p = 0.35 \sqrt{B \quad k_p}$$

where B is the relevant bearing force and k_p is the material factor as given in S10.1.3.1.

7.2 The minimum dimensions of threads and nuts are to be determined according to para S10.6.2.2.

S10.8 Rudder stock–, rudder shaft– and pintle bearings

8.1 Minimum bearing surface

An adequate lubrication is to be ensured.

The bearing surface A_b (defined as the projected area: length x outer diameter of liner) is not to be less than:

$$A_b = P / q_a \quad [mm^2]$$

where

P = reaction force [N] in bearing as determined in S10.4.2;
q_a = allowable surface pressure according to the table below.

The maximum surface pressure q_a for the various combinations is to be taken as reported in the table below. Higher values than given in the table may be taken in accordance with makers' specifications if they are verified by tests:

Bearing material	q_a [N/mm^2]
lignum vitae	2,5
white metal, oil lubricated	4,5
synthetic material with hardness between 60 and 70 Shore D[1)]	5,5
steel[2)] and bronze and hot-pressed bronze-graphite materials	7,0

1) Indentation hardness test at 23°C and with 50% moisture, acc. to a recognized standard. Synthetic bearing materials to be of approved type.
2) Stainless and wear-resistant steel in an approved combination with stock liner.

8.2 Length of bearings

The length/diameter ratio of the bearing surface is not to be greater than 1.2.

8.3 Bearing clearances

With metal bearings clearances should not be less than $d_b / 1000 + 1,0$ [mm] on the diameter. If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties. This clearance in no way is to be taken less than 1.5 mm on bearing diameter.

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S10.9 Strength of sole pieces and of rudder horns

9.1 Sole piece

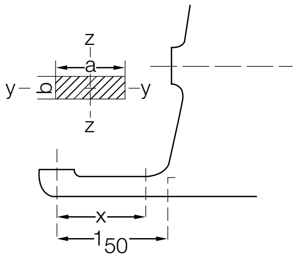

Fig.5

The section modulus around the vertical (z)-axis is not to be less than:

$Z_z = M_b K / 80$ [cm^3].

The section modulus around the transverse (y)-axis is not to be less than:

$Z_y = 0.5 Z_z$.

The sectional area is not to be less than :

$A_s = B_1 K / 48$ [mm^2]
K = material factor as given S10.1.3.1 or UR S4 respectively.

9.1.1 Equivalent stress

At no section within the length l_{50} the equivalent stress is to exceed 115 / K. The equivalent stress is to be determined by the following formula:

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2} \quad \text{[N/mm}^2\text{];}$$

$\sigma_b = M_b / Z_z (x)$ [N/mm^2];
$\tau = B_1 / A_S$ [N/mm^2]
M_b = bending moment at the section considered [Nm];
$M_b = B_1 x$ [Nm];
$M_{bmax} = B_1 l_{50}$ [Nm]
B_1 = supporting force in the pintle bearing [N] (normally $B_1 = C_R / 2$).

9.2 Rudder horn

When the connection between the rudder horn and the hull structure is designed as a curved transition into the hull plating, special consideration should be given to the effectiveness of the rudder horn plate in bending and to the stresses in the transverse web plates.

The loads on the rudder horn are as follows:

M_b = bending moment = $B_1 \cdot z$ [Nm], $M_{bmax} = B_1 \cdot d$ [Nm]
q = shear force = B_1 [N]
$M_T(z)$ = torsional moment = $B_1 \cdot e(z)$ [Nm]
see Fig. 6

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S10
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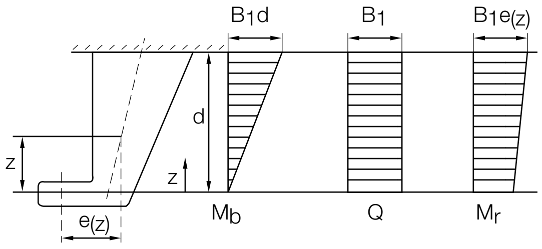

Fig. 6

An estimate for B1 is

$B_1 = C_R\, b / (1_{20} + 1_{30})$ [N].

For b, 1_{20} and 1_{30}, *see* Fig. 2 of annex.

The section modulus around the horizontal x-axis is not to be less than:

$Z_x = M_b\, K / 67$ [cm^3].

The shear stress is not to be larger than:

$\tau = 48 / K$ [N/mm^2].

9.2.1 Equivalent stress

At no section within the length d the equivalent stress is to exceed 120 / K. The equivalent stress is to be calculated by the following formula:

$\sigma_e = \sqrt{\sigma_b{}^2 + 3\,(\tau^2 + \tau_T{}^2)}$ [N/mm^2]

$\sigma_b = M_b / Z_X$ [N/mm^2]
$\tau = B_1 / A_h$ [N/mm^2]
$\tau_T = M_T\ 10^3 / 2 \cdot A_T \cdot t_h$ [N/mm^2]
A_h = effective shear area of rudder horn in y-direction;
A_T = area in the horizontal section enclosed by the rudder horn [mm^2];
t_h = plate thickness of rudder horn [mm];
K = material factor as given in S10.1.3.1 or UR S4 respectively.

9.3 Pintle housing

The bearing length L_p of the pintle is to be such that

$D_p \leq L_p \leq 1.2\, D_p$.

The length of the pintle housing in the gudgeon is not to be less than the pintle diameter D_p.
The thickness of the pintle housing is not to be less than 0.25 D_p.

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S10 Annex
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Guidelines for calculation of bending moment and shear force distribution

1. General

The evaluation of bending moments, shear forces and support forces for the system rudder – rudder stock may be carried out for some basic rudder types as shown in Fig. 1-3 as outlined below.

2. Data for the analysis

l_{10} - l_{50} = lengths of the individual girders of the system in [m];
I_{10} - I_{50} = moments of inertia of these girders in [cm^4].

For rudders supported by a sole piece the length l_{20} is the distance between lower edge of rudder body and centre of sole piece and I_{20} the moment of inertia of the pintle in the sole piece.

Load of rudder body (general)

$P_R = C_R / 10^3 \times l_{10}$ [kN/m].

Load for semi-spade rudders

$P_{R10} = C_{R2} / l_{10} \times 10^3$ [kN/m];
$P_{R20} = C_{R1} / l_{10} \times 10^3$ [kN/m]

for C_R, C_{R1}, C_{R2}, *see* S10.2.2

Z = spring constant of support in the sole piece or rudder horn respectively;
$Z = 6.18 \times I_{50} / l_{50}^3$ [kN/m] for the support in the sole piece (Fig. 1)
I_{50} = moment of inertia of sole piece around the z-axis [cm^4];
l_{50} = effective length of sole piece in [m];
$Z = 1 / (f_b + f_t)$ [kN/m] for the support in the rudder horn (Fig. 2);
f_b = unit displacement of rudder horn in [m] due to a unit force of 1 kN acting in the centre of support;
$f_b = 1.3\, d^3 / (6.18\ I_n)$ [m/kN] (guidance value);
I_n = moment of inertia of rudder horn around the x-axis in [cm^4] (*see also* Fig. 6 of S10.9.2);
f_t = unit displacement due to torsion;
$f_t = d \cdot e^2 \cdot \sum u_i / t_i / (3.14 \cdot 10^8 \cdot F_T^2)$ [m/kN];
F_T = mean sectional area of rudder horn in [m^2];
u_i = breadth in [mm] of the individual plates forming the mean horn sectional area;
t_i = thickness within the individual breadth u_i in [mm];
for e, d, see Fig. 2.

3. Moments and forces to be evaluated

The bending moment M_R and the shear force Q_1 in the rudder body, the bending moment M_b in the neck bearing and the support forces B_1, B_2, B_3 are to be evaluated. The so evaluated moments and forces are to be used for the stress analyses required by S10.4, S10.6, S10.8 and S10.9.

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4. Estimates for spade rudders

For spade rudders the moments and forces may be determined by the following formulæ:

$M_b = C_R \left(l_{20} + \left(l_{10} (2\,c_1 + c_2) / 3\,(c_1 + c_2)\right)\right)$ [Nm];
$B_3 = M_b / l_{30}$ [N];
$B_2 = C_R + B_3$ [N].

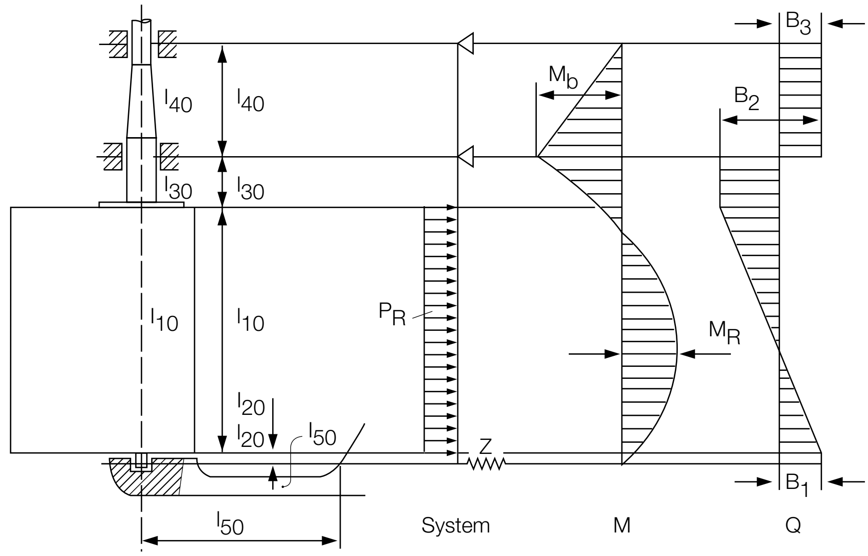

Fig. 1: Rudder supported by sole piece

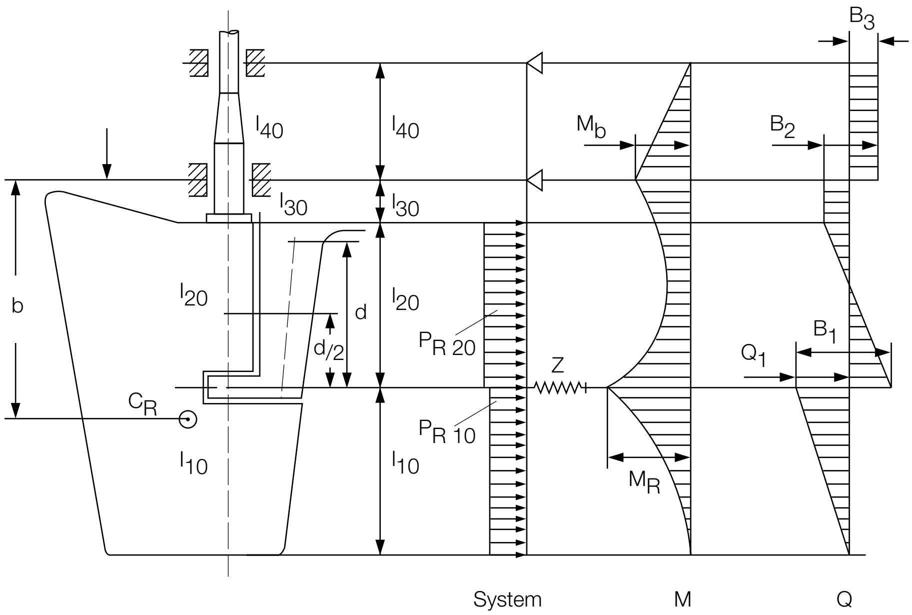

Fig. 2: Semi-spade rudder

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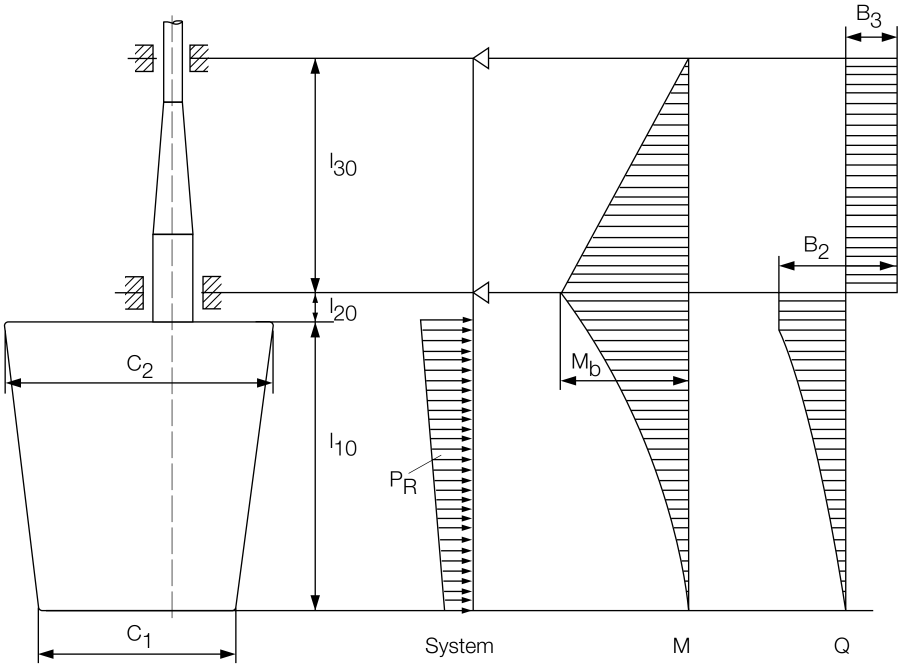

Fig. 3: Spade rudder

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S11 Longitudinal strength standard

(1989)
(Rev. 1 1993)
(Rev.2 Nov.2001)
(Rev.3 June 2003)
(Rev.4 July 2004)

S11.1 Application

This requirement applies only to steel ships of length 90 m and greater in unrestricted service. For ships having one or more of the following characteristics, special additional considerations will be given by each Classification Society.

(i)	Proportion	$L/B \leq 5$,	$B/D \geq 2,5$
(ii)	Length	$L \geq 500$ m	
(iii)	Block coefficient	$Cb < 0,6$	
(iv)	Large deck opening		
(v)	Ships with large flare		
(vi)	Carriage of heated cargoes		
(vii)	Unusual type or design		

For bulk carriers with notation BC-A, BC-B or BC-C, as defined in UR S25, this UR is to be complied with by ships contracted for construction on or after 1 July 2003. For other ships, this revision of this UR is to be complied with by ships contracted for construction on or after 1 July 2004.

S11.2 Loads

S11.2.1 Still water bending moment and shear force

S11.2.1.1 General

Still water bending moments, *Ms* (kN-m), and still water shear forces, *Fs* (kN), are to be calculated at each section along the ship length for design cargo and ballast loading conditions as specified in S11.2.1.2.

For these calculations, downward loads are assumed to be taken as positive values, and are to be integrated in the forward direction from the aft end of *L*. The sign conventions of *Ms* and *Fs* are as shown in Fig. 1.

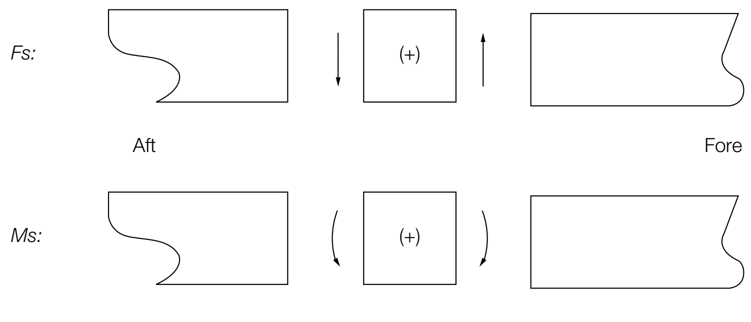

Fig. 1 Sign Conventions of *MS* and *Fs*

S11.2.1.2 Design loading Conditions

In general, the following design cargo and ballast loading conditions, based on amount of bunker, fresh water and stores at departure and arrival, are to be considered for the *Ms* and *Fs* calculations. Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or deballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or deballasting any ballast tank are to be submitted and where approved included in the loading manual for guidance.

Note
1. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.

S11
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General cargo ships, container ships, roll-on/roll-off and refrigerated cargo carriers, bulk carriers, ore carriers:
– Homogeneous loading conditions at maximum draught
– Ballast conditions
– Special loading conditions e.g., container or light load conditions at less than the maximum draught, heavy cargo, empty holds or non-homogeneous cargo conditions, deck cargo conditions, etc., where applicable.
_ All loading conditions specified in UR S25 Section 4 for bulk carriers with notation BC-A, BC-B or BC-C, as applicable.

Oil tankers:
– Homogeneous loading conditions (excluding dry and clean ballast tanks) and ballast or part loaded conditions
– Any specified non-uniform distribution of loading
– Mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions.

Chemical tankers:
– Conditions as specified for oil tankers
– Conditions for high density or segregated cargo.

Liquefied gas carriers:
– Homogeneous loading conditions for all approved cargoes
– Ballast conditions
– Cargo conditions where one or more tanks are empty or partially filled or where more than one type of cargo having significantly different densities are carried.

Combination Carriers:
– Conditions as specified for oil tankers and cargo ships.

S11.2.1.3 Partially filled ballast tanks in ballast loading conditions

Ballast loading conditions involving partially filled peak and/or other ballast tanks at departure, arrival or during intermediate conditions are not permitted to be used as design conditions unless:

- design stress limits are satisfied for all filling levels between empty and full, and

- for bulk carriers, UR S17, as applicable, is complied with for all filling levels between empty and full.

However, for the purpose of design, it will be acceptable if, in each condition at departure, arrival and, where required by S11.2.1.2, any intermediate condition, the tanks intended to be partially filled are assumed to be empty and full. In addition, the specified partly filled level in the intended condition is to be considered.

S11.2.1.4 Partially filled ballast tanks in cargo loading conditions

In cargo loading conditions, the requirement in S11.2.1.3. applies to the peak tanks only.

S11.2.2 Wave loads

S11.2.2.1 Wave bending moment

The wave bending moments, Mw, at each section along the ship length are given by the following formulae:

$Mw\ (+) = +\ 190\ M\ C\ L^2\ B\ Cb \times 10^{-3}$ (kN - m) ... For positive moment
$Mw\ (+) = -\ 110\ M\ C\ L^2\ B\ (Cb + 0{,}7) \times 10^{-3}$ (kN - m) ... For negative moment

where, M = Distribution factor given in Fig. 2_

$C = 10{,}75 - \left[\frac{300 - L}{100}\right]^{1{,}5}$ for $90 \le L \le 300$

or 10,75 for $300 \le L \le 350$

or $10{,}75 - \left[\frac{L - 350}{150}\right]^{1{,}5}$ for $350 \le L \le 500$

L = Length of the ships in metres, defined by S2
B = Greatest moulded breadth in metres
Cb = Block coefficient, defined by S2, but not to be taken less than 0,6

S11
cont'd

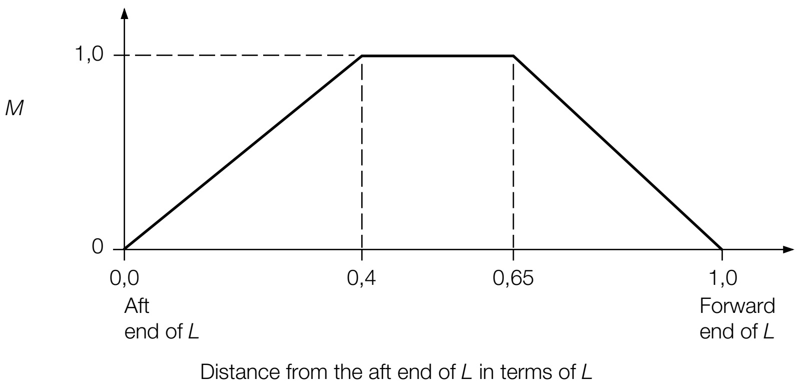

Fig. 2 Distribution factor *M*

S11 2.2.2 Wave shear force

The wave shear forces, *Fw*, at each section along the length of the ship are given by the following formulae:

$Fw\ (+) = +\ 30\ F1\ C\ L\ B\ (Cb + 0{,}7) \times 10^{-2}$ (kN) ... For positive shear force
$Fw\ (-) = -\ 30\ F2\ C\ L\ B\ (Cb + 0{,}7) \times 10^{-2}$ (kN) ... For negative shear force

Where, *F1, F2* = Distribution factors given in Figs. 3 and 4
C, L, B, Cb = As specified in S11.2.2.1

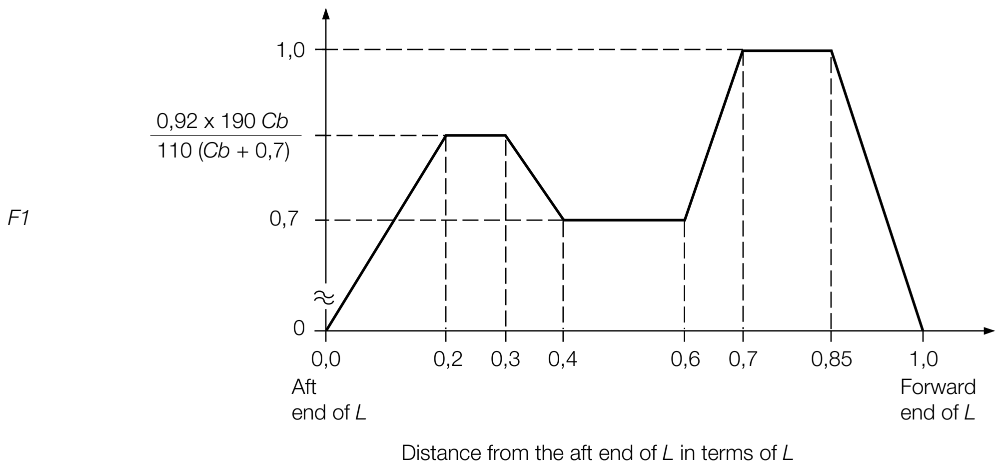

Fig. 3 Distribution factor *F1*

S11
cont'd

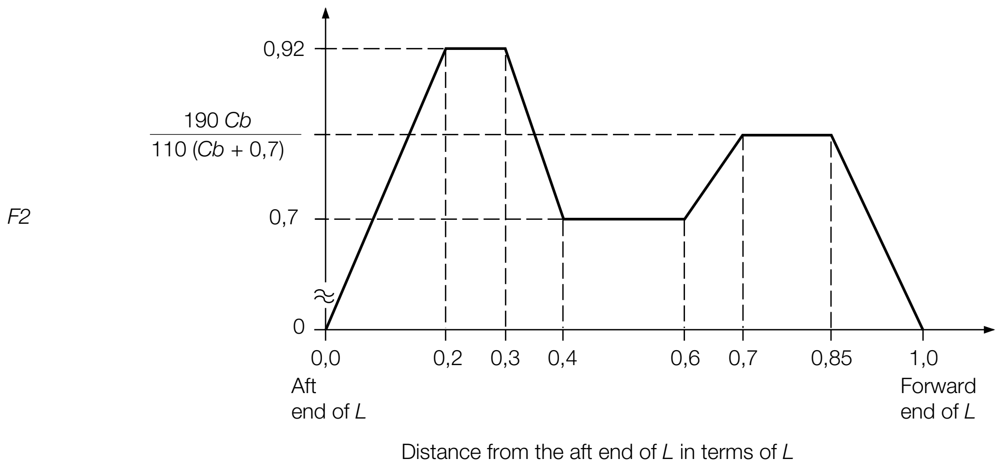

Fig. 4 Distribution factor *F2*

S11.3 Bending strength

S11.3.1 Bending strength amidships

S11 3.1.1 Section modulus

(i) Hull section modulus, Z, calculated in accordance with S5, is not to be less than the values given by the following formula in way of 0,4 *L* midships for the still water bending moments *Ms* given in S11.2.1.1 and the wave bending moments *Mw* given in S11.2.2.1, respectively:

$$\frac{|Ms + Mw|}{\sigma} \text{ x } 10^3 \ (cm^3)$$

where, σ = permissable bending stress = 175 /*k* (N/mm^2)
k = 1,0 for ordinary hull structural steel
k < 1,0 for higher tensile steel according to S4.

(ii) In any case, the longitudinal strength of the ship is to be in compliance with S7.

S11 3.1.2 Moment of inertia

Moment of inertia of hull section at the midship point is not to be less than

$$I_{\min} = 3CL^3B\,(Cb + 0{,}7) \qquad (cm^4)$$

Where *C, L, B, Cb* = As specified in S11.2.2.1.

S11.3.2 Bending strength outside amidships.

The required bending strength outside 0,4 *L* amidships is to be determined at the discretion of each Classification Society.

S11.4 Shearing strength

S11.4.1 General

The thickness requirements given in S11.4.2 or S11.4.3 apply unless smaller values are proved satisfactory by a method of direct stress calculation approved by each Classification Society, where the

S11
cont'd

calculated shear stress is not to exceed $110/k$ (N/mm^2).

S11.4.2 Shearing strength for ships without effective longitudinal bulkheads

(i) The thickness of side shell is not to be less than the values given by the following formula for the still water shear forces *Fs* given in S11.2.1.1 and the wave shear forces *Fw* given in S11.2.2.2, respectively:

$$t = \frac{0,5\ |Fs + Fw|}{\tau} \frac{S}{I} \times 10^2 \quad \text{(mm)}$$

where, I = Moment of inertia in cm^4 about the horizontal neutral axis at the section under consideration
S = First moment in cm^3, about the neutral axis, of the area of the effective longitudinal members between the vertical level at which the shear stress is being determined and the vertical extremity of effective longitudinal members, taken at the section under consideration
τ = permissible shear stress = $110/k$ (N/mm^2)
k = As specified in S11.3.1.1 (i)

(ii) The value of *Fs* may be corrected for the direct transmission of forces to the transverse bulkheads at the discretion of each Classification Society.

S11.4.3 Shearing strength for ships with two effective longitudinal bulkheads

The thickness of side shell and longitudinal bulkheads are not to be less than the values given by the following formulae:

For side shell:

$$t = \frac{|(0.5 - \phi)(Fs + Fw) + \Delta Fsh|}{\tau} \frac{S}{I} \times 10^2 \quad \text{(mm)}$$

For longitudinal bulkheads:

$$t = \frac{|\phi (Fs + Fw) + \Delta Fbl|}{\tau} \frac{S}{I} \times 10^2 \quad \text{(mm)}$$

where, ϕ = ratio of shear force shared by the longitudinal bulkhead to the total shear force, and given by each Classification Society.
ΔFsh, ΔFbl = shear force acting upon the side shell plating and longitudinal bulkhead plating, respectively, due to local loads, and given by each Classification Society, subject to the sign convention specified in S11.2.1.1
S, I, τ = As specified in S11.4.2 (i)

S11
cont'd

S 11.5 Buckling strength

S 11.5.1 Application

These requirements apply to plate panels and longitudinals subject to hull girder bending and shear stresses.

S 11.5.2 Elastic buckling stresses

S 11.5.2.1 Elastic buckling of plates

1. Compression

The ideal elastic buckling stress is given by:

$$\sigma_E = 0.9m\,E\left(\frac{t_b}{1000s}\right)^2 \quad (N/mm^2)$$

For plating with longitudinal stiffeners (parallel to compressive stress):

$$m = \frac{8.4}{\Psi + 1.1} \qquad \text{for } (0 \le \Psi \le 1)$$

For plating with transverse stiffeners (perpendicular to compressive stress):

$$m = c\left[1 + \left(\frac{s}{\ell}\right)^2\right]^2 \frac{2.1}{\Psi + 1.1} \qquad \text{for } (0 \le \Psi \le 1)$$

where

E = modulus of elasticity of material

= 2.06×10^5 N/mm^2 for steel

t_b = net thickness, in mm, of plating, considering standard deductions equal to the values given in the table here after:

S11
cont'd

Structure	Standard deduction (mm)	Limit values min-max (mm)
- Compartments carrying dry bulk cargoes - One side exposure to ballast and/or liquid cargo Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line	0.05 t	0.5 - 1
- One side exposure to ballast and/or liquid cargo Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line - Two side exposure to ballast and/or liquid cargo Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line	0.10 t	2 - 3
- Two side exposure to ballast and/or liquid cargo Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line	0.15 t	2 - 4

S11
cont'd

s = shorter side of plate panel, in m,

ℓ = longer side of plate panel, in m,

c = 1.3 when plating stiffened by floors or deep girders,

= 1.21 when stiffeners are angles or T-sections,

= 1.10 when stiffeners are bulb flats,

= 1.05 when stiffeners are flat bars,

ψ = ratio between smallest and largest compressive σa stress when linear variation across panel.

2. Shear

The ideal elastic buckling stress is given by:

$$\tau_E = 0.9 k_t E \left(\frac{t_b}{1000s} \right)^2 \qquad (\text{N/mm}^2)$$

$$K_t = 5.34 + 4\left(\frac{s}{\ell} \right)^2$$

E, t_b, s and ℓ are given in 1.

S 11.5.2.2 Elastic buckling of longitudinals

1. Column buckling without rotation of the cross section

For the column buckling mode (perpendicular to plane of plating) the ideal elastic buckling stress is given by:

$$\sigma_E = 0.001 E \frac{I_a}{A\ell^2} \qquad (\text{N/mm}^2)$$

I_a = moment of inertia, in cm^4, of longitudinal, including plate flange and calculated with thickness as specified in S 11.5.2.1.1,

A = cross-sectional area, in cm^2, of longitudinal, including plate flange and calculated with thickness as specified in S 11.5.2.1.1,

ℓ = span, in m, of longitudinal,

A plate flange equal to the frame spacing may be included.

2. Torsional buckling mode

The ideal elastic buckling stress for the torsional mode is given by:

$$\sigma_E = \frac{\pi^2 E I_w}{10^4 I_p \ell^2}\left(m^2 + \frac{K}{m^2} \right) + 0.385 E \frac{I_t}{I_p} \qquad (\text{N/mm}^2)$$

$$K = \frac{C\ell^4}{\pi^4 E I_w} 10^6$$

S11
cont'd

m = number of half waves, given by the following table:

	0< K < 4	4 < K < 36	36 < K < 144	(m-1) ^{2}m^2 <K≤ m^2 (m+1)^2
m	1	2	3	m

I_t = St Venant's moment of inertia, in cm^4, of profile (without plate flange)

$$= \frac{h_w t_w^3}{3} 10^{-4} \quad \text{for flat bars (slabs)}$$

$$= \frac{1}{3}\left[h_w t_w^3 + b_f t_f^3 \left(1 - 0.63\frac{t_f}{b_f}\right)\right] 10^{-4} \quad \text{for flanged profiles}$$

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plate

$$= \frac{h_w^3 t_w}{3} 10^{-4} \quad \text{for flat bars (slabs)}$$

$$= \left(\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f\right) 10^{-4} \quad \text{for flanged profiles}$$

I_w = sectorial moment of inertia, in cm^6, of profile about connection of stiffener to plate

$$= \frac{h_w^3 t_w^3}{36} 10^{-6} \quad \text{for flat bars (slabs)}$$

$$= \frac{t_f b_f^3 h_w^2}{12} 10^{-6} \quad \text{for "Tee" profiles}$$

$$= \frac{b_f^3 h_w^2}{12(b_f + h_w)^2}\left[t_f\left(b_f^2 + 2b_f h_w + 4h_w^2\right) + 3t_w b_f h_w\right] 10^{-6} \quad \text{for angles and bulb profiles}$$

h_w = web height, in mm,

t_w = web thickness, in mm, considering standard deductions as specified in S 11.5.2.1.1,

b_f = flange width, in mm,

t_f = flange thickness, in mm, considering standard deductions as specified in S 11.5.2.1.1. For bulb profiles the mean thickness of the bulb may be used.

S11
cont'd

ℓ = span of profile, in m,

s = spacing of profiles, in m,

C = spring stiffeness exerted by suporting plate p

$$= \frac{k_p E t_p^{\,3}}{3s\left(1+\dfrac{1.33 k_p h_w t_p^{\,3}}{1000 s t_w^{\,3}}\right)} 10^{-3}$$

k_p = 1 - ηp not to be taken less than zero

t_p = plate thickness, in mm, considering standard deductions as specified in S 11.5.2.1.1.

$$\eta_p = \frac{\sigma_a}{\sigma_{Ep}}$$

σ_a = calculated compressive stress. For longitudinals, see S 11.5.4.1,

σ_{Ep} = elastic buckling stress of supporting plate as calculated in S 11.5.2.1,

For flanged profiles, k_p need not be taken less than 0.1.

3. Web and flange buckling

For web plate of longitudinals the ideal elastic buckling stress is given by:

$$\sigma_E = 3.8E\left(\frac{t_w}{h_w}\right)^2 \qquad (\text{N/mm}^2)$$

For flanges on angles and T-sections of longitudinals, buckling is taken care of by the following requirement:

$$\frac{b_f}{t_f} \le 15$$

b_f = flange width, in mm, for angles, half the flange width for T-sections.
t_f = as built flange thickness.

S 11.5.3 Critical buckling stresses

S 11.5.3.1 Compression

The critical buckling stress in compression σ_c is determined as follows:

S11
cont'd

$$\sigma_C = \sigma_E \qquad \text{when} \quad \sigma_E \le \frac{\sigma_F}{2}$$

$$= \sigma_F\left(1 - \frac{\sigma_F}{4\sigma_E}\right) \qquad \text{when} \quad \sigma_E > \frac{\sigma_F}{2}$$

σ_F = yield stress of material, in N/mm^2 σ_F may be taken as 235 N/mm^2 for mild steel,

σ_E = ideal elastic buckling stress calculated according to S 11.5.2.

S 11.5.3.2 Shear

The critical buckling stress in shear τ_c is determined as follows:

$$\tau_C = \tau_E \qquad \text{when } \tau_E \le \frac{\tau_F}{2}$$

$$= \tau_F\left(1 - \frac{\tau_F}{4\tau_E}\right) \qquad \text{when } \tau_E > \frac{\tau_F}{2}$$

$$\tau_F = \frac{\sigma_F}{\sqrt{3}}$$

σ_F = as given in S 11.5.3.1,

τ_E = ideal elastic buckling stress in shear calculated according to S11.5.2.1.2.

S 11.5.4 Working stress

S 11.5.4.1 Longitudinal compressive stresses

The compressive stresses are given in the following formula:

$$\sigma_a = \frac{M_s + M_w}{I_n} y \cdot 10^5 \text{ N/mm}^2$$

$$= \text{minimum} \frac{30}{k}$$

M_s = still water bending moment (kN.m), as given in S 11.2.1,

M_W = wave bending moment (kN.m) as given in S 11.2.2.1,

I_n = moment of inertia, in cm4, of the hull girder,

y = vertical distance, in m, from neutral axis to considered point.

k = as specified in S 11.3.1.1 (i).

M_S and M_W are to be taken as sagging or hogging bending moments, respectively, for members above or below the neutral axis.

Where the ship is always in hogging condition in still water, the sagging bending moment ($M_S + M_W$) is to be specially considered.

S11
cont'd

S 11.5.4.2 *Shear stresses*

1. Ships without effective longitudinal bulkheads

For side shell

$$\tau_a = \frac{0.5 \,|\, F_s + F_w \,|}{t} \cdot \frac{S}{I} \cdot 10^2 \ \text{N/mm}^2$$

F_S, F_W, t, s, I as specified in S 11.4.2

2. Ships with two effective longitudinal bulkheads

For side shell

$$\tau_a = \frac{|\,(0.5 - \phi)(F_s + F_w) + \Delta F_{sh}\,|}{t} \cdot \frac{S}{I} \cdot 10^2 \ \text{N/mm}^2$$

For longitudinal bulkheads

$$\tau_a = \frac{|\,\phi \ (F_s + F_w) + \Delta F_{b\ell}\,|}{t} \cdot \frac{S}{I} \cdot 10^2 \ \text{N/mm}^2$$

F_S, F_W, ΔF_{sh}, $\Delta F_{b\ell}$, t, S, I as specified in S 11.4.3.

S 11.5.5 Scantling criteria

S 11.5.5.1 *Buckling Stress*

The design buckling stress σ_c of plate panels and longitudinals (as calculated in S 11.5.3.1) is not to be less than:

$$\sigma_c \geq \beta \sigma_a$$

where

$\beta = 1$ for plating and for web plating of stiffeners (local buckling)

$\beta = 1.1$ for stiffeners

The critical buckling stress τ_c of plate panels (as calculated in S 11.5.3.2) is not to be less than:

$$\tau_c \geq \tau_a$$

END

S11 Longitudinal strength standard

(1989)
(Rev. 1
1993)
(Rev.2
Nov.2001)

S11.1 Application

This requirement applies only to steel ships of length 90 m and greater in unrestricted service. For ships having one or more of the following characteristics, special additional considerations will be given by each Classification Society.

(i)	Proportion	$L/B \leq 5$,	$B/D \geq 2,5$
(ii)	Length	$L \geq 500$ m	
(iii)	Block coefficient	$Cb < 0,6$	
(iv)	Large deck opening		
(v)	Ships with large flare		
(vi)	Carriage of heated cargoes		
(vii)	Unusual type or design		

◀

S11.2 Loads

S11.2.1 Still water bending moment and shear force

S11.2.1.1 General

Still water bending moments, Ms (kN-m), and still water shear forces, Fs (kN), are to be calculated at each section along the ship length for design load conditions and ballast conditions as specified in S11.2.1.2.
For these calculations, downward loads are assumed to be taken as positive values, and are to be integrated in the forward direction from the aft end of L. The sign conventions of Ms and Fs are as shown in Fig. 1.

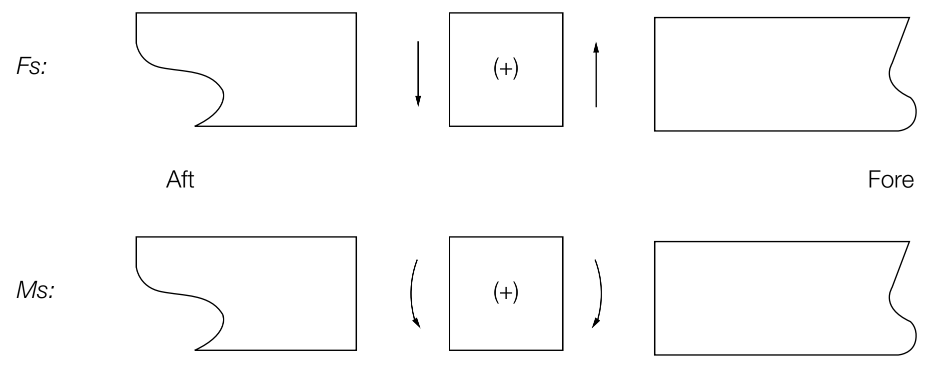

Fig. 1 Sign Conventions of *MS* and *Fs*

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S11
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S11.2.1.2 Load Conditions

In general, the following load conditions, based on amount of bunker, fresh water and stores at departure and arrival, are to be considered for the *Ms* and *Fs* calculations.

General cargo ships, container ships, roll-on/roll-off and refrigerated cargo carriers, bulk carriers, ore carriers:
- Homogeneous loading conditions at maximum draught
- Ballast conditions
- Special loading conditions e.g., container or light load conditions at less than the maximum draught, heavy cargo, empty holds or non-homogeneous cargo conditions, deck cargo conditions, etc., where applicable.

Oil tankers:
- Homogeneous loading conditions (excluding dry and clean ballast tanks) and ballast or part loaded conditions
- Any specified non-uniform distribution of loading
- Mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions.

Chemical tankers:
- Conditions as specified for oil tankers
- Conditions for high density or segregated cargo.

Liquefied gas carriers:
- Homogeneous loading conditions for all approved cargoes
- Ballast conditions
- Cargo conditions where one or more tanks are empty or partially filled or where more than one type of cargo having significantly different densities are carried.

Combination Carriers:
- Conditions as specified for oil tankers and cargo ships.

Ballast conditions involving partially filled peak and other ballast tanks are not permitted to be used as design conditions where alternative filling levels would result in design stress limits being exceeded. The partial filling of such tanks is, however, permitted in service to satisfy operational requirements providing design stress limits are satisfied for all conditions intermediate between empty and full.

S11.2.2 Wave loads

S11.2.2.1 Wave bending moment

The wave bending moments, *Mw*, at each section along the ship length are given by the following formulae:

$Mw\ (+) = +\ 190\ M\ C\ L^2\ B\ Cb \times 10^{-3}$ (kN - m) ... For positive moment
$Mw\ (+) = -\ 110\ M\ C\ L^2\ B\ (Cb + 0{,}7) \times 10^{-3}$ (kN - m) ... For negative moment

where, M = Distribution factor given in Fig. 2

$$C = 10{,}75 - \left[\frac{300 - L}{100}\right]^{1{,}5} \quad \text{for } 90 \leqq L \leqq 300$$

$$\text{or } 10{,}75 \quad \text{for } 300 < L < 350$$

$$\text{or } 10{,}75 - \left[\frac{L - 350}{150}\right]^{1{,}5} \quad \text{for } 350 \leqq L \leqq 500$$

L = Length of the ships in metres, defined by S2
B = Greatest moulded breadth in metres
Cb = Block coefficient, defined by S2, but not to be taken less than 0,6

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S11
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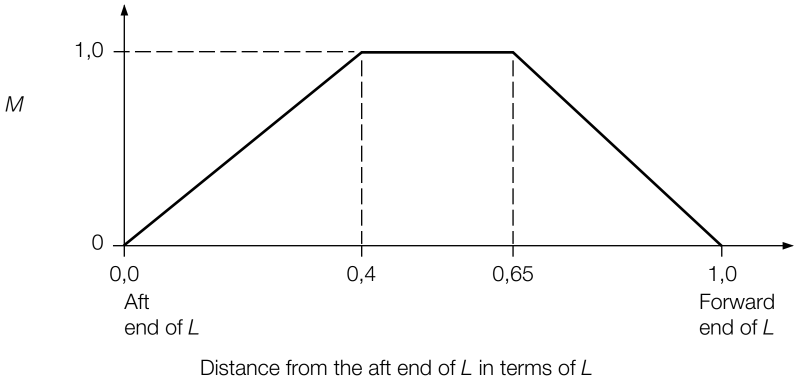

Fig. 2 Distribution factor *M*

S11 2.2.2 Wave shear force

The wave shear forces, *Fw*, at each section along the length of the ship are given by the following formulae:

Fw (+) = + 30 *F1 C L B* (*Cb* + 0,7) x 10^{-2} (kN) ... For positive shear force
Fw (–) = – 30 *F2 C L B* (*Cb* + 0,7) x 10^{-2} (kN) ... For negative shear force

Where, *F1, F2* = Distribution factors given in Figs. 3 and 4
C, L, B, Cb = As specified in S11.2.2.1

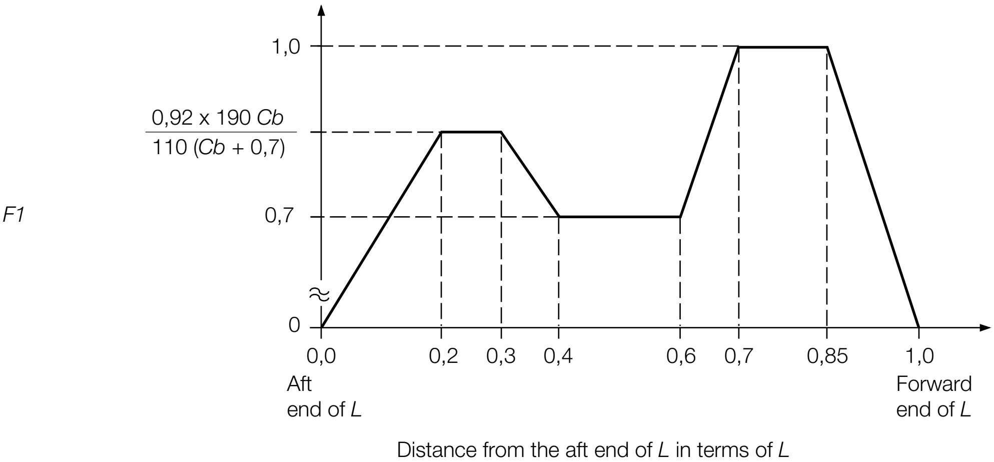

Fig. 3 Distribution factor *F1*

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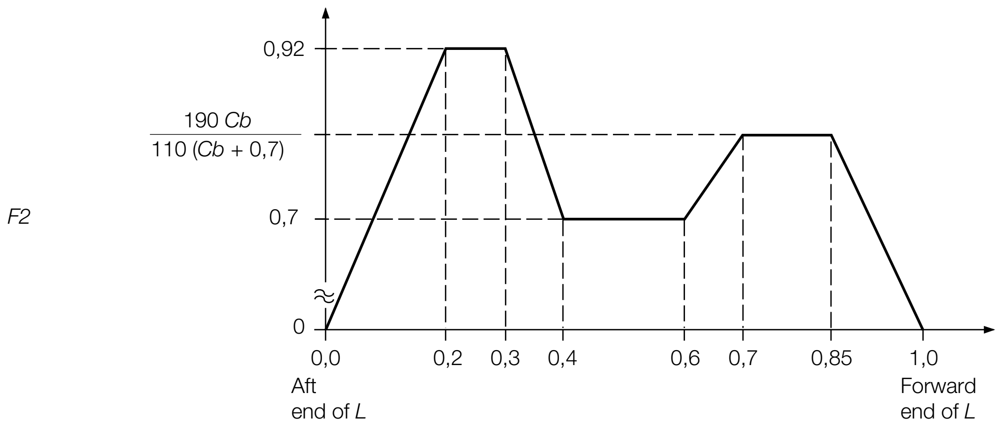

Fig. 4 Distribution factor *F2*

S11.3 Bending strength

S11.3.1 Bending strength amidships

S11 3.1.1 Section modulus

(i) Hull section modulus, Z, calculated in accordance with S5, is not to be less than the values given by the following formula in way of 0,4 *L* midships for the still water bending moments *Ms* given in S11.2.1.1 and the wave bending moments *Mw* given in S11.2.2.1, respectively:

$$\frac{|Ms + Mw|}{\sigma} \text{ x } 10^3 \ (cm^3)$$

where, σ = 175 /k (N/mm^2)
k = 1,0 for ordinary hull structural steel
k < 1,0 for higher tensile steel according to S4.

(ii) In any case, the longitudinal strength of the ship is to be in compliance with S7.

S11 3.1.2 Moment of inertia

Moment of inertia of hull section at the midship point is not to be less than

$$I_{min} = 3CL^3B\,(Cb + 0{,}7) \qquad (cm^4)$$

Where *C, L, B, Cb* = As specified in S11.2.2.1.

S11.3.2 Bending strength outside amidships.

The required bending strength outside 0,4 *L* amidships is to be determined at the discretion of each Classification Society.

S11.4 Shearing strength

S11.4.1 General

The thickness requirements given in S11.4.2 or S11.4.3 apply unless smaller values are proved satisfactory by a method of direct stress calculation approved by each Classification Society, where the

S11
cont'd

calculated shear stress is not to exceed 110/k (N/mm^2).

S11.4.2 Shearing strength for ships without effective longitudinal bulkheads

(i) The thickness of side shell is not to be less than the values given by the following formula for the still water shear forces *Fs* given in S11.2.1.1 and the wave shear forces *Fw* given in S11.2.2.2, respectively:

$$t = \frac{0{,}5\ \left| Fs + Fw \right|}{\tau} \ \frac{S}{I} \ \text{x}\ 10^2 \qquad \text{(mm)}$$

where, I = Moment of inertia in cm^4 about the horizontal neutral axis at the section under consideration

S = First moment in cm^3, about the neutral axis, of the area of the effective longitudinal members between the vertical level at which the shear stress is being determined and the vertical extremity of effective longitudinal members, taken at the section under consideration

τ = 110/k (N/mm^2)

k = As specified in S11.3.1.1 (i)

(ii) The value of *Fs* may be corrected for the direct transmission of forces to the transverse bulkheads at the discretion of each Classification Society.

S11.4.3 Shearing strength for ships with two effective longitudinal bulkheads

The thickness of side shell and longitudinal bulkheads are not to be less than the values given by the following formulae:

For side shell:

$$t = \frac{\left| (0.5 - \phi)\ (Fs + Fw\ ) + \Delta\ Fsh \right|}{\tau} \ \frac{S}{I} \ \text{x}\ 10^2 \qquad \text{(mm)}$$

For longitudinal bulkheads:

$$t = \frac{\left| \phi\ (Fs + Fw\ ) + \Delta\ Fbl \right|}{\tau} \ \frac{S}{I} \ \text{x}\ 10^2 \qquad \text{(mm)}$$

where, ϕ = ratio of shear force shared by the longitudinal bulkhead to the total shear force, and given by each Classification Society.

$\Delta\ Fsh$, $\Delta\ Fbl$ = shear force acting upon the side shell plating and longitudinal bulkhead plating, respectively, due to local loads, and given by each Classification Society, subject to the sign convention specified in S11.2.1.1

S, I, τ = As specified in S11.4.2 (i)

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S11
cont'd

S 11.5 Buckling strength

S 11.5.1 Application

These requirements apply to plate panels and longitudinals subject to hull girder bending and shear stresses.

S 11.5.2 Elastic buckling stresses

S 11.5.2.1 Elastic buckling of plates

1. Compression

The ideal elastic buckling stress is given by:

$$\sigma_E = 0.9 m\, E \left(\frac{t_b}{1000 s} \right)^2 \quad (\text{N/mm}^2)$$

For plating with longitudinal stiffeners (parallel to compressive stress):

$$m = \frac{8.4}{\Psi + 1.1} \qquad \text{for } (0 \le \Psi \le 1)$$

For plating with transverse stiffeners (perpendicular to compressive stress):

$$m = c\left[1 + \left(\frac{s}{\ell}\right)^2\right]^2 \frac{2.1}{\Psi + 1.1} \qquad \text{for } (0 \le \Psi \le 1)$$

where

E = modulus of elasticity of material

= 2.06×10^5 N/mm^2 for steel

t_b = net thickness, in mm, of plating, considering standard deductions equal to the values given in the table here after:

S11
cont'd

Structure	Standard deduction (mm)	Limit values min-max (mm)
- Compartments carrying dry bulk cargoes - One side exposure to ballast and/or liquid cargo Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line	0.05 t	0.5 - 1
- One side exposure to ballast and/or liquid cargo Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line - Two side exposure to ballast and/or liquid cargo Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line	0.10 t	2 - 3
- Two side exposure to ballast and/or liquid cargo Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line	0.15 t	2 - 4

▶

S11
cont'd

s = shorter side of plate panel, in m,

ℓ = longer side of plate panel, in m,

c = 1.3 when plating stiffened by floors or deep girders,

= 1.21 when stiffeners are angles or T-sections,

= 1.10 when stiffeners are bulb flats,

= 1.05 when stiffeners are flat bars,

ψ = ratio between smallest and largest compressive σa stress when linear variation across panel.

2. Shear

The ideal elastic buckling stress is given by:

$$\tau_E = 0.9 k_t E \left(\frac{t_b}{1000s} \right)^2 \qquad (\text{N/mm}^2)$$

$$K_t = 5.34 + 4\left(\frac{s}{\ell} \right)^2$$

E, t_b, s and ℓ are given in 1.

S 11.5.2.2 Elastic buckling of longitudinals

1. Column buckling without rotation of the cross section

For the column buckling mode (perpendicular to plane of plating) the ideal elastic buckling stress is given by:

$$\sigma_E = 0.001E \frac{I_a}{A\ell^2} \qquad (\text{N/mm}^2)$$

I_a = moment of inertia, in cm^4, of longitudinal, including plate flange and calculated with thickness as specified in S 11.5.2.1.1,

A = cross-sectional area, in cm^2, of longitudinal, including plate flange and calculated with thickness as specified in S 11.5.2.1.1,

ℓ = span, in m, of longitudinal,

A plate flange equal to the frame spacing may be included.

2. Torsional buckling mode

The ideal elastic buckling stress for the torsional mode is given by:

$$\sigma_E = \frac{\pi^2 E L_w}{10^4 I_p \ell^2}\left(m^2 + \frac{K}{m^2} \right) + 0.385E \frac{I_t}{I_p} \quad (\text{N/mm}^2)$$

$$K = \frac{C\ell^4}{\pi^4 E I_w} 10^6$$

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S11
cont'd

m = number of half waves, given by the following table:

	0< K < 4	4 < K < 36	36 < K < 144	$(m-1)^2 m^2 < K \le m^2 (m+1)^2$
m	1	2	3	m

I_t = St Venant' s moment of inertia, in cm^4, of profile (without plate flange)

$$= \frac{h_w t_w^3}{3} 10^{-4} \quad \text{for flat bars (slabs)}$$

$$= \frac{1}{3}\left[h_w t_w^3 + b_f t_f^3 \left(1 - 0.63\frac{t_f}{b_f}\right)\right] 10^{-4} \quad \text{for flanged profiles}$$

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plate

$$= \frac{h_w^3 t_w}{3} 10^{-4} \quad \text{for flat bars (slabs)}$$

$$= \left(\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f\right) 10^{-4} \quad \text{for flanged profiles}$$

I_w = sectional moment of inertia, in cm^6, of profile about connection of stiffener to plate

$$= \frac{h_w^3 t_w^3}{36} 10^{-6} \quad \text{for flat bars (slabs)}$$

$$= \frac{t_f b_f^3 h_w^2}{12} 10^{-6} \quad \text{for "Tee" profiles}$$

$$= \frac{b_f^3 h_w^2}{12(b_f + h_w)^2}\left[t_f\left(b_f^2 + 2b_f h_w + 4h_w^2\right) + 3t_w b_f h_w\right] 10^{-6} \quad \text{for angles and bulb profiles}$$

h_w = web height, in mm,

t_w = web thickness, in mm, considering standard deductions as specified in S 11.5.2.1.1,

b_f = flange width, in mm,

t_f = flange thickness, in mm, considering standard deductions as specified in S 11.5.2.1.1. For bulb profiles the mean thickness of the bulb may be used.

▶

S11
cont'd

ℓ = span of profile, in m,

s = spacing of profiles, in m,

C = spring stiffeness exerted by suporting plate p

$$= \frac{k_p E t_p{}^3}{3s\left(1+\frac{1.33 k_p h_w t_p{}^3}{1000 s t_w{}^3}\right)} 10^{-3}$$

k_p = 1 - ηp not to be taken less than zero

t_p = plate thickness, in mm, considering standard deductions as specified in S 11.5.2.1.1.

$$\eta_p = \frac{\sigma_a}{\sigma_{Ep}}$$

σ_a = calculated compressive stress. For longitudinals, see S 11.5.4.1,

σ_{Ep} = elastic buckling stress of supporting plate as calculated in S 11.5.2.1,

For flanged profiles, k_p need not be taken less than 0.1.

3. Web and flange buckling

For web plate of longitudinals the ideal elastic buckling stress is given by:

$$\sigma_E = 3.8E\left(\frac{t_w}{h_w}\right)^2 \qquad (N/mm^2)$$

For flanges on angles and T-sections of longitudinals, buckling is taken care of by the following requirement:

$$\frac{b_f}{t_f} \le 15$$

b_f = flange width, in mm, for angles, half the flange width for T-sections.
t_f = as built flange thickness.

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S 11.5.3 Critical buckling stresses

S 11.5.3.1 Compression

The critical buckling stress in compression σ_c is determined as follows:

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S11
cont'd

$$\sigma_C = \sigma_E \qquad \text{when} \quad \sigma_E \le \frac{\sigma_F}{2}$$

$$= \sigma_F\left(1 - \frac{\sigma_F}{4\sigma_E}\right) \qquad \text{when} \quad \sigma_E > \frac{\sigma_F}{2}$$

σ_F = yield stress of material, in N/mm^2 σ_F may be taken as 235 N/mm^2 for mild steel,

σ_E = ideal elastic buckling stress calculated according to S 11.5.2.

S 11.5.3.2 *Shear*

The critical buckling stress in shear τ_C is determined as follows:

$$\tau_C = \tau_E \qquad \text{when} \ \tau_E \le \frac{\tau_F}{2}$$

$$= \tau_F\left(1 - \frac{\tau_F}{4\tau_E}\right) \qquad \text{when} \ \tau_E > \frac{\tau_F}{2}$$

$$\tau_F = \frac{\sigma_F}{\sqrt{3}}$$

σ_F = as given in S 11.5.3.1,

τ_E = ideal elastic buckling stress in shear calculated according to S11.5.2.1.2.

S 11.5.4 Working stress

S 11.5.4.1 *Longitudinal compressive stresses*

The compressive stresses are given in the following formula:

$$\sigma_a = \frac{M_s + M_w}{I_n} y \cdot 10^5 \ \text{N/mm}^2$$

$$= \text{minimum} \ \frac{30}{k}$$

M_S = still water bending moment (kN.m), as given in S 11.2.1,

M_W = wave bending moment (kN.m) as given in S 11.2.2.1,

I_n = moment of inertia, in cm4, of the hull girder,

y = vertical distance, in m, from neutral axis to considered point.

k = as specified in S 11.3.1.1 (i).

M_S and M_W are to be taken as sagging or hogging bending moments, respectively, for members above or below the neutral axis.

Where the ship is always in hogging condition in still water, the sagging bending moment (M_S + M_W) is to be specially considered. ▶

S11
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S 11.5.4.2 Shear stresses

1. Ships without effective longitudinal bulkheads

For side shell

$$\tau_a = \frac{0.5\,|\,F_s + F_w\,|}{t} \cdot \frac{S}{I} \cdot 10^2 \text{ N/mm}^2$$

F_S, F_W, t, s, I as specified in S 11.4.2

2. Ships with two effective longitudinal bulkheads

For side shell

$$\tau_a = \frac{|\,(0.5 - \phi)(F_s + F_w) + \Delta F_{sh}\,|}{t} \cdot \frac{S}{I} \cdot 10^2 \text{ N/mm}^2$$

For longitudinal bulkheads

$$\tau_a = \frac{|\,\phi\;(F_s + F_w) + \Delta F_{b\ell}\,|}{t} \cdot \frac{S}{I} \cdot 10^2 \text{ N/mm}^2$$

F_S, F_W, ΔF_{sh}, $\Delta F_{b\ell}$, t, S, I as specified in S 11.4.3.

S 11.5.5 Scantling criteria

S 11.5.5.1 Buckling Stress

The design buckling stress σ_C of plate panels and longitudinals
(as calculated in S 11.5.3.1) is not to be less than:

$$\sigma_c \geq \beta \sigma_a$$

where

$\beta = 1$ for plating and for web plating of stiffeners (local buckling)

$\beta = 1.1$ for stiffeners

The critical buckling stress τ_C of plate panels (as calculated in S 11.5.3.2) is not to be less than:

$$\tau_c \geq \tau_a$$

◀◀

S12
(1992)
(Rev 1
1997)
(Rev 2.1
1997)
(Rev.3
Sept.
2000)
(Rev.4
July 2004)

Side Structures in Single Side Skin Bulk Carriers

S12.1 - Application and definitions

These requirements apply to side structures of cargo holds bounded by the side shell only of bulk carriers constructed with single deck, topside tanks and hopper tanks in cargo spaces intended primarily to carry dry cargo in bulk, which are contracted for construction on or after 1st July 1998.

S12.2 - Scantlings of side structures

The thickness of the side shell plating and the section modulus and shear area of side frames are to be determined according to the Society's criteria.

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

S12.3 - Minimum thickness of frame webs

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

$$t_{w,\min} = 7,0 + 0,03 \cdot L$$

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

where L is the Rule length, in m, as defined in UR S2 but need not be taken greater than 200m.

S12.4 - Lower and upper brackets

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

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

The dimensions of the lower and upper brackets are not to be less than those shown in Figure 2.

Structural continuity with the upper and lower end connections of side frames is to be ensured within topsides and hopper tanks by connecting brackets as shown in Figure 3. The brackets are to be stiffened against buckling according to the Society's criteria.

The section moduli of the side longitudinals and sloping bulkhead longitudinals which support the connecting brackets are to be determined according to the Society's criteria with the span taken between transverses. Other arrangements may be adopted at the Society's discretion. In these cases, the section moduli of the side longitudinals and sloping bulkhead longitudinals are to be determined according to the Society's criteria for the purpose of effectively supporting the brackets.

Note:
1. Changes introduced in Rev.3 are to be uniformly implemented by IACS Members and Associates from 1 July 2001.

2. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.

S12
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S12.5 - Side frame sections

Frames are to be fabricated symmetrical sections with integral upper and lower brackets and are to be arranged with soft toes.

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

$$r = \frac{0,4 \cdot b_f^2}{t_f}$$

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

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

The web depth to thickness ratio of frames is not to exceed the following values:

- $60 \cdot k^{0,5}$ for symmetrically flanged frames
- $50 \cdot k^{0,5}$ for asymmetrically flanged frames

where k = 1,0 for ordinary hull structural steel and k < 1 for higher tensile steel according to UR S4.

The outstanding flange is not to exceed $10 \cdot k^{0,5}$ times the flange thickness.

S12.6 - Tripping brackets

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

S12.7 - Weld connections of frames and end brackets

Double continuous welding is to be adopted for the connections of frames and brackets to side shell, hopper and upper wing tank plating and web to face plates.

For this purpose, the weld throat is to be (see Figure 1):

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

where t is the thinner of the two connected members.

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

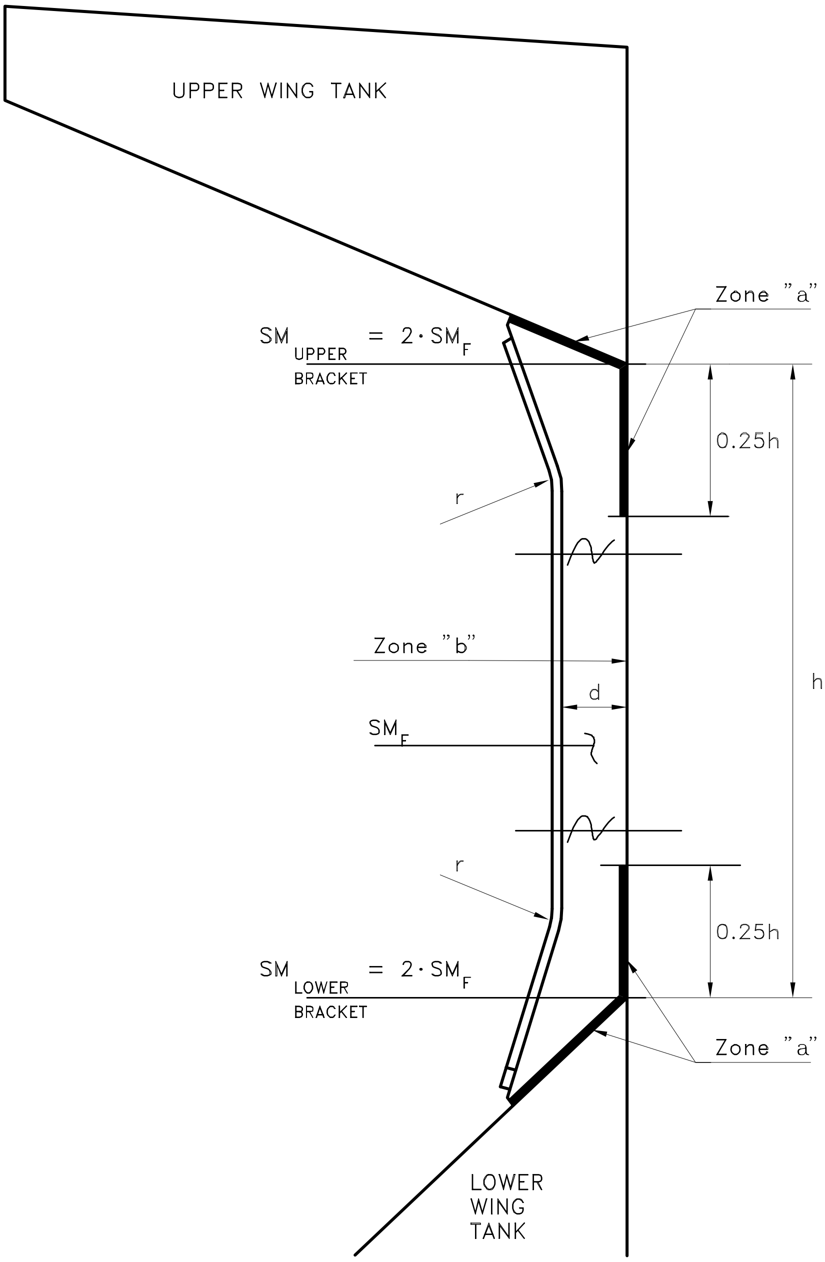
S12.8 - Minimum thickness of side shell plating

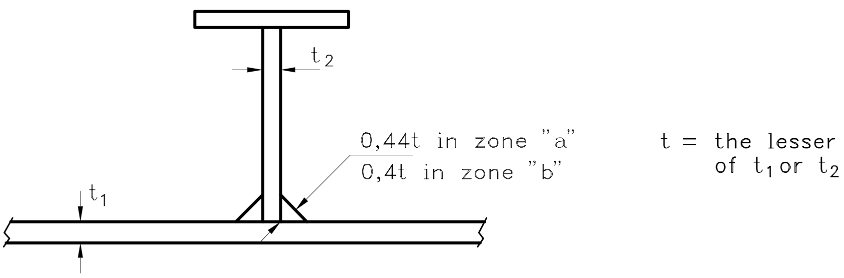
The thickness of side shell plating located between hopper and upper wing tanks is not to be less than $t_{p,min}$ in mm, given by:

$$t_{p,\min} = \sqrt{L}$$

S12
cont'd

Figure 1





S12
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Figure 2

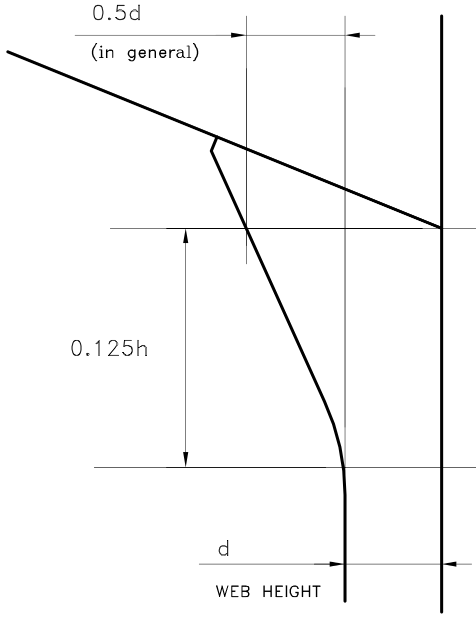
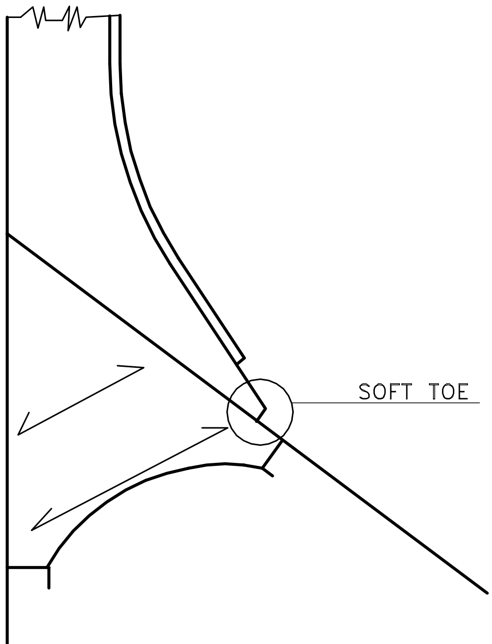


Figure 3



S12
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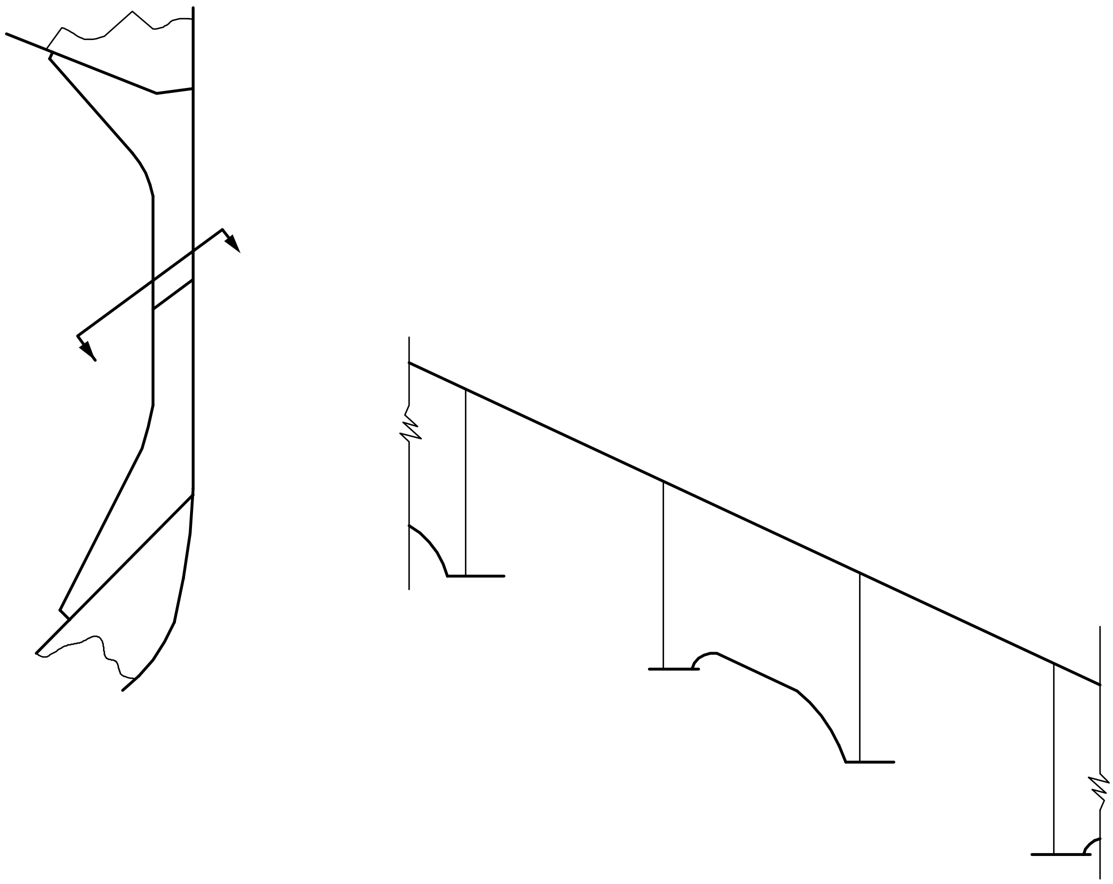
Figure 4

Tripping brackets to be fitted in way of foremost hold



END

S13 Strength of bottom forward in oil tankers

(1993)
(Rev. 1
1993)

S13.1 General

For every oil tanker subject to Regulation 13 of MARPOL 73/78 Annex I, the strengthening of bottom forward is to be based on the draught obtained by using segregated ballast tanks only.

S13.2 Scantlings

Determination of scantlings to comply with the above requirement should be based on the Rules of individual Societies.

Note: Mandatory implementation date of the unified requirement is the 1st. July 1994. (This note was adopted by IACS Council on 2nd December 1993).

S14 Testing Procedures of Watertight Compartments

(1996)
(Rev.1
Feb. 2001)
(Rev.2
May 2001)

S14.1 - General

S14.1.1 - Definitions

Shop primer is a thin coating applied after surface preparation and prior to fabrication as a protection against corrosion during fabrication.

Protective coating is a final coating protecting the structure from corrosion.

Structural testing is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible (for example when it is difficult, in practice, to apply the required head at the top of the tank), hydropneumatic testing may be carried out instead. When a hydropneumatic testing is performed, the conditions should simulate, as far as practicable, the actual loading of the tank.

Hydropneumatic testing is a combination of hydrostatic and air testing, consisting in filling the tank with water up to its top and applying an additional air pressure. The value of the additional air pressure is at the discretion of the Society, but is to be at least as defined in S14.2.2.

Leak testing is an air or other medium test carried out to demonstrate the tightness of the structure.

Hose testing is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing and to other components which contribute to the watertight or weathertight integrity of the hull.

S14.1.2 - Application

The following requirements determine the testing conditions for:

- gravity tanks, excluding independent tanks of less than 5 m^3 in capacity,
- watertight or weathertight structures.

The purpose of these tests is to check the tightness and/or the strength of structural elements at time of ships construction and on the occasion of major repairs.

Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion so that any subsequent work would not impair the strength and tightness of the structure.

For the general testing requirements, see items S14.3 and S14.4.

S14.2 - Testing methods

S14.2.1 - Structural testing

Structural testing may be carried out after application of the shop primer.

Structural testing may be carried out after the protective coating has been applied, provided that one of the following two conditions is satisfied:

a) all the welds are completed and carefully inspected visually to the satisfaction of the Surveyor prior to the application of the protective coating,

b) leak testing is carried out prior to the application of the protective coating.

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S14
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In absence of leak testing, protective coating should be applied after the structural testing of:
- all erection welds, both manual and automatic,
- all manual fillet weld connections on tank boundaries and manual penetration welds.

S14.2.2 - Leak testing

Where leak testing is carried out, in accordance with Table 1, an air pressure of $0.15 \cdot 10^5$ Pa is to be applied during the test.

Prior to inspection, it is recommended that the air pressure in the tank is raised to $0.20 \cdot 10^5$ Pa and kept at this level for about 1 hour to reach a stabilized state, with a minimum number of personnel in the vicinity of the tank, and then lowered to the test pressure.

Individual Societies may accept that the test is conducted after the pressure has reached a stabilized state at $0.20 \cdot 10^5$ Pa, without lowering the pressure, provided they are satisfied of the safety of the personnel involved in the test.

Welds are to be coated with an efficient indicating liquid.

A U-tube filled with water up to a height corresponding to the test pressure is to be fitted to avoid overpressure of the compartment tested and verify the test pressure. The U-tube should have a cross section larger than that of the pipe supplying air.

In addition, the test pressure is also to be verified by means of one master pressure gauges. The Society may accept alternative means which are considered to be equivalently reliable.

Leak testing is to be carried out, prior to the application of a protective coating, on all fillet weld connections on tank boundaries, penetrations and erection welds on tank boundaries excepting welds made by automatic processes. Selected locations of automatic erection welds and pre-erection manual or automatic welds may be required to be similarly tested at the discretion of the Surveyor taking account of the quality control procedures operating in the shipyard. For other welds, leak testing may be carried out, after the protective coating has been applied, provided that these welds were carefully inspected visually to the satisfaction of the Surveyor.

Any other recognized method may be accepted to the satisfaction of the Surveyor.

S14.2.3 - Hose testing

When hose testing is required to verify the tightness of the structures, as defined in Table 1, the minimum pressure in the hose, at least equal to $2 \cdot 10^5$ Pa, is to be applied at a maximum distance of 1,5 m. The nozzle diameter is not to be less than 12 mm.

S14.2.4 - Hydropneumatic testing

When hydropneumatic testing is performed, the same safety precautions as for leak testing (see S14.2.2) are to be adopted.

S14.2.5 - Other testing methods

Other testing methods may be accepted, at the discretion of the Society, based upon equivalency considerations.

S14.3 - General testing requirements

General requirements for testing are given in Table 1.
S14.4 - Additional requirements for special type vessels/tanks

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S14
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In addition to the requirements of Table 1, particular requirements for testing of certain spaces within the cargo area of:

- liquefied gas carriers,
- edible liquid carriers,
- chemical carriers,

are given in Table 2.

These requirements intend generally to verify the adequacy of the structural design of the tank, based on the loading conditions which prevailed when determining the tank structure scantlings.

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S14
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Table 1 - General testing requirements

Item number	Structure to be tested	Type of testing	Structural test pressure	Remarks
1	Double bottom tanks	Structural testing [1]	The greater of the following: • head of water up to the top of overflow • head of water up to the margin line	Tank boundaries tested from at least one side
2	Double side tanks	Structural testing [1]	The greater of the following: • head of water up to the top of overflow • 2,4 m head of water above highest point of tank	Tank boundaries tested from at least one side
3	Tank bulkheads, deep tanks	Structural testing [1]	The greater of the following [2]: • head of water up to the top of overflow • 2,4 m head of water above highest point of tank • setting pressure of the safety relief valves, where relevant	Tank boundaries tested from at least one side
	Fuel oil bunkers	Structural testing		
4	Ballast holds in bulk carriers	Structural testing [1]	The greater of the following: • head of water up to the top of overflow • 0,90 m head of water above top of hatch	
5	Fore peak and after peak used as tank	Structural testing	The greater of the following: • head of water up to the top of overflow • 2,4 m head of water above highest point of tank	Test of the after peak carried out after the stern tube has been fitted
	Fore peak not used as tank	Refer to SOLAS Ch. II.1 Reg. 14		
	After peak not used as tank	Leak testing		

Notes:

[1] Leak or hydropneumatic testing may be accepted under the conditions specified in S14.2.2, provided that at least one tank for each type is structurally tested, to be selected in connection with the approval of the design. In general, structural testing need not be repeated for subsequent vessels of a series of identical newbuildings. This relaxation does not apply to cargo space boundaries in tankers and comb ination carriers and tanks for segregated cargoes or polluta nts. If the structural test reveals weakness or severe faults not detected by the leak test, all tanks are to be structurally tested.

[2] Where applicable, the highest point of tank is to be measured to the deck and excluding hatches. In holds for liquid cargo or ballast with large hatch covers, the highest point of tank is to be taken at the top of the hatch.

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S14
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Table 1 - General testing requirements

(cont'd)

Item number	Structure to be tested	Type of testing	Structural test pressure	Remarks
6	Cofferdams	Structural testing [3]	The greater of the following: • head of water up to the top of overflow • 2,4 m head of water above highest point of tank	
7	Watertight bulkheads	Refer to SOLAS Ch. II.1 Reg. 14 [4]		
8	Watertight doors below freeboard or bulkhead deck	Refer to SOLAS Ch. II.1 Reg. 18		
9	Double plate rudders	Leak testing		
10	Shaft tunnel clear of deep tanks	Hose testing		
11	Shell doors	Hose testing		
12	Watertight hatchcovers of tanks in bulk-carriers	Hose testing		
	Watertight hatchcovers of tanks in combination carriers	Structural testing [1]	The greater of the following: • 2,4 m head of water above the top of hatchcover • setting pressure of the safety relief valves, where relevant	At least every 2nd hatch cover are to be tested
13	Weathertight hatchcovers and closing appliances	Hose testing		

Note:

[1] Leak or hydropneumatic testing may be accepted under the conditions specified in S14.2.2, provided that at least one tank for each type is structurally tested, to be selected in connection with the approval of the design. In general, structural testing need not be repeated for subsequent vessels of a series of identical newbuildings. This relaxation does not apply to cargo space boundaries in tankers and combination carriers and tanks for segregated cargoes or pollutants. If the structural test reveals weakness or severe faults not detected by the leak test, all tanks are to be structurally tested.

[3] Leak or hydropneumatic testing may be accepted under the conditions specified in S14.2.2 when, at the Society's discretion, the latter is considered significant also in relation to the construction techniques and the welding procedures adopted.

[4] When hose test cannot be performed without damaging possible outfitting (machinery, cables, switchboards, insulation, etc.) already installed, it may be replaced, at the Society's discretion, by a careful visual inspection of all the crossings and welded joints; where necessary, dye penetrant test or ultrasonic leak test may be required.

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S14
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Table 1 - General testing requirements

(cont'd)

Item number	Structure to be tested	Type of testing	Structural test pressure	Remarks
14	Chain locker (if aft of collision bulkhead)	Structural testing	Head of water up to the top	
15	Independent tanks	Structural testing	Head of water up to the top of overflow, but not less than 0,9 m	
16	Ballast ducts	Structural testing	Ballast pump maximum pressure	

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S14
cont'd

Table 2 - Additional testing requirements for spaces within the cargo area of certain types of ships

Item number	Types of ships	Structure to be tested	Testing requirements	Structural test pressure	Remarks
1	Liquefied gas carriers	Integral tanks	Refer to UR G1		
		Hull structure supporting membrane or semi-membrane tanks	Refer to UR G1		
		Independent tanks type A	Refer to UR G1		
		Independent tanks type B	Refer to UR G1		
		Independent tanks type C	Refer to UR G2		

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S14
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Table 2 - Additional testing requirements for spaces within the cargo area of certain types of ships

(cont'd)

Item number	Types of ships	Structure to be tested	Testing requirements	Structural test pressure	Remarks
2	Edible liquid carriers	Independent tanks	Structural testing	Head of water up to the top of overflow without being less than 0,9 m	
3	Chemical carriers	Integral or independent tanks	Structural testing of cargo tanks boundaries from at least one side	The greater of the following: • 2,4 m head of water above highest point of tank • setting pressure of the safety relief valves, where relevant	

▶

S15 Side Shell Doors and Stern Doors

(1996)
(Rev.1
Nov. 2003)

Retrospective application of UR-S9 to existing ro-ro passenger ships

1. The structural condition of side shell doors and stern doors, especially the primary structure, the securing and supporting arrangements and the hull structure alongside and above the doors, are to be specially examined and any defects rectified.

2. The following measures are to be complied with by all existing ro-ropassenger ships with the date of building before the 30th June 1996, including, when not differently deliberated by the competent flag Administrations, ships only engaged on domestic sea voyages.

a) The structural arrangement of securing devices and supporting devices of inwards opening doors in way of these securing devices and, where applicable, of the surrounding hull structure is to be re-assessed in accordance with the applicable requirements of S9.5 and modified accordingly.

b) The securing and locking arrangements for side shell doors and stern doors which may lead to the flooding of a special category space or ro-ro spaces as defined in S9.1.3, are to comply with the following requirements :

-Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It shall not be possible to turn off the indicator light.

-The indication panel on the navigation bridge is to be equipped with a mode selection function "harbour/sea voyage", so arranged that audible alarm is given if the vessel leaves harbour with side shell or stern doors not closed or with any of the securing devices not in the correct position.

-A water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors.

3. Documented operating procedures for closing and securing side shell and stern doors are to be kept on board and posted at the appropriate places.

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S16

(1995)
(Rev.1
Nov 2003)
(Corr.1
Aug 2004)

Bow Doors and Inner Doors - Retrospective Application of UR-S8, as amended 1995, to existing Ro-Ro Passenger Ships

1. The structural condition of bow doors and inner doors, especially the primary structure, the securing and supporting arrangements and the hull structure alongside and above the doors, are to be specially examined and any defects rectified.

2. The requirements of S8.8 concerning operating procedures of the bow door and inner door are to be complied with.

3. The following measures are to be complied with by all existing ro-ro passenger ships with the date of building before the 30th June 1996, including, when not differently deliberated by the competent flag Administrations, ships only engaged on domestic sea voyages.

a) The location and arrangement of inner doors are to comply with the applicable requirements of the SOLAS Convention and with S8.1.2d.

b) Ships with visor door are to comply with S8.6.2g requiring redundant provision of securing devices preventing the upward opening of the bow door. In addition, where the visor door is not self closing under external loads (i.e. the closing moment M_y calculated in accordance with S8.3.1c is less than zero) then the opening moment M_o is not to be taken less than $-M_y$. If drainage arrangements in the space between the inner and bow doors are not fitted, the value of M_o is to be specially considered.

Where available space above the tanktop does not enable the full application of S.8.6.2g, equivalent measures are to be taken to ensure that the door has positive means for being kept closed during seagoing operation.

c) Ships with visor door are to comply with S8.6.2h requiring securing and supporting devices excluding hinges to be capable of bearing the vertical design force (F_z - 10W) without exceeding the permissable stresses given in S8.2.1a.

d) For side-opening doors, the structural arrangements for supporting vertical loads, including securing devices, supporting devices and, where applicable, hull structure above the door, are to be re-assessed in accordance with the applicable requirements of S8.6 and modified accordingly.

e) The securing and locking arrangements for bow doors and inner doors which may lead to the flooding of a special category space or ro-ro space as defined in the S8.1.3 are to comply with the following requirements:

- Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each panel to indicate that the doors are closed and that their securing and locking devices are properly positioned.

- The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

- The indication panel on the navigation bridge is to be equipped with a mode selection function “harbour/sea voyage”, so arranged that audible alarm is given if the vessel leaves harbour with the bow doors or inner doors not closed or with any of the securing devices not in the correct position.

- A water leakage detection system with audible alarm and television surveillance are to be arranged to provide an indication to the navigation bridge and to the engine control station of any leakage through the doors.

END

S17

(1997)
(Rev. 1 1997)
(Rev.2 1998)
(Rev.3 Sept. 2000)
(Rev.4 June 2002)
(Rev.5 June 2003)
(Rev.6 July 2004)

Longitudinal Strength of Hull Girder in flooded condition for Bulk Carriers (Rev.6)

S17.1 - General

This revision of this UR is to be complied with in respect of the flooding of any cargo hold of bulk carriers with notation BC-A or BC-B, as defined in UR S25, which are contracted for construction on or after 1 July 2003[Note].

Such ships are to have their hull girder strength checked for specified flooded conditions, in each of the cargo and ballast loading conditions defined in UR S11.2.1.2 to S11.2.1.4. and in every other condition considered in the intact longitudinal strength calculations, including those according to UR S1 and S1A, except that harbour conditions, docking condition afloat, loading and unloading transitory conditions in port and loading conditions encountered during ballast water exchange need not be considered.

S17.2 - Flooding conditions

S 17.2.1. Floodable holds

Each cargo hold is to be considered individually flooded up to the equilibrium waterline, except that cargo holds of double side skin construction of not less than 1000mm breadth at any location within the hold length, measured perpendicular to the side shell in ships need not be considered flooded.

S 17.2.2 Loads

The still water loads in flooded conditions are to be calculated for the above cargo and ballast loading conditions.

The wave loads in the flooded conditions are assumed to be equal to 80% of those given in UR S11.

S17.3 - Flooding criteria

To calculate the weight of ingressed water, the following assumptions are to be made:

a) The permeability of empty cargo spaces and volume left in loaded cargo spaces above any cargo is to be taken as 0.95.

b) Appropriate permeabilities and bulk densities are to be used for any cargo carried. For iron ore, a minimum permeability of 0.3 with a corresponding bulk density of 3.0 t/m^3 is to be used. For cement, a minimum permeability of 0.3 with a corresponding bulk density of 1.3 t/m^3 is to be used. In this respect, "permeability" for solid bulk cargo means the ratio of the floodable volume between the particles, granules or any larger pieces of the cargo, to the gross volume of the bulk cargo.

For packed cargo conditions (such as steel mill products), the actual density of the cargo should be used with a permeability of zero.

Note:

1. Bulk carriers contracted before 1 July 2003 are to comply with the applicable version of S17.

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.

S17
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S17.4 - Stress assessment

The actual hull girder bending stress σ_{fld}, in N/mm^2, at any location is given by:

$$\sigma_{fld} = \frac{M_{sf} + 0{,}8 \cdot M_w}{W_z} \cdot 10^3$$

where:

M_{sf} = still water bending moment, in kN·m, in the flooded conditions for the section under consideration

M_W = wave bending moment, in kN·m, as given in UR S11.2.2.1 for the section under consideration

W_Z = section modulus, in cm^3, for the corresponding location in the hull girder.

The actual hull girder shear stress τ_{fld}, in N/mm^2, at any location is given by:

$$\tau_{fld} = \frac{0{,}5 \cdot (F_{sf} \cdot f_{sfc} + 0{,}8 \cdot F_w) \cdot S}{I \cdot t} \cdot 10$$

where:

F_{sf} = still water shear force, in kN, in the flooded conditions for the section under consideration

F_W = wave shear force, in kN, as given in UR S11.2.2.2 for the section under consideration

f_{sfc} = still water shear force correction factor for loading condition with empty holds, to be determined at the discretion of each Classification Society

I, S = as defined in UR S11.4.2(i)

t = thickness of plating, in mm.

S17.5 - Strength criteria

The damaged structure is assumed to remain fully effective in resisting the applied loading.

Permissible stress and axial stress buckling strength are to be in accordance with UR S11.

END

S18
(1997)
(Rev. 1 1997)
(Rev. 1.1 March, 1998)/ Corr.1)
(Rev.2 Sept. 2000)
(Rev.3 Feb. 2001)
(Rev.4 Nov. 2001)
(Rev.5 July 2003)
(Rev.6 July 2004)

Evaluation of Scantlings of Corrugated Transverse Watertight Bulkheads in Bulk Carriers Considering Hold Flooding

S18.1 - Application and definitions

These requirements are to be complied with in respect of the flooding of any carego hold of bulk carriers of 150 m in length and above, with single deck, topside tanks and hopper tanks, intending to carry solid bulk cargoes having a density of 1,0 t/m^3, or above, with vertically corrugated transverse watertight bulkheads, which are contracted for construction on or after 1 July 1998, except as stipulated below:

(i) Cargo holds of double side skin construction in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 July 1999,

(ii) Cargo holds of double side skin construction of not less than 760 mm breadth at any location within the hold length, measured perpendicular to the side shell in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 January 2000,

(iii) Cargo holds of double side skin construction of not less than 1,000 mm breadth at any location within the hold length, measured perpendicular to the side shell in ships, the keels of which are laid, or which are at a similar stage of construction, on or after 1 January 2000,

The net thickness t_{net} is the thickness obtained by applying the strength criteria given in S18.4.

The required thickness is obtained by adding the corrosion addition t_s, given in S18.6, to the net thickness t_{net}.

In this requirement, homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for each hold, does not exceed 1,20, to be corrected for different cargo densities.

S18.2 - Load model

S18.2.1 - General

The loads to be considered as acting on the bulkheads are those given by the combination of the cargo loads with those induced by the flooding of one hold adjacent to the bulkhead under examination. In any case, the pressure due to the flooding water alone is to be considered.

The most severe combinations of cargo induced loads and flooding loads are to be used for the check of the scantlings of each bulkhead, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions;
- non homogeneous loading conditions;

considering the individual flooding of both loaded and empty holds.

The specified design load limits for the cargo holds are to be represented by loading conditions defined by the Designer in the loading manual.

Notes: 1. A change introduced in revision 1.1 1998 of UR S18, i.e. in the last paragraph of S18.2.1 is to be applied to all ships applicable under S18.1
2. Changes introduced in Rev.2 are to be uniformly implemented by IACS Members and Associates from 1 July 2001.
3. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.

S18
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Non homogeneous part loading conditions associated with multiport loading and unloading operations for homogeneous loading conditions need not to be considered according to these requirements.

Holds carrying packed cargoes are to be considered as empty holds for this application.

Unless the ship is intended to carry, in non homogeneous conditions, only iron ore or cargo having bulk density equal or greater than 1,78 t/m^3, the maximum mass of cargo which may be carried in the hold shall also be considered to fill that hold up to the upper deck level ***at centreline***.

S18.2.2 - Bulkhead corrugation flooding head

The flooding head h_f (see Figure 1) is the distance, in m, measured vertically with the ship in the upright position, from the calculation point to a level located at a distance d_f, in m, from the baseline equal to:

a) in general:

- D for the foremost transverse corrugated bulkhead
- $0{,}9 \cdot D$ for the other bulkheads

Where the ship is to carry cargoes having bulk density less than 1,78 t/m^3 in non homogeneous loading conditions, the following values can be assumed:

- $0{,}95 \cdot D$ for the foremost transverse corrugated bulkhead
- $0{,}85 \cdot D$ for the other bulkheads

b) for ships less than 50,000 tonnes deadweight with Type B freeboard:

- $0{,}95 \cdot D$ for the foremost transverse corrugated bulkhead
- $0{,}85 \cdot D$ for the other bulkheads

Where the ship is to carry cargoes having bulk density less than 1,78 t/m^3 in non homogeneous loading conditions, the following values can be assumed:

- $0{,}9 \cdot D$ for the foremost transverse corrugated bulkhead
- $0{,}8 \cdot D$ for the other bulkheads

D being the distance, in m, from the baseline to the freeboard deck at side amidship (see Figure 1).

S18.2.3 - Pressure in the non-flooded bulk cargo loaded holds

At each point of the bulkhead, the pressure p_c, in kN/m^2, is given by:

$$p_c = \rho_c \cdot g \cdot h_1 \cdot \tan^2 \gamma$$

where:

ρ_c = bulk cargo density, in t/m^3

g = 9,81 m/s^2, gravity acceleration

h_1 = vertical distance, in m, from the calculation point to horizontal plane corresponding to the level height of the cargo (see Figure 1), located at a distance d_1, in m, from the baseline.

S18
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γ = 45° -(φ/2)

φ = angle of repose of the cargo, in degrees, that may generally be taken as 35° for iron ore and 25° for cement

The force F_c, in kN, acting on a corrugation is given by:

$$F_c = \rho_c \cdot g \cdot s_1 \cdot \frac{(d_1 - h_{DB} - h_{LS})^2}{2} \cdot \tan^2 \gamma$$

where:

ρ_c, g, d_1, γ = as given above

s_1 = spacing of corrugations, in m (see Figure 2a)

h_{LS} = mean height of the lower stool, in m, from the inner bottom.

h_{DB} = height of the double bottom, in m

S18.2.4 - Pressure in the flooded holds

S18.2.4.1 - Bulk cargo holds

Two cases are to be considered, depending on the values of d_1 and d_f.

a) $d_f \geq d_1$

At each point of the bulkhead located at a distance between d_1 and d_f from the baseline, the pressure $p_{c,f}$, in kN/m^2, is given by:

$$p_{c,f} = \rho \cdot g \cdot h_f$$

where:

ρ = sea water density, in t/m^3

g = as given in S18.2.3

h_f = flooding head as defined in S18.2.2.

At each point of the bulkhead located at a distance lower than d1 from the baseline, the pressure $p_{c,f}$, in kN/m^2, is given by:

$$p_{c,f} = \rho \cdot g \cdot h_f + [\rho_c - \rho \cdot (1 - perm)] \cdot g \cdot h_1 \cdot \tan^2 \gamma$$

where:

ρ, h_f = as given above

ρ_c, g, h_1, γ = as given in S18.2.3

perm = permeability of cargo, to be taken as 0,3 for ore (corresponding bulk cargo density for iron ore may generally be taken as 3,0 t/m^3), coal cargoes and for cement (corresponding bulk cargo density for cement may generally be taken as 1,3 t/m^3)

S18
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The force $F_{c,f}$, in kN, acting on a corrugation is given by:

$$F_{c,f} = s_1 \cdot \left[\rho \cdot g \cdot \frac{(d_f - d_1)^2}{2} + \frac{\rho \cdot g \cdot (d_f - d_1) + (p_{c,f})_{le}}{2} \cdot (d_1 - h_{DB} - h_{LS}) \right]$$

where:

ρ	=	as given above
s_1, g, d_1, h_{DB}, h_{LS}	=	as given in S18.2.3
d_f	=	as given in S18.2.2
$(p_{c,f})_{le}$	=	pressure, in kN/m^2, at the lower end of the corrugation.

b) $d_f < d_1$

At each point of the bulkhead located at a distance between d_f and d_1 from the baseline, the pressure $p_{c,f}$, in kN/m^2, is given by:

$$p_{c,f} = \rho_c \cdot g \cdot h_1 \cdot \tan^2 \gamma$$

where:

ρ_c, g, h_1, γ = as given in S18.2.3.

At each point of the bulkhead located at a distance lower than d_f from the baseline, the pressure $p_{c,f}$, in kN/m^2, is given by:

$$p_{c,f} = \rho \cdot g \cdot h_f + \left[\rho_c \cdot h_1 - \rho \cdot (1 - perm) \cdot h_f \right] \cdot g \cdot \tan^2 \gamma$$

where:

ρ, h_f, perm = as given in a) above

ρ_c, g, h_1, γ = as given in S18.2.3

$$F_{c,f} = s_1 \cdot \left[\rho_c \cdot g \cdot \frac{(d_1 - d_f)^2}{2} \cdot \tan^2 \gamma + \frac{\rho_c \cdot g \cdot (d_1 - d_f) \cdot \tan^2 \gamma + (p_{c,f})_{le}}{2} \cdot (d_f - h_{DB} - h_{LS}) \right]$$

The force $F_{c,f}$, in kN, acting on a corrugation is given by:
where:

s_1, ρ_c, g, d_1, γ, h_{DB}, h_{LS} = as given in S18.2.3

d_f = as given in S18.2.2

S18
cont'd

$(p_{c,f})_{le}$ = pressure, in kN/m^2, at the lower end of the corrugation.

S18.2.4.2 - Pressure in empty holds due to flooding water alone

At each point of the bulkhead, the hydrostatic pressure pf induced by the flooding head h_f is to be considered.

The force F_f, in kN, acting on a corrugation is given by:

$$F_f = s_1 \cdot \rho \cdot g \cdot \frac{(d_f - h_{DB} - h_{LS})^2}{2}$$

where:

s_1, g, h_{DB}, h_{LS}	=	as given in S18.2.3
ρ	=	as given in S18.2.4.1 a)
d_f	=	as given in S18.2.2.

S18.2.5 - Resultant pressure and force

S18.2.5.1 - Homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure p, in kN/m^2, to be considered for the scantlings of the bulkhead is given by:

$$p = p_{c,f} - 0.8 \cdot p_c$$

The resultant force F, in kN, acting on a corrugation is given by:

$$F = F_{c,f} - 0.8 \cdot F_c$$

S18.2.5.2 - Non homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure p, in kN/m^2, to be considered for the scantlings of the bulkhead is given by:

$$p = p_{c,f}$$

The resultant force F, in kN, acting on a corrugation is given by:

$$F = F_{c,f}$$

S18.3 - Bending moment and shear force in the bulkhead corrugations

The bending moment M and the shear force Q in the bulkhead corrugations are obtained using the formulae given in S18.3.1 and S18.3.2. The M and Q values are to be used for the checks in S18.4.5.

S18.3.1 - Bending moment

The design bending moment M, in kN·m, for the bulkhead corrugations is given by:

S18
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$$M = \frac{F \cdot \ell}{8}$$

where:

F = resultant force, in kN, as given in S18.2.5

ℓ = span of the corrugation, in m, to be taken according to Figures 2a and 2b

S18.3.2 - Shear force

The shear force Q, in kN, at the lower end of the bulkhead corrugations is given by:

$$Q = 0{,}8 \cdot F$$

where:

F = as given in S18.2.5

S18.4 - Strength criteria

S18.4.1 - General

The following criteria are applicable to transverse bulkheads with vertical corrugations (see Figure 2). For ships of 190 m of length and above, these bulkheads are to be fitted with a lower stool, and generally with an upper stool below deck. For smaller ships, corrugations may extend from inner bottom to deck; if the stool is fitted, it is to comply with the requirements in S18.4.1.

The corrugation angle φ shown in Figure 2a is not to be less than 55°.

Requirements for local net plate thickness are given in S18.4.7.

In addition, the criteria as given in S18.4.2 and S18.4.5 are to be complied with.

The thicknesses of the lower part of corrugations considered in the application of S18.4.2 and S18.4.3 are to be maintained for a distance from the inner bottom (if no lower stool is fitted) or the top of the lower stool not less than 0,15·l.

The thicknesses of the middle part of corrugations as considered in the application of S18.4.2 and S18.4.4 are to be maintained to a distance from the deck (if no upper stool is fitted) or the bottom of the upper stool not greater than 0,3·l.
The section modulus of the corrugation in the remaining upper part of the bulkhead is not to be less than 75% of that required for the middle part, corrected for different yield stresses.

(a) - Lower stool

The height of the lower stool is generally to be not less than 3 times the depth of the corrugations. The thickness and material of the stool top plate is not to be less than those required for the bulkhead plating above. The thickness and material of the upper portion of vertical or sloping stool side plating within the depth equal to the corrugation flange width from the stool top is not to be less than the required flange plate thickness and material to meet the bulkhead stiffness requirement at lower end of corrugation. The thickness of the stool side plating and the section modulus of the stool side stiffeners is not to be less than those required by each Society on the basis of the load model in S18.2. The ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool.

S18
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The distance from the edge of the stool top plate to the surface of the corrugation flange is to be in accordance with Figure 5. The stool bottom is to be installed in line with double bottom floors and is to have a width not less than 2,5 times the mean depth of the corrugation. The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders for effective support of the corrugated bulkhead. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

Where corrugations are cut at the lower stool, corrugated bulkhead plating is to be connected to the stool top plate by full penetration welds. The stool side plating is to be connected to the stool top plate and the inner bottom plating by either full penetration or deep penetration welds (see Figure 6). The supporting floors are to be connected to the inner bottom by either full penetration or deep penetration welds (see Figure 6).

(b) - Upper stool

The upper stool, where fitted, is to have a height generally between 2 and 3 times the depth of corrugations. Rectangular stools are to have a height generally equal to 2 times the depth of corrugations, measured from the deck level and at hatch side girder. The upper stool is to be properly supported by girders or deep brackets between the adjacent hatch-end beams.

The width of the stool bottom plate is generally to be the same as that of the lower stool top plate. The stool top of non rectangular stools is to have a width not less then 2 times the depth of corrugations. The thickness and material of the stool bottom plate are to be the same as those of the bulkhead plating below. The thickness of the lower portion of stool side plating is not to be less than 80% of that required for the upper part of the bulkhead plating where the same material is used. The thickness of the stool side plating and the section modulus of the stool side stiffeners is not to be less than those required by each Society on the basis of the load model in S18.2. The ends of stool side stiffeners are to be attached to brackets at upper and lower end of the stool. Diaphragms are to be fitted inside the stool in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders for effective support of the corrugated bulkhead. Scallops in the brackets and diaphragms in way of the connection to the stool bottom plate are to be avoided.

(c) - Alignment

At deck, if no stool is fitted, two transverse reinforced beams are to be fitted in line with the corrugation flanges.

At bottom, if no stool is fitted, the corrugation flanges are to be in line with the supporting floors.
Corrugated bulkhead plating is to be connected to the inner bottom plating by full penetration welds. The plating of supporting floors is to be connected to the inner bottom by either full penetration or deep penetration welds (see Figure 6).
The thickness and material properties of the supporting floors are to be at least equal to those provided for the corrugation flanges. Moreover, the cut-outs for connections of the inner bottom longitudinals to double bottom floors are to be closed by collar plates. The supporting floors are to be connected to each other by suitably designed shear plates, as deemed appropriate by the Classification Society.

Stool side plating is to align with the corrugation flanges and stool side vertical stiffeners and their brackets in lower stool are to align with the inner bottom longitudinals to provide appropriate load transmission between these stiffening members. Stool side plating is not to be knuckled anywhere between the inner bottom plating and the stool top.

S18.4.2 - Bending capacity and shear stress τ

The bending capacity is to comply with the following relationship:

$$10^3 \cdot \frac{M}{0,5 \cdot Z_{le} \cdot \sigma_{a,le} + Z_m \cdot \sigma_{a,m}} \le 0,95$$

where:

M = bending moment, in kN·m, as given in S18.3.1

Z_{le} = section modulus of one half pitch corrugation, in cm^3, at the lower end of corrugations, to be

S18
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calculated according to S18.4.3.

Z_m = section modulus of one half pitch corrugation, in cm^3, at the mid-span of corrugations, to be calculated according to S18.4.4.

$\sigma_{a,le}$ = allowable stress, in N/mm^2, as given in S18.4.5, for the lower end of corrugations

$\sigma_{a,m}$ = allowable stress, in N/mm^2, as given in S18.4.5, for the mid-span of corrugations

In no case Z_m is to be taken greater than the lesser of $1{,}15 \cdot Z_{le}$ and $1{,}15 \cdot Z'_{le}$ for calculation of the bending capacity, Z'_{le} being defined below.

In case shedders plates are fitted which:

- are not knuckled;
- are welded to the corrugations and the top of the lower stool by one side penetration welds or equivalent;
- are fitted with a minimum slope of 45° and their lower edge is in line with the stool side plating;
- have thicknesses not less than 75% of that provided by the corrugation flange;
- and material properties at least equal to those provided by the flanges.

or gusset plates are fitted which:

- are in combination with shedder plates having thickness, material properties and welded connections in accordance with the above requirements;
- have a height not less than half of the flange width;
- are fitted in line with the stool side plating;
- are generally welded to the top of the lower stool by full penetration welds, and to the corrugations and shedder plates by one side penetration welds or equivalent.
- have thickness and material properties at least equal to those provided for the flanges.

the section modulus Z_{le}, in cm^3, is to be taken not larger than the value Z'_{le}, in cm^3, given by:

$$Z'_{le} = Z_g + 10^3 \cdot \frac{Q \cdot h_g - 0{,}5 \cdot h_g^2 \cdot s_1 \cdot p_g}{\sigma_a}$$

where:

Z_g = section modulus of one half pitch corrugation, in cm^3, of the corrugations calculated, according to S18.4.4, in way of the upper end of shedder or gusset plates, as applicable

Q = shear force, in kN, as given in S18.3.2

h_g = height, in m, of shedders or gusset plates, as applicable (see Figures 3a, 3b, 4a and 4b)

s_1 = as given in S18.2.3

p_g = resultant pressure, in kN/m^2, as defined in S18.2.5, calculated in way of the middle of the shedders or gusset plates, as applicable

S18
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σ_a = allowable stress, in N/mm^2, as given in S18.4.5.

Stresses τ are obtained by dividing the shear force Q by the shear area. The shear area is to be reduced in order to account for possible non-perpendicularity between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by (sin φ), φ being the angle between the web and the flange.

When calculating the section modulus and the shear area, the net plate thicknesses are to be used.

The section modulus of corrugations are to be calculated on the basis of the following requirements given in S18.4.3 and S18.4.4.

S18.4.3 - Section modulus at the lower end of corrugations

The section modulus is to be calculated with the compression flange having an effective flange width, b_{ef}, not larger than as given in S18.4.6.

If the corrugation webs are not supported by local brackets below the stool top (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

a) Provided that effective shedder plates, as defined in S18.4.2, are fitted (see Figures 3a and 3b), when calculating the section modulus of corrugations at the lower end (cross-section ① in Figures 3a and 3b), the area of flange plates, in cm^2, may be increased by :

$\left(2{,}5 \cdot a \cdot \sqrt{t_f \cdot t_{sh}}\right)$ (not to be taken greater than $2{,}5 \cdot a \cdot t_f$) where:

a = width, in m, of the corrugation flange (see Figure 2a)

t_{sh} = net shedder plate thickness, in mm

t_f = net flange thickness, in mm

b) Provided that effective gusset plates, as defined in S18.4.2, are fitted (see Figures 4a and 4b), when calculating the section modulus of corrugations at the lower end (cross-section ① in Figures 4a and 4b), the area of flange plates, in cm^2, may be increased by ($7 \cdot h_g \cdot t_f$) where:

h_g = height of gusset plate in m, see Figures 4a and 4b, not to be taken greater than

$$\left(\frac{10}{7} \cdot s_{gu}\right)$$

s_{gu} = width of the gusset plates, in m

t_f = net flange thickness, in mm, based on the as built condition.

c) If the corrugation webs are welded to a sloping stool top plate which have an angle not less than 45º with the horizontal plane, the section modulus of the corrugations may be calculated considering the corrugation webs fully effective. In case effective gusset plates are fitted, when calculating the section modulus of corrugations the area of flange plates may be increased as specified in b) above. No credit can be given to shedder plates only.

For angles less than 45º, the effectiveness of the web may be obtained by linear interporation between 30% for 0º and 100% for 45º.

S18
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S18.4.4 - Section modulus of corrugations at cross-sections other than the lower end

The section modulus is to be calculated with the corrugation webs considered effective and the compression flange having an effective flange width, b_{ef}, not larger than as given in S18.4.6.1.

S18.4.5 - Allowable stress check

The normal and shear stresses σ and τ are not to exceed the allowable values σ_a and τ_a, in N/mm^2, given by:

$$\sigma a = \sigma_F$$

$$\tau a = 0{,}5\sigma_F$$

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

S18.4.6 - Effective compression flange width and shear buckling check

S18.4.6.1 - Effective width of the compression flange of corrugations

The effective width b_{ef}, in m, of the corrugation flange is given by:

$$b_{ef} = C_e \cdot a$$

where:

$$C_e = \frac{2{,}25}{\beta} - \frac{1{,}25}{\beta^2} \quad \text{for } \beta > 1{,}25$$

$$C_e = 1{,}0 \quad \text{for } \beta \leq 1{,}25$$

$$\beta = 10^3 \cdot \frac{a}{t_f} \cdot \sqrt{\frac{\sigma_F}{E}}$$

t_f = net flange thickness, in mm

a = width, in m, of the corrugation flange (see Figure 2a)

σ_F = minimum upper yield stress, in N/mm^2, of the material

E = modulus of elasticity of the material, in N/mm^2, to be assumed equal to $2{,}06 \cdot 10^5$ for steel.

S18.4.6.2 - Shear

The buckling check is to be performed for the web plates at the corrugation ends.

The shear stress τ is not to exceed the critical value τ_c, in N/mm^2 obtained by the following:

S18
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$$\tau_C = \tau_E \qquad \text{when } \tau_E \le \frac{\tau_F}{2}$$

$$= \tau_F\left(1 - \frac{\tau_F}{4\tau_E}\right) \qquad \text{when } \tau_E > \frac{\tau_F}{2}$$

where:

$$\tau_F = \frac{\sigma_F}{\sqrt{3}}$$

σ_F = minimum upper yield stress, in N/mm^2, of the material

$$\tau_E = 0.9 k_t E\left(\frac{t}{1000c}\right)^2 \qquad (\text{N/mm}^2)$$

k_t, E, t and c are given by:

k_t = 6.34

E = modulus of elasticity of material as given in S18.4.6.1

t = net thickness, in mm, of corrugation web

c = width, in m, of corrugation web (See Figure 2a)

S18.4.7 - Local net plate thickness

The bulkhead local net plate thickness t, in mm, is given by:

$$t = 14{,}9 \cdot s_w \cdot \sqrt{\frac{1{,}05 \cdot p}{\sigma_F}}$$

where:

s_w = plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is the greater (see Figure 2a)

p = resultant pressure, in kN/m^2, as defined in S18.2.5, at the bottom of each strake of plating; in all cases, the net thickness of the lowest strake is to be determined using the resultant pressure at the top of the lower stool, or at the inner bottom, if no lower stool is fitted or at the top of shedders, if shedder or gusset/shedder plates are fitted.

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

For built-up corrugation bulkheads, when the thicknesses of the flange and web are different, the net thickness of the narrower plating is to be not less than t_n, in mm, given by:

$$t_n = 14{,}9 \cdot s_n \cdot \sqrt{\frac{1{,}05 \cdot p}{\sigma_F}}$$

s_n being the width, in m, of the narrower plating.

The net thickness of the wider plating, in mm, is not to be taken less than the maximum of the following

S18
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$$t_w = 14{,}9 \cdot s_w \cdot \sqrt{\frac{1{,}05 \cdot p}{\sigma_F}}$$

and

$$t_w = \sqrt{\frac{440 \cdot s_w^2 \cdot 1{,}05 \cdot p}{\sigma_F} - t_{np}^2}$$

where $t_{np} \le$ actual net thickness of the narrower plating and not to be greater than

$$14{,}9 \cdot s_w \cdot \sqrt{\frac{1{,}05 \cdot p}{\sigma_F}}$$

S18.5 - Local details

As applicable, the design of local details is to comply with the Society requirements for the purpose of transferring the corrugated bulkhead forces and moments to the boundary structures, in particular to the double bottom and cross-deck structures.

In particular, the thickness and stiffening of effective gusset and shedder plates, as defined in S18.4.3, is to comply with the Society requirements, on the basis of the load model in S18.2.

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the Society requirements.

S18.6 - Corrosion addition and steel renewal

The corrosion addition t_s is to be taken equal to 3,5 mm.

Steel renewal is required where the gauged thickness is less than t_{net} + 0,5 mm.

Where the gauged thickness is within the range t_{net} + 0,5 mm and t_{net} + 1,0 mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal.

S18
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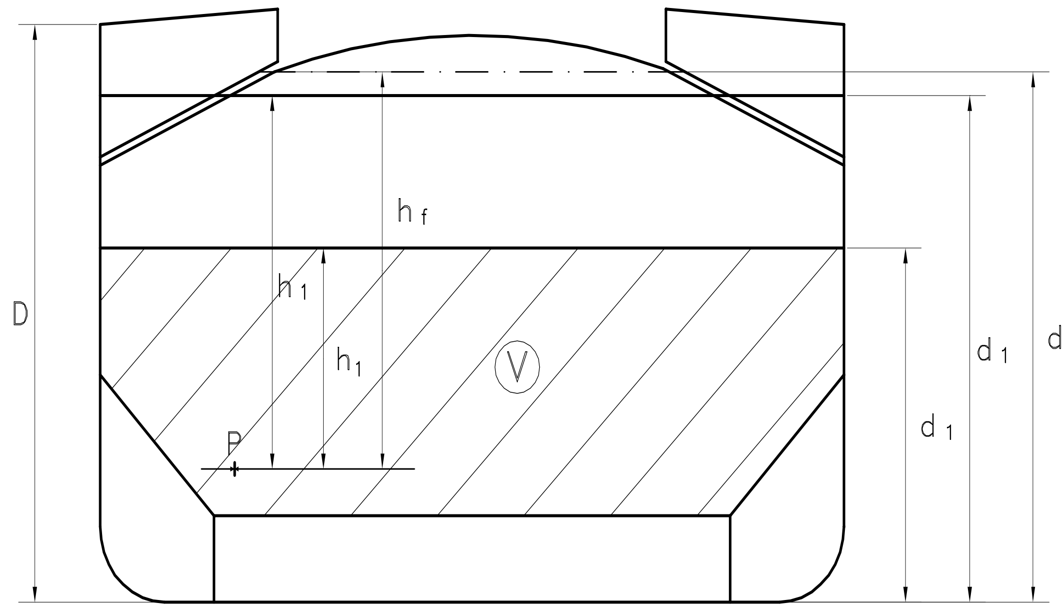
Figure 1



V = Volume of cargo

P = Calculation point

S18
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Figure 2a

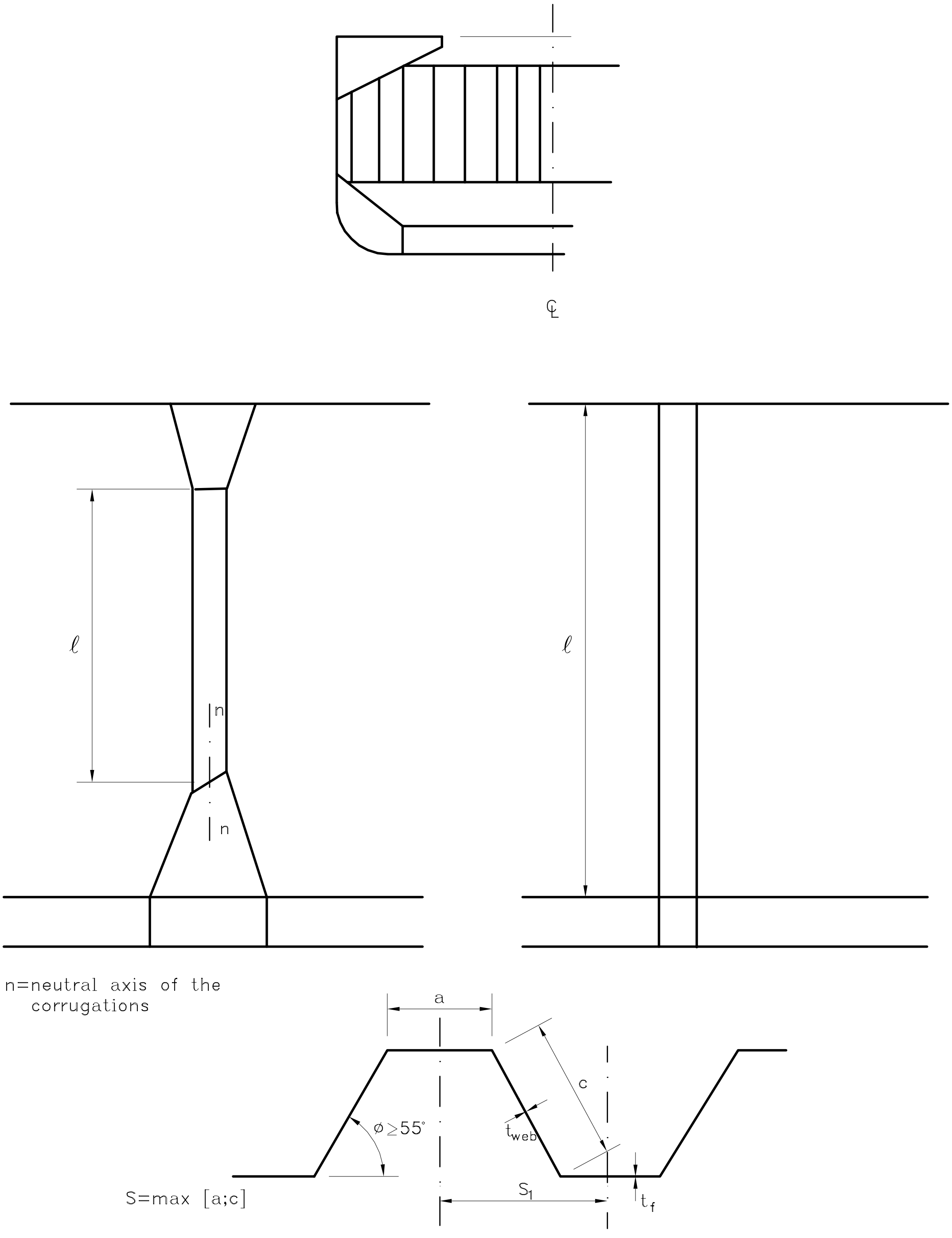

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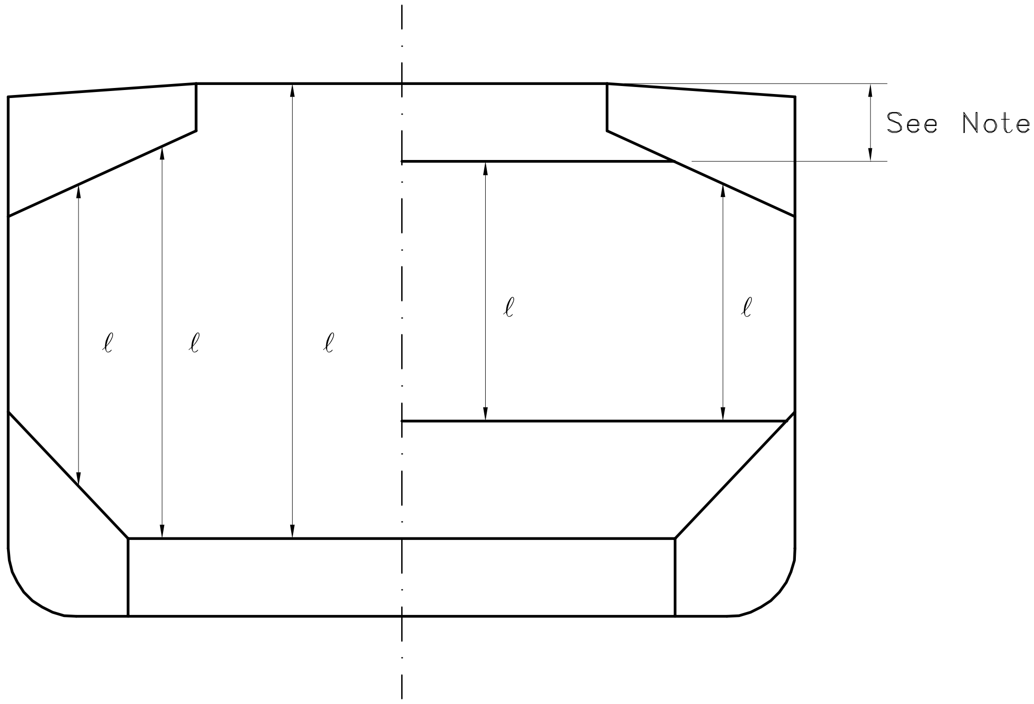
Figure 2b



Note For the definition of ℓ, the internal end of the upper stool is not to be taken more than a distance from the deck at the centre line equal to:
- 3 times the depth of corrugations, in general
- 2 times the depth of corrugations, for rectangular stool

S18
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Figure 3a
Symmetric shedder plates

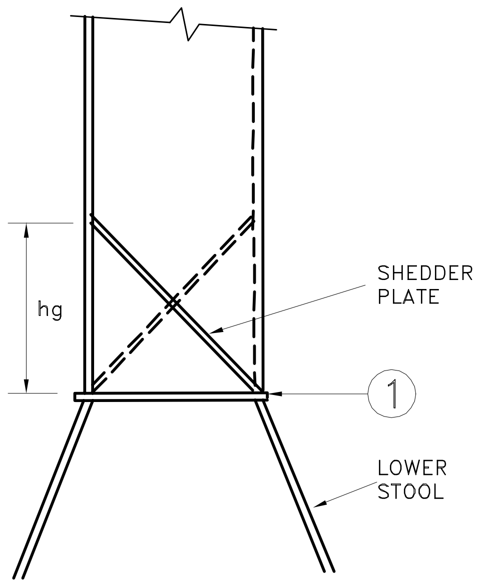

Figure 3b
Asymmetric shedder plates

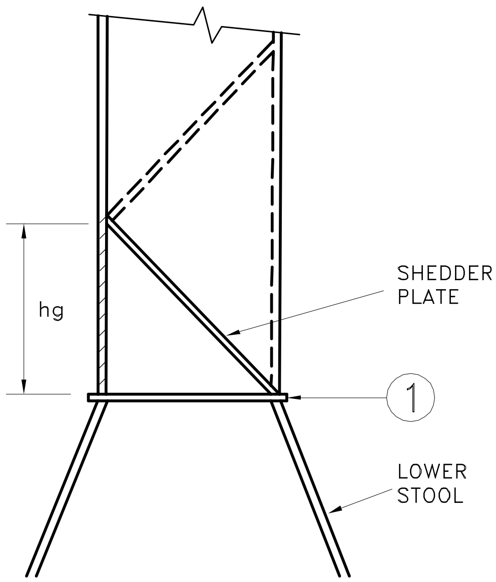

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Figure 4a
Symmetric gusset / shedder plates

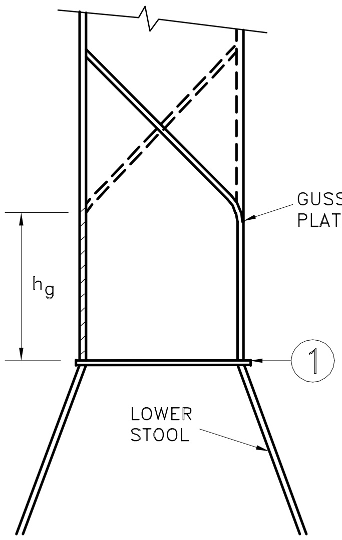

Figure 4b
Asymmetric gusset / shedder plates

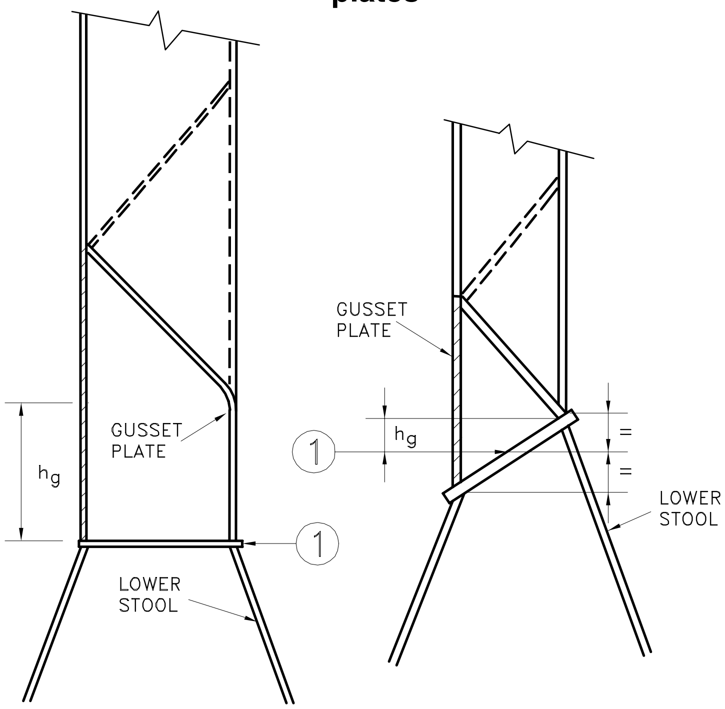

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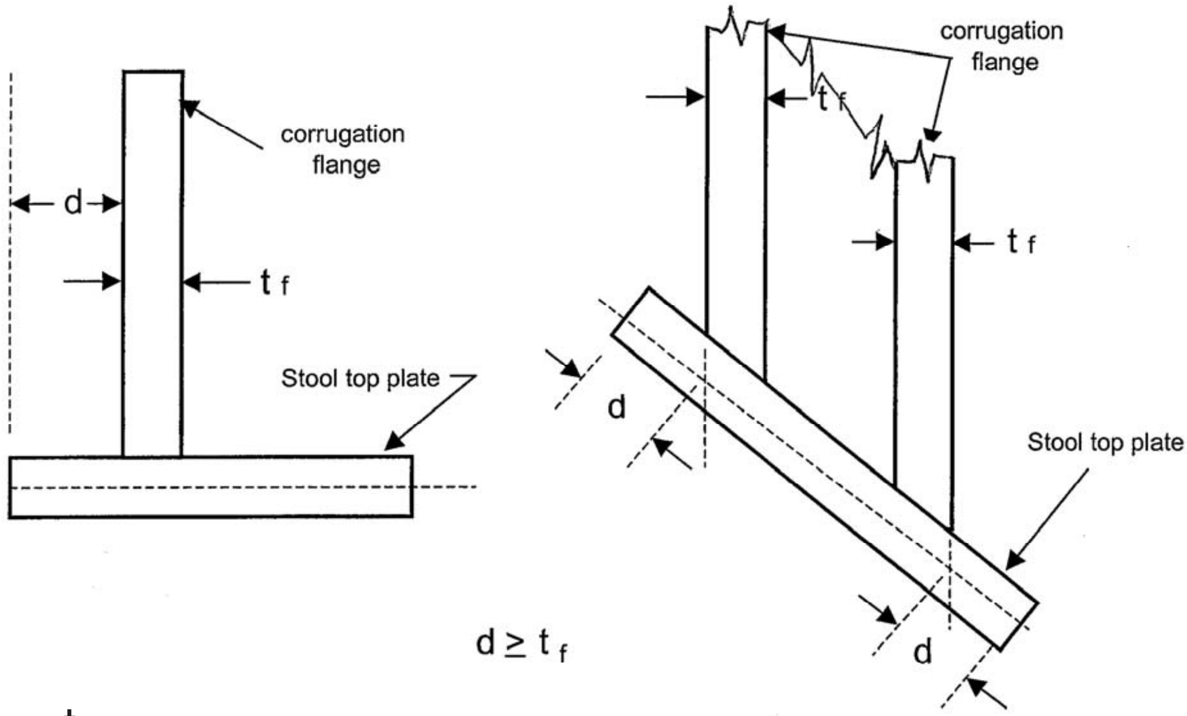
Figure.5 Permitted distance, d, from edge of stool top plate to surface of corrugation flange



* t f : As-Built Flange Thickness

S18
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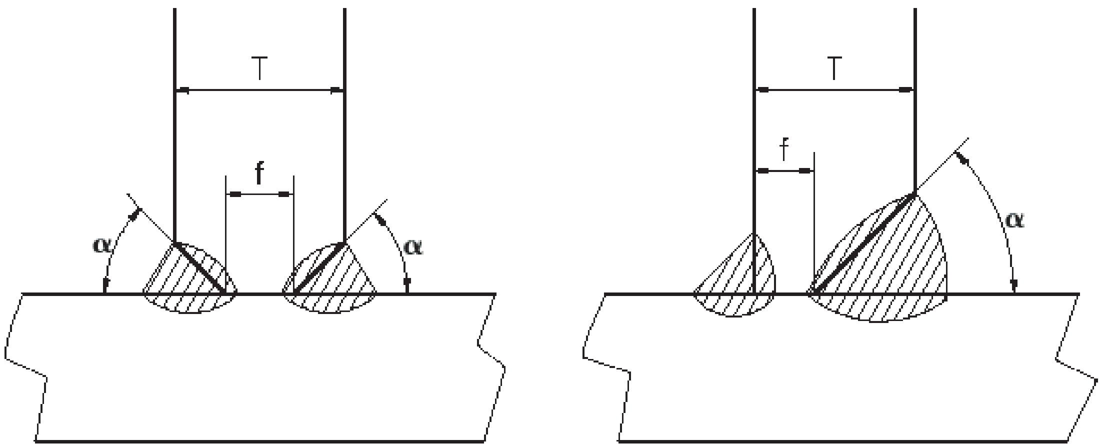
Figure.6



Root Face (f):	3 mm to T/3 mm
Groove Angle (**α**):	40^o to 60^o

END

S19
(1997)
(Rev. 1
1997)
(Rev. 2
Feb. 1998)
(Rev.3
Jun. 1998)
(Rev.4
Sept. 2000)
(Rev.5
July 2004)

Evaluation of Scantlings of the Transverse Watertight Corrugated Bulkhead between Cargo Holds Nos. 1 and 2, with Cargo Hold No. 1 Flooded, for Existing Bulk Carriers

S19.1 - Application and definitions

These requirements apply to all bulk carriers of 150 m in length and above, in the foremost hold, intending to carry solid bulk cargoes having a density of 1,78 t/m^3, or above, with single deck, topside tanks and hopper tanks, fitted with vertically corrugated transverse watertight bulkheads between cargo holds No. 1 and 2 where:

(i) the foremost hold is bounded by the side shell only for ships which were contracted for construction prior to 1 July 1998, and have not been constructed in compliance with IACS Unified Requirement S18,

(ii) the foremost hold is double side skin construction of less than 760 mm breadth measured perpendicular to the side shell in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 July 1999 and have not been constructed in compliance with IACS Unified Requirement S18 (Rev. 2, Sept. 2000).

The net scantlings of the transverse bulkhead between cargo holds Nos. 1 and 2 are to be calculated using the loads given in S19.2, the bending moment and shear force given in S19.3 and the strength criteria given in S19.4.

Where necessary, steel renewal and/or reinforcements are required as per S19.6.

In these requirements, homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for the two foremost cargo holds, does not exceed 1,20, to be corrected for different cargo densities.

S19.2 - Load model

S19.2.1 - General

The loads to be considered as acting on the bulkhead are those given by the combination of the cargo loads with those induced by the flooding of cargo hold No.1.

The most severe combinations of cargo induced loads and flooding loads are to be used for the check of the scantlings of the bulkhead, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions;
- non homogeneous loading conditions.

Non homogeneous part loading conditions associated with multiport loading and unloading operations for homogeneous loading conditions need not to be considered according to these requirements.

Notes:

1. Changes introduced in Revision 2 to UR S19, i.e. the introduction of the first sentence of S19.6 as well as the Annex are to be applied by all Member societies and Associates not later than 1 July 1998.
2. Annex 2 contains, for guidance only, a flow chart entitled “Guidance to assess capability of Carriage of High Density Cargoes on Existing Bulk Carriers according to the Strength of Transverse Bulkhead between Cargo Holds Nos. 1 and 2”.
3. Changes introduced in Rev.4 are to be uniformly implemented by IACS Members and Associates from 1 July 2001.
4. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.

S19
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S19.2.2 - Bulkhead corrugation flooding head

The flooding head h_f (see Figure 1) is the distance, in m, measured vertically with the ship in the upright position, from the calculation point to a level located at a distance d_f, in m, from the baseline equal to:

a) in general:

- D

b) for ships less than 50,000 tonnes deadweight with Type B freeboard:

- $0{,}95 \cdot D$

D being the distance, in m, from the baseline to the freeboard deck at side amidship (see Figure 1).

c) for ships to be operated at an assigned load line draught T_r less than the permissible load line draught T, the flooding head defined in a) and b) above may be reduced by $T - T_r$.

S19.2.3 - Pressure in the flooded hold

S19.2.3.1 - Bulk cargo loaded hold

Two cases are to be considered, depending on the values of d1 and df, d1 (see Figure 1) being a distance from the baseline given, in m, by:

$$d_1 = \frac{M_c}{\rho_c \cdot l_c \cdot B} + \frac{V_{LS}}{l_c \cdot B} + \left(h_{HT} - h_{DB}\right) \cdot \frac{b_{HT}}{B} + h_{DB}$$

where:

M_c = mass of cargo, in tonnes, in hold No. 1

ρ_c = bulk cargo density, in t/m^3

l_c = length of hold No. 1, in m

B = ship's breadth amidship, in m

v_{LS} = volume, in m^3, of the bottom stool above the inner bottom

h_{HT} = height of the hopper tanks amidship, in m, from the baseline

h_{DB} = height of the double bottom, in m

b_{HT} = breadth of the hopper tanks amidship, in m.

S19
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a) $d_f \geq d_1$

At each point of the bulkhead located at a distance between d_1 and d_f from the baseline, the pressure $p_{c,f}$, in kN/m^2, is given by:

$$p_{c,f} = \rho \cdot g \cdot h_f$$

where:

ρ = sea water density, in t/m^3

g = 9,81 m/s^2, gravity acceleration

h_f = flooding head as defined in S19.2.2.

At each point of the bulkhead located at a distance lower than d_1 from the baseline, the pressure $p_{c,f}$, in kN/m^2, is given by:

$$p_{c,f} = \rho \cdot g \cdot h_f + [\rho_c - \rho \cdot (1 - \text{perm})] \cdot g \cdot h_1 \cdot \tan^2 \gamma$$

where:

ρ, g, h_f = as given above

ρ_c = bulk cargo density, in t/m^3

perm = permeability of cargo, to be taken as 0,3 for ore (corresponding bulk cargo density for iron ore may generally be taken as 3,0 t/m^3),

h_1 = vertical distance, in m, from the calculation point to a level located at a distance d_1, as defined above, from the base line (see Figure 1)

γ = 45° -(ϕ/2)

ϕ = angle of repose of the cargo, in degrees, and may generally be taken as 35° for iron ore.

The force $F_{c,f}$, in kN, acting on a corrugation is given by:

$$F_{c,f} = s_1 \cdot \left(\rho \cdot g \cdot \frac{(d_f - d_1)^2}{2} + \frac{\rho \cdot g \cdot (d_f - d_1) + (p_{c,f})_{le}}{2} \cdot (d_1 - h_{DB} - h_{LS}) \right)$$

S19
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where:

s_1	=	spacing of corrugations, in m (see Figure 2a)
ρ, g, d_1, h_{DB}	=	as given above
d_f	=	as given in S19.2.2
$(p_{c,f})_{le}$	=	pressure, in kN/m^2, at the lower end of the corrugation
h_{LS}	=	height of the lower stool, in m, from the inner bottom.

b) $d_f < d_1$

At each point of the bulkhead located at a distance between d_f and d_1 from the baseline, the pressure $p_{c,f}$, in kN/m^2, is given by:

$$p_{c,f} = \rho_c \cdot g \cdot h_1 \cdot \tan^2 \gamma$$

where:

ρ_c, g, h_1, γ = as given in a) above

At each point of the bulkhead located at a distance lower than d_f from the baseline, the pressure $p_{c,f}$, in kN/m^2, is given by:

$$p_{c,f} = \rho \cdot g \cdot h_f + \left[\rho_c \cdot h_1 - \rho \cdot (1 - perm) \cdot h_f\right] \cdot g \cdot \tan^2 \gamma$$

where:

ρ, g, h_f, ρ_c, h_1, perm, γ = as given in a) above

The force $F_{c,f}$, in kN, acting on a corrugation is given by:

$$F_{c,f} = s_1 \cdot \left(\rho_c \cdot g \cdot \frac{(d_1 - d_f)^2}{2} \cdot \tan^2 \gamma + \frac{\rho_c \cdot g \cdot (d_1 - d_f) \cdot \tan^2 \gamma + (p_{c,f})_{le}}{2} \cdot (d_f - h_{DB} - h_{LS}) \right)$$

where:

s_1, ρ_c, g, γ, $(p_{c,f})_{le}$, h_{LS}	=	as given in a) above
d_1, h_{DB}	=	as given in S19.2.3.1
d_f	=	as given in S19.2.2.

S19
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S19.2.3.2 - Empty hold

At each point of the bulkhead, the hydrostatic pressure p_f induced by the flooding head h_f is to be considered.

The force F_f, in kN, acting on a corrugation is given by:

$$F_f = s_1 \cdot \rho \cdot g \cdot \frac{\left(d_f - h_{DB} - h_{LS}\right)^2}{2}$$

where:

s_1, ρ, g, h_{LS}	=	as given in S19.2.3.1 a)
h_{DB}	=	as given in S19.2.3.1
d_f	=	as given in S19.2.2.

S19.2.4 - Pressure in the non-flooded bulk cargo loaded hold

At each point of the bulkhead, the pressure p_c, in kN/m^2, is given by:

$$p_c = \rho_c \cdot g \cdot h_1 \cdot \tan^2\gamma$$

where:

ρ_c, g, h_1, γ = as given in S19.2.3.1 a)

The force F_c, in kN, acting on a corrugation is given by:

$$F_c = \rho_c \cdot g \cdot s_1 \cdot \frac{\left(d_1 - h_{DB} - h_{LS}\right)^2}{2} \cdot \tan^2\gamma$$

where:

ρ_c, g, s_1, h_{LS}, γ	=	as given in S19.2.3.1 a)
d_1, h_{DB}	=	as given in S19.2.3.1

S19.2.5 - Resultant pressure

S19.2.5.1 - Homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure p, in kN/m^2, to be considered for the scantlings of the bulkhead is given by:

$$p = \rho_{c,f} - 0{,}8 \cdot \rho_c$$

S19
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The resultant force F, in kN, acting on a corrugation is given by:

$$F = F_{c,f} - 0{,}8 \cdot F_c$$

S19.2.5.2 - Non homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure p, in kN/m^2, to be considered for the scantlings of the bulkhead is given by:

$$p = \rho_{c,f}$$

The resultant force F, in kN, acting on a corrugation is given by:

$$F = F_{c,f}$$

In case hold No.1, in non homogeneous loading conditions, is not allowed to be loaded, the resultant pressure p, in kN/m^2, to be considered for the scantlings of the bulkhead is given by:

$$p = p_f$$

and the resultant force F, in kN, acting on a corrugation is given by:

$$F = F_f$$

S19.3 - Bending moment and shear force in the bulkhead corrugations

The bending moment M and the shear force Q in the bulkhead corrugations are obtained using the formulae given in S19.3.1 and S19.3.2. The M and Q values are to be used for the checks in S19.4.

S19.3.1 - Bending moment

The design bending moment M, in kN·m, for the bulkhead corrugations is given by:

$$M = \frac{F \cdot l}{8}$$

where:

F = resultant force, in kN, as given in S19.2.5

l = span of the corrugation, in m, to be taken according to Figures 2a and 2b

S19
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S19.3.2 - Shear force

The shear force Q, in kN, at the lower end of the bulkhead corrugations is given by:

$$Q = 0{,}8 \cdot F$$

where:

F = as given in S19.2.5

S19.4 - Strength criteria

S19.4.1 - General

The following criteria are applicable to transverse bulkheads with vertical corrugations (see Figure 2a).

Requirements for local net plate thickness are given in S19.4.7.

In addition, the criteria given in S19.4.2 and S19.4.5 are to be complied with.

Where the corrugation angle ϕ shown in Figure 2a if less than 50°, an horizontal row of staggered shedder plates is to be fitted at approximately mid depth of the corrugations (see Figure 2a) to help preserve dimensional stability of the bulkhead under flooding loads. The shedder plates are to be welded to the corrugations by double continuous welding, but they are not to be welded to the side shell.

The thicknesses of the lower part of corrugations considered in the application of S19.4.2 and S19.4.3 are to be maintained for a distance from the inner bottom (if no lower stool is fitted) or the top of the lower stool not less than 0,15·l.

The thicknesses of the middle part of corrugations considered in the application of S19.4.2 and S19.4.4 are to be maintained to a distance from the deck (if no upper stool is fitted) or the bottom of the upper stool not greater than 0,3·l.

S19.4.2 - Bending capacity and shear stress τ

The bending capacity is to comply with the following relationship:

$$10^3 \cdot \frac{M}{0{,}5 \cdot Z_{le} \cdot \sigma_{a,le} + Z_m \cdot \sigma_{a,m}} \leq 1{,}0$$

where:

M = bending moment, in kN·m, as given in S19.3.1.

Z_{le} = section modulus of one half pitch corrugation, in cm^3, at the lower end of corrugations, to be calculated according to S19.4.3.

Z_m = section modulus of one half pitch corrugation, in cm^3, at the mid-span of corrugations, to be calculated according to S19.4.4.

$\sigma_{a,le}$ = allowable stress, in N/mm^2, as given in S19.4.5, for the lower end of corrugations

$\sigma_{a,m}$ = allowable stress, in N/mm^2, as given in S19.4.5, for the mid-span of corrugations.

In no case Z_m is to be taken greater than the lesser of $1{,}15 \cdot Z_{le}$.and $1{,}15 \cdot Z'_{le}$ for calculation of the

S19
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bending capacity, Z'_{le} being defined below.

In case effective shedders plates are fitted which:

- are not knuckled;
- are welded to the corrugations and the top of the lower stool by one side penetration welds or equivalent;
- are fitted with a minimum slope of 45° and their lower edge is in line with the stool side plating;

or effective gusset plates are fitted which:

- are fitted in line with the stool side plating;
- have material properties at least equal to those provided for the flanges,

the section modulus Z_{le}, in cm^3, is to be taken not larger than the value Z'_{le}, in cm^3, given by:

$$Z'_{le} = Z_g + 10^3 \cdot \frac{Q \cdot h_g - 0{,}5 \cdot h_g^2 \cdot s_1 \cdot p_g}{\sigma_a}$$

where:

Z_g = section modulus of one half pitch corrugation, in cm^3, according to S19.4.4, in way of the upper end of shedder or gusset plates, as applicable

Q = shear force, in kN, as given in S19.3.2

h_g = height, in m, of shedders or gusset plates, as applicable (see Figures 3a, 3b, 4a and 4b)

s_1 = as given in S19.2.3.1 a)

p_g = resultant pressure, in kN/m^2, as defined in S19.2.5, calculated in way of the middle of the shedders or gusset plates, as applicable

σ_a = allowable stress, in N/mm^2, as given in S19.4.5.

Stresses τ are obtained by dividing the shear force Q by the shear area. The shear area is to be reduced in order to account for possible non-perpendicularity between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by (sin ϕ), ϕ being the angle between the web and the flange.

When calculating the section moduli and the shear area, the net plate thicknesses are to be used.

The section moduli of corrugations are to be calculated on the basis of the requirements given in S19.4.3 and S19.4.4.

S19.4.3 - Section modulus at the lower end of corrugations

The section modulus is to be calculated with the compression flange having an effective flange width, b_{ef}, not larger than as given in S19.4.6.1.

S19
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If the corrugation webs are not supported by local brackets below the stool top (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

a) Provided that effective shedder plates, as defined in S19.4.2, are fitted (see Figures 3a and 3b), when calculating the section modulus of corrugations at the lower end (cross-section ① in Figures 3a and 3b), the area of flange plates, in cm^2, may be increased by

$$\left(2{,}5 \cdot a \cdot \sqrt{t_f \cdot t_{sh}} \cdot \sqrt{\frac{\sigma_{Fsh}}{\sigma_{Ffl}}}\right)$$

(not to be taken greater than $2{,}5 \cdot a \cdot t_f$) where:

a = width, in m, of the corrugation flange (see Figure 2a)

t_{sh} = net shedder plate thickness, in mm

t_f = net flange thickness, in mm

σ_{Fsh} = minimum upper yield stress, in N/mm^2, of the material used for the shedder plates

σ_{Ffl} = minimum upper yield stress, in N/mm^2, of the material used for the corrugation flanges.

b) Provided that effective gusset plates, as defined in S19.4.2, are fitted (see Figures 4a and 4b), when calculating the section modulus of corrugations at the lower end (cross-section ① in Figures 4a and 4b), the area of flange plates, in cm^2, may be increased by (7•hg•tgu) where:

h_g = height of gusset plate in m, see Figures 4a and 4b, not to be taken greater than :

$$\left(\frac{10}{7} \cdot s_{gu}\right)$$

s_{gu} = width of the gusset plates, in m

t_{gu} = net gusset plate thickness, in mm, not to be taken greater than t_f

t_f = net flange thickness, in mm, based on the as built condition.

c) If the corrugation webs are welded to a sloping stool top plate, which is at an angle not less than 45º with the horizontal plane, the section modulus of the corrugations may be calculated considering the corrugation webs fully effective. In case effective gusset plates are fitted, when calculating the section modulus of corrugations the area of flange plates may be increased as specified in b) above. No credit can be given to shedder plates only.

For angles less than 45º, the effectiveness of the web may be obtained by linear interporation between 30% for 0º and 100% for 45º.

S19.4.4 - Section modulus of corrugations at cross-sections other than the lower end

The section modulus is to be calculated with the corrugation webs considered effective and the compression flange having an effective flange width, b_{ef}, not larger than as given in S19.4.6.1.

S19
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S19.4.5 - Allowable stress check

The normal and shear stresses σ and τ are not to exceed the allowable values σ_a and τ_a, in N/mm^2, given by:

$$\sigma_a = \sigma F$$

$$\tau_a = 0{,}5 \bullet \sigma F$$

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

S19.4.6 - Effective compression flange width and shear buckling check

S19.4.6.1 - Effective width of the compression flange of corrugations

The effective width b_{ef}, in m, of the corrugation flange is given by:

$$b_{ef} = C_e \cdot a$$

where:

$$C_e = \frac{2{,}25}{\beta} - \frac{1{,}25}{\beta^2} \quad \text{for } \beta > 1{,}25$$

$$C_e = 1{,}0 \quad \text{for } \beta \le 1{,}25$$

$$\beta = 10^3 \cdot \frac{a}{t_f} \cdot \sqrt{\frac{\sigma_F}{E}}$$

t_f = net flange thickness, in mm

a = width, in m, of the corrugation flange (see Figure 2a)

σ_F = minimum upper yield stress, in N/mm^2, of the material

E = modulus of elasticity, in N/mm^2, to be assumed equal to $2{,}06 \bullet 10^5$ N/mm^2 for steel

S19.4.6.2 - Shear

The buckling check is to be performed for the web plates at the corrugation ends.

The shear stress τ is not to exceed the critical value τ_c, in N/mm^2 obtained by the following:

$$\tau_C = \tau_E \quad \text{when } \tau_E \le \frac{\tau_F}{2}$$

$$= \tau_F\left(1 - \frac{\tau_F}{4\tau_E}\right) \quad \text{when } \tau_E > \frac{\tau_F}{2}$$

S19
cont'd

$$\tau_F = \frac{\sigma_F}{\sqrt{3}}$$

where:

σ_F = minimum upper yield stress, in N/mm^2, of the material

$$\tau_E = 0.9 k_t E \left(\frac{t}{1000c}\right)^2 \qquad (\text{N/mm}^2)$$

k_t, E, t and c are given by:

k_t = 6.34

E = modulus of elasticity of material as given in S19.4.6.1

t = net thickness, in mm, of corrugation web

c = width, in m, of corrugation web (See Figure 2a)

S19.4.7 - Local net plate thickness

The bulkhead local net plate thickness t, in mm, is given by:

$$t = 14{,}9 \cdot s_w \cdot \sqrt{\frac{p}{\sigma_F}}$$

where:

s_w = plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is the greater (see Figure 2a)

p = resultant pressure, in kN/m^2, as defined in S19.2.5, at the bottom of each strake of plating; in all cases, the net thickness of the lowest strake is to be determined using the resultant pressure at the top of the lower stool, or at the inner bottom, if no lower stool is fitted or at the top of shedders, if shedder or gusset/shedder plates are fitted.

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

For built-up corrugation bulkheads, when the thicknesses of the flange and web are different, the net thickness of the narrower plating is to be not less than t_n, in mm, given by:

$$t_n = 14{,}9 \cdot s_n \cdot \sqrt{\frac{p}{\sigma_F}}$$

s_n being the width, in m, of the narrower plating.

S19
cont'd

The net thickness of the wider plating, in mm, is not to be taken less than the maximum of the following values:

$$t_w = 14{,}9 \cdot s_w \cdot \sqrt{\frac{p}{\sigma_F}}$$

$$t_w = \sqrt{\frac{440 \cdot s_w^2 \cdot p}{\sigma_F} - t_{np}^2}$$

where $t_{np} \leq$ actual net thickness of the narrower plating and not to be greater than:

$$14{,}9 \cdot s_w \cdot \sqrt{\frac{p}{\sigma_F}}$$

S19.5 - Local details

As applicable, the design of local details is to comply with the Society's requirements for the purpose of transferring the corrugated bulkhead forces and moments to the boundary structures, in particular to the double bottom and cross-deck structures.

In particular, the thickness and stiffening of gusset and shedder plates, installed for strengthening purposes, is to comply with the Society's requirements, on the basis of the load model in S19.2.

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the Society's requirements.

S19.6 - Corrosion addition and steel renewal

Renewal/reinforcement shall be done in accordance with the following requirements and the guidelines contained in the Annex.

a) Steel renewal is required where the gauged thickness is less than t_{net} + 0,5 mm, t_{net} being the thickness used for the calculation of bending capacity and shear stresses as given in S19.4.2. or the local net plate thickness as given in S19.4.7. Alternatively, reinforcing doubling strips may be used providing the net thickness is not dictated by shear strength requirements for web plates (see S19.4.5 and S19.4.6.2) or by local pressure requirements for web and flange plates (see S19.4.7).

   Where the gauged thickness is within the range t_{net} + 0,5 mm and t_{net} + 1,0 mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal.

b) Where steel renewal or reinforcement is required, a minimum thickness of t_{net} + 2,5 mm is to be replenished for the renewed or reinforced parts.

c) When:

$$0{,}8 \cdot (\sigma_{Ffl} \cdot t_{fl}) \geq \sigma_{Fs} \cdot t_{st}$$

S19
cont'd

where:

σ_{Ffl} = minimum upper yield stress, in N/mm^2, of the material used for the corrugation flanges

σ_{Fs} = minimum upper yield stress, in N/mm^2, of the material used for the lower stool side plating or floors (if no stool is fitted)

t_{fl} = flange thickness, in mm, which is found to be acceptable on the basis of the criteria specified in a) above or, when steel renewal is required, the replenished thickness according to the criteria specified in b) above. The above flange thickness dictated by local pressure requirements (see S19.4.7) need not be considered for this purpose

t_{st} = as built thickness, in mm, of the lower stool side plating or floors (if no stool is fitted)

gussets with shedder plates, extending from the lower end of corrugations up to 0,1·l, or reinforcing doubling strips (on bulkhead corrugations and stool side plating) are to be fitted.

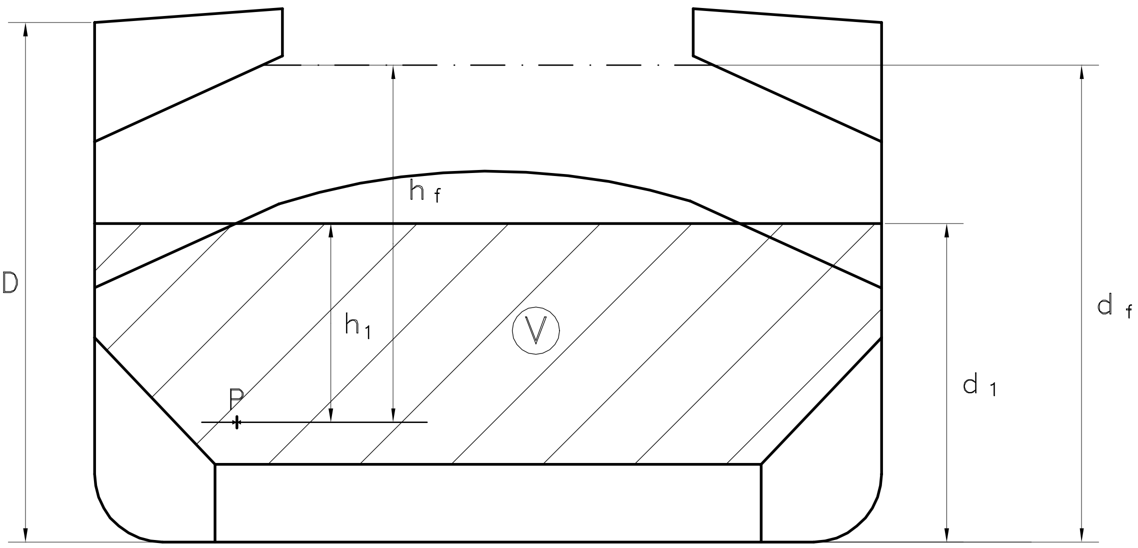
If gusset plates are fitted, the material of such gusset plates is to be the same as that of the corrugation flanges. The gusset plates are to be connected to the lower stool shelf plate or inner bottom (if no lower stool is fitted) by deep penetration welds (see Figure 5).

d) Where steel renewal is required, the bulkhead connections to the lower stool shelf plate or inner bottom (if no stool is fitted) are to be at least made by deep penetration welds (see Figure 5).

e) Where gusset plates are to be fitted or renewed, their connections with the corrugations and the lower stool shelf plate or inner bottom (if no stool is fitted) are to be at least made by deep penetration welds (see Figure 5).

S19
cont'd

Figure 1

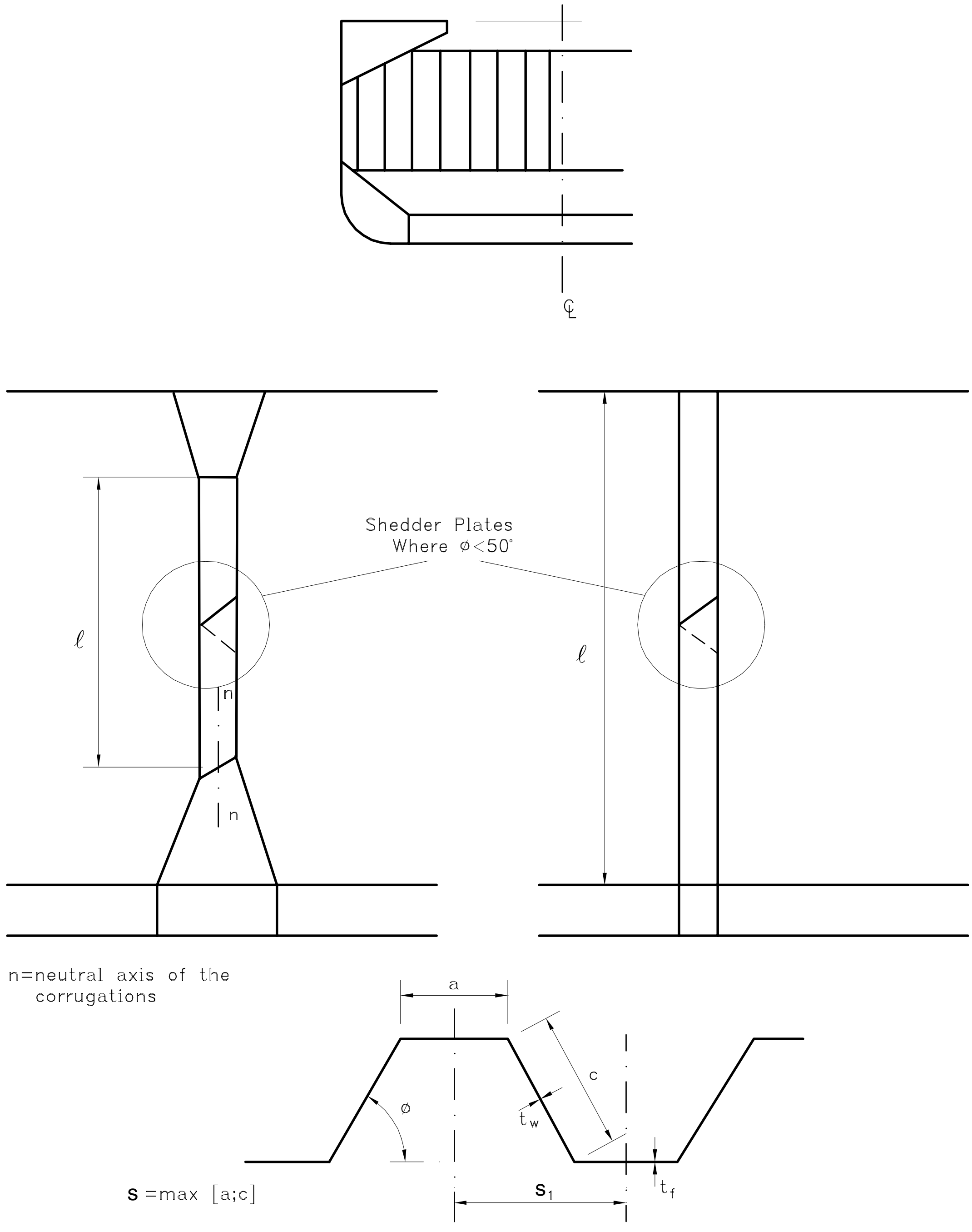


V = Volume of cargo

P = Calculation point

S19
cont'd

Figure 2a



S19
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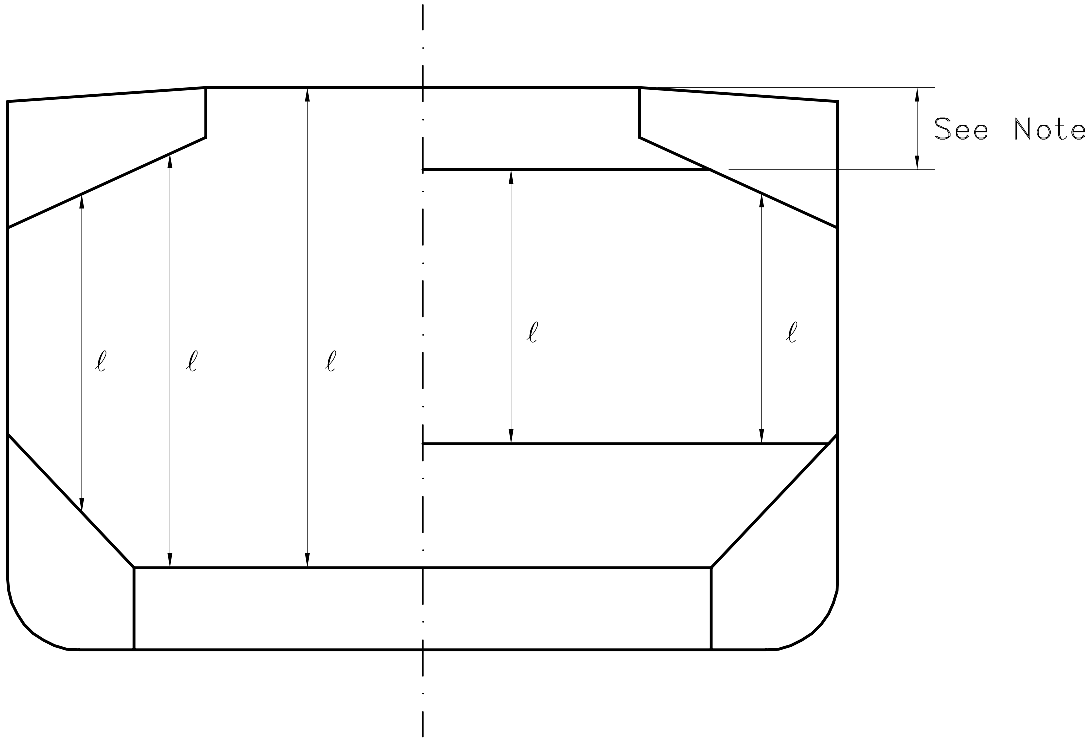
Figure 2b



Note: For the definition of ℓ, the internal end of the upper stool is not to be taken more than a distance from the deck at the centre line equal to:
- 3 times the depth of corrugations, in general
- 2 times the depth of corrugations, for rectangular stool

S19
cont'd

Figure 3a
Symmetric shedder plates

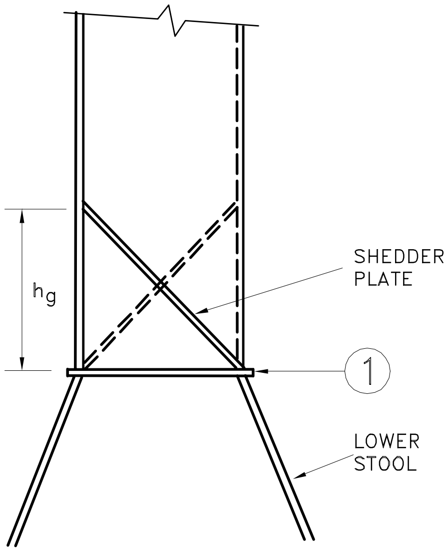
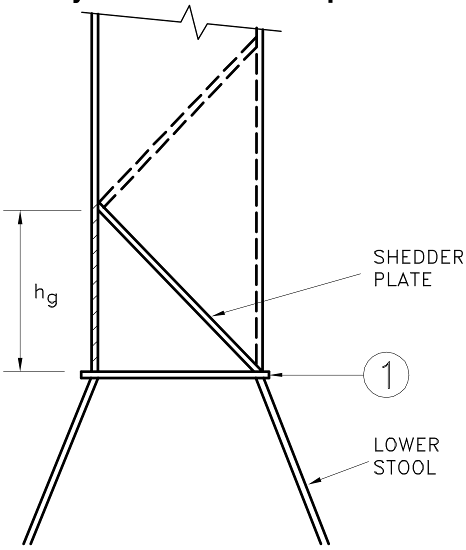


Figure 3b
Asymmetric shedder plates



S19
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Figure 4a
Symmetric gusset / shedder plates

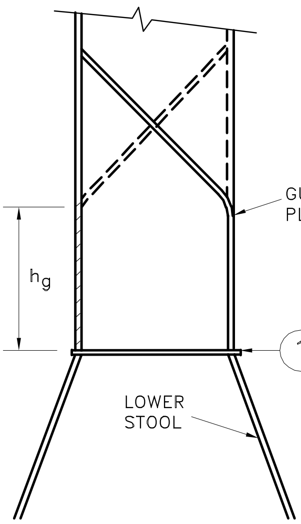
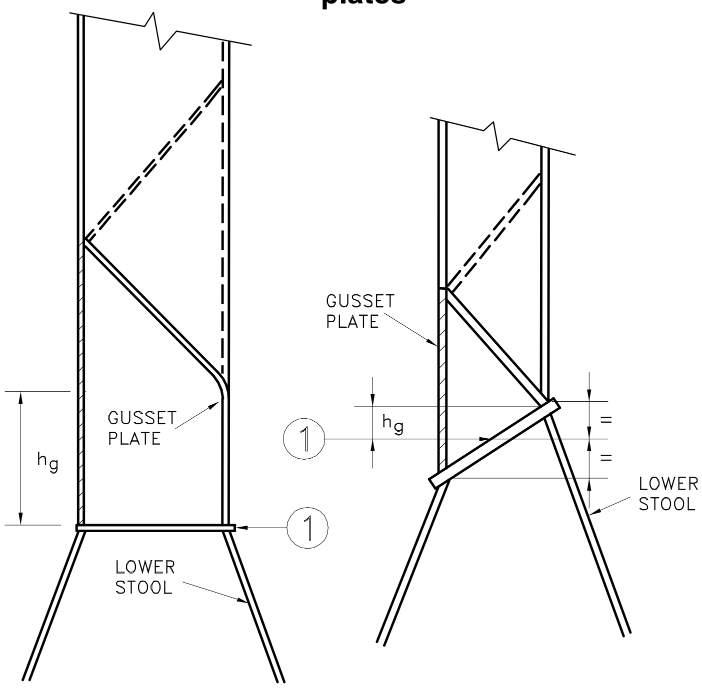


Figure 4b
Asymmetric gusset / shedder plates



S19
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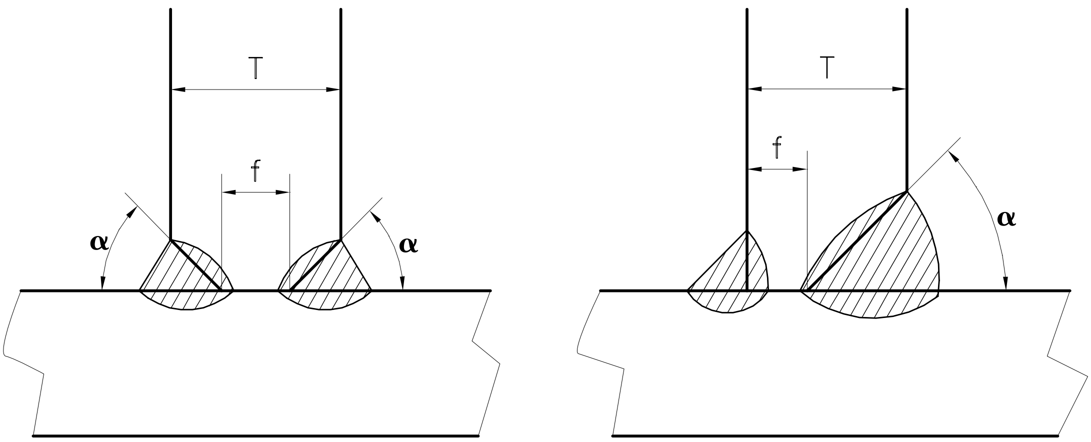
Figure 5



Root Face (f) : 3 mm to T/3 mm
Groove Angle (α) : 40° to 60°

ANNEX 1

Guidance on renewal/reinforcement of vertically corrugated transverse watertight bulkhead between cargo holds Nos. 1 and 2

1. The need for renewal or reinforcement of the vertically corrugated transverse watertight bulkhead between cargo holds Nos. 1 and 2 will be determined by the classification society on a case by case basis using the criteria given in S19 in association with the most recent gaugings and findings from survey.

2. In addition to class requirements, the S19 assessment of the transverse corrugated bulkhead will take into account the following:-

   (a) Scantlings of individual vertical corrugations will be assessed for reinforcement/renewal based on thickness measurements obtained in accordance with Annex III to UR Z10.2 at their lower end, at mid-depth and in way of plate thickness changes in the lower 70%. These considerations will take into account the provision of gussets and shedder plates and the benefits they offer, provided that they comply with S19.4.2 and S19.6.

   (b) Taking into account the scantlings and arrangements for each case, permissible levels of diminution will be determined and appropriate measures taken in accordance with S19.6.

3. Where renewal is required, the extent of renewal is to be shown clearly in plans. The vertical distance of each renewal zone is to be determined by considering S19 and in general is to be not less than 15% of the vertical distance between the upper and lower end of the corrugation - measured at the ship's centreline.

4. Where the reinforcement is accepted by adding strips, the length of the reinforcing strips is to be sufficient to allow it to extend over the whole depth of the diminished plating. In general, the width and thickness of strips should be sufficient to comply with the S19 requirements. The material of the strips is to be the same as that of the corrugation plating. The strips are to be attached to the existing bulkhead plating by continuous fillet welds. The strips are to be suitably tapered or connected at ends in accordance with Class Society practice.

5. Where reinforcing strips are connected to the inner bottom or lower stool shelf plates, one side full penetration welding is to be used. When reinforcing strips are fitted to the corrugation flange and are connected to the lower stool shelf plate, they are normally to be aligned with strips of the same scantlings welded to the stool side plating and having a minimum length equal to the breadth of the corrugation flange.

6. Figure 1 gives a general arrangement of structural reinforcement.

S19
cont'd

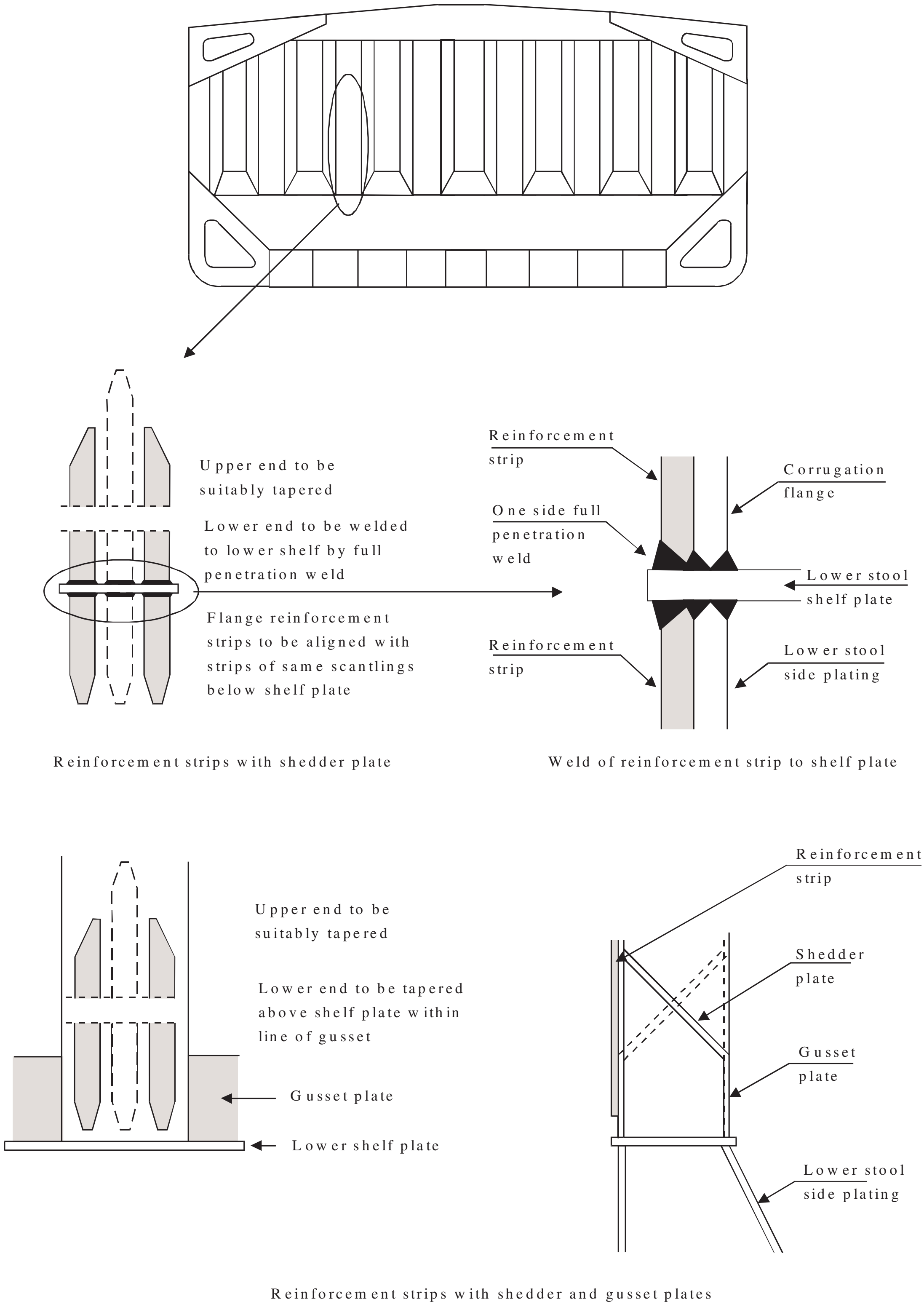


Figure 1

S19
cont'd

Notes to Figure 1 on reinforcement:-

1. Square or trapezoidal corrugations are to be reinforced with plate strips fitted to each corrugation flange sufficient to meet the requirements of S19.

2. The number of strips fitted to each corrugation flange is to be sufficient to meet the requirements of S19.

3. The shedder plate may be fitted in one piece or prefabricated with a welded knuckle (gusset plate).

4. Gusset plates, where fitted, are to be welded to the shelf plate in line with the flange of the corrugation, to reduce the stress concentrations at the corrugation corners. Ensure good alignment between gusset plate, corrugation flange and lower stool sloping plate. Use deep penetration welding at all connections. Ensure start and stop of welding is as far away as practically possible from corners of corrugation.

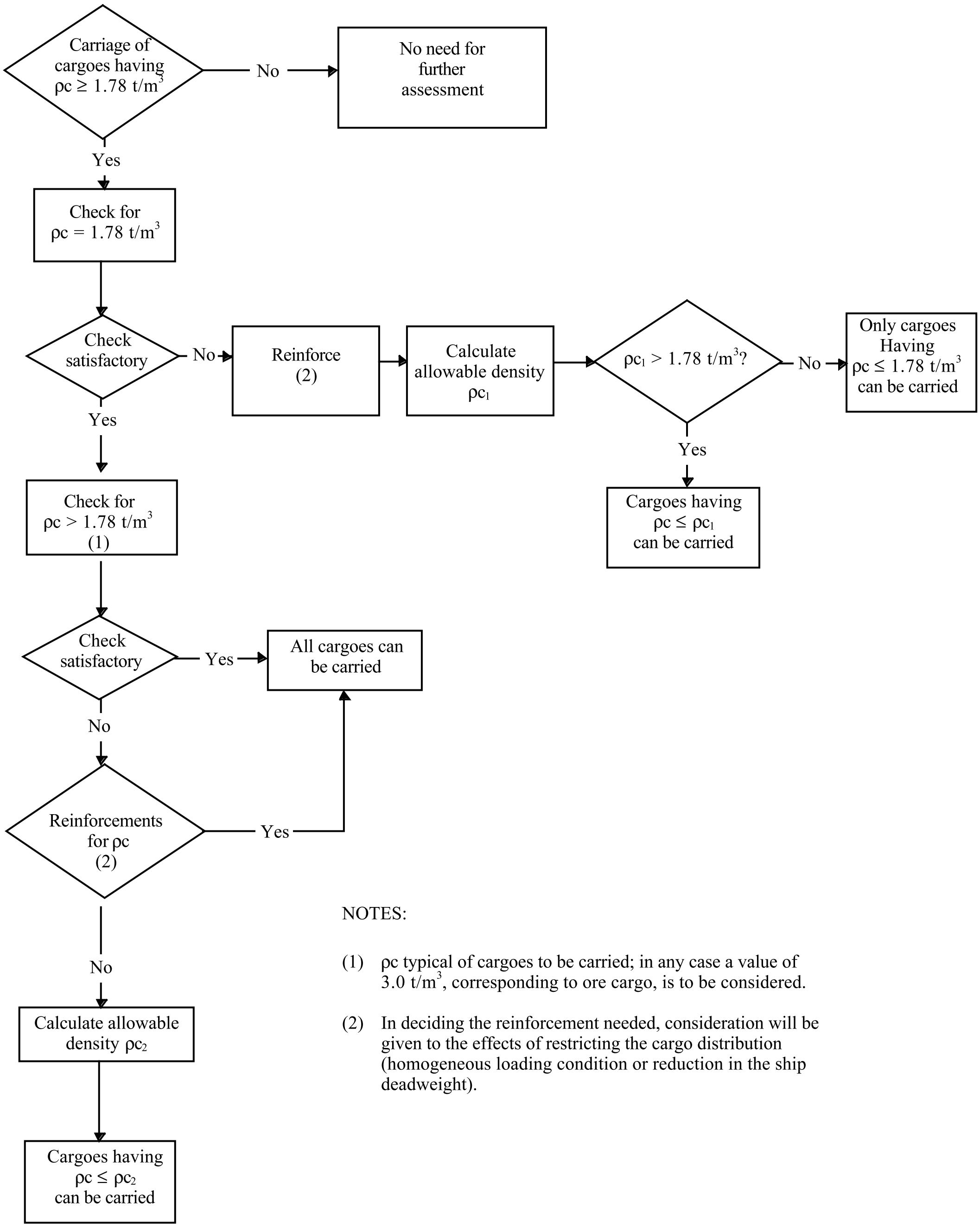
5. Shedder plates are to be attached by one side full penetration welds onto backing bars.

6. Shedder and gusset plates are to have a thickness equal to or greater than the original bulkhead thickness. Gusset plate is to have a minimum height (on the vertical part) equal to half of the width of the corrugation flange. Shedders and gussets are to be same material as flange material.

ANNEX 2

S19
cont'd

Guidance to Assess Capability of Carriage of High Density Cargoes on Existing Bulk Carriers according to the Strength of Transverse Bulkhead between Cargo Holds Nos. 1 and 2



NOTES:

(1) ρc typical of cargoes to be carried; in any case a value of 3.0 t/m^3, corresponding to ore cargo, is to be considered.

(2) In deciding the reinforcement needed, consideration will be given to the effects of restricting the cargo distribution (homogeneous loading condition or reduction in the ship deadweight).

END

S20 Evaluation of Allowable Hold Loading for Bulk Carriers Considering Hold Flooding

(1997)
(Rev. 1 1997)
(Rev.2 Sept. 2000)
(Rev.3 July 2004)

S20.1 - Application and definitions

These requirements are to be complied with in respect of the flooding of any cargo hold of bulk carriers, of 150m in length and above, with single deck, topside tanks and hopper tanks, intending to carry solid bulk cargoes having a density 1,0 t/m^3, or above, which are contracted for construction on or after 1 July 1998, except as stipulated below:

(i) Cargo holds of double side skin construction in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 July 1999,

(ii) Cargo holds of double side skin construction of not less than 760 mm breadth at any location within the hold length, measured perpendicular to the side shell in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 January 2000,

(iii) Cargo holds of double side skin construction of not less than 1,000 mm breadth at any location within the hold length, measured perpendicular to the side shell in ships, the keels of which are laid, or which are at a similar stage of construction, on or after 1 January 2000.

The loading in each hold is not to exceed the allowable hold loading in flooded condition, calculated as per S20.4, using the loads given in S20.2 and the shear capacity of the double bottom given in S20.3.

In no case is the allowable hold loading, considering flooding, to be taken greater than the design hold loading in intact condition.

S20.2 - Loading model

S20.2.1 - General

The loads to be considered as acting on the double bottom are those given by the external sea pressures and the combination of the cargo loads with those induced by the flooding of the hold which the double bottom belongs to.

The most severe combinations of cargo induced loads and flooding loads are to be used, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions;
- non homogeneous loading conditions;
- packed cargo conditions (such as steel mill products).

For each loading condition, the maximum bulk cargo density to be carried is to be considered in calculating the allowable hold loading limit.

S20.2.2 - Inner bottom flooding head

The flooding head h_f (see Figure 1) is the distance, in m, measured vertically with the ship in the upright position, from the inner bottom to a level located at a distance d_f, in m, from the baseline equal to:

a) in general:

- D for the foremost hold
- 0,9·D for the other holds

Note:

1. Changes introduced in Rev.2 are to be uniformly implemented by IACS Members and Associates from 1 July 2001.

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.

S20
cont'd

b) for ships less than 50,000 tonnes deadweight with Type B freeboard:

- 0,95·D for the foremost hold
- 0,85·D for the other holds

D being the distance, in m, from the baseline to the freeboard deck at side amidship (see Figure 1).

S20.3 - Shear capacity of the double bottom

The shear capacity C of the double bottom is defined as the sum of the shear strength at each end of:

- all floors adjacent to both hoppers, less one half of the strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted (see Figure 2).

- all double bottom girders adjacent to both stools, or transverse bulkheads if no stool is fitted.

Where in the end holds, girders or floors run out and are not directly attached to the boundary stool or hopper girder, their strength is to be evaluated for the one end only.

Note that the floors and girders to be considered are those inside the hold boundaries formed by the hoppers and stools (or transverse bulkheads if no stool is fitted). The hopper side girders and the floors directly below the connection of the bulkhead stools (or transverse bulkheads if no stool is fitted) to the inner bottom are not to be included.

When the geometry and/or the structural arrangement of the double bottom are such to make the above assumptions inadequate, to the Society's discretion, the shear capacity C of double bottom is to be calculated according to the Society's criteria.

In calculating the shear strength, the net thickness of floors and girders is to be used. The net thickness t_{net}, in mm, is given by:

$$t_{net} = t - 2,5$$

where:

t = thickness, in mm, of floors and girders.

S20.3.1 - Floor shear strength

The floor shear strength in way of the floor panel adjacent to hoppers S_{f1}, in kN, and the floor shear strength in way of the openings in the outmost bay (i.e. that bay which is closer to hopper) S_{f2}, in kN, are given by the following expressions:

$$S_{f1} = 10^{-3} \cdot A_f \cdot \frac{\tau_a}{\eta_1}$$

$$S_{f2} = 10^{-3} \cdot A_{f,h} \cdot \frac{\tau_a}{\eta_2}$$

where:

A_f = sectional area, in mm^2, of the floor panel adjacent to hoppers

$A_{f,h}$ = net sectional area, in mm^2, of the floor panels in way of the openings in the outmost bay (i.e. that bay which is closer to hopper)

S20
cont'd

τa = allowable shear stress, in N/mm^2, to be taken equal to the lesser of

$$\tau_a = \frac{162 \cdot \sigma_F^{0,6}}{\left(s/t_{net}\right)^{0,8}} \quad \text{and} \quad \frac{\sigma_F}{\sqrt{3}}$$

For floors adjacent to the stools or transverse bulkheads, as identified in S20.3 τa may be taken $\sigma_F / \sqrt{3}$

σ_F = minimum upper yield stress, in N/mm^2, of the material

s = spacing of stiffening members, in mm, of panel under consideration

η_1 = 1,10

η_2 = 1,20

η_2 may be reduced, to the Society's discretion, down to 1.10 where appropriate reinforcements are fitted to the Society's satisfaction

S20.3.2 - Girder shear strength

The girder shear strength in way of the girder panel adjacent to stools (or transverse bulkheads, if no stool is fitted) S_{g1}, in kN, and the girder shear strength in way of the largest opening in the outmost bay (i.e. that bay which is closer to stool, or transverse bulkhead, if no stool is fitted) S_{g2}, in kN, are given by the following expressions:

$$S_{g1} = 10^{-3} \cdot A_g \cdot \frac{\tau_a}{\eta_1}$$

$$S_{g2} = 10^{-3} \cdot A_{g,h} \cdot \frac{\tau_a}{\eta_2}$$

where:

A_g = minimum sectional area, in mm^2, of the girder panel adjacent to stools (or transverse bulkheads, if no stool is fitted)

$A_{g,h}$ = net sectional area, in mm^2, of the girder panel in way of the largest opening in the outmost bay (i.e. that bay which is closer to stool, or transverse bulkhead, if no stool is fitted)

τ_a = allowable shear stress, in N/mm^2, as given in S20.3.1

η_1 = 1,10

η_2 = 1,15

η_2 may be reduced, to the Society's discretion, down to 1.10 where appropriate reinforcements are fitted to the Society's satisfaction

S20
cont'd

S20.4 - Allowable hold loading

The allowable hold loading W, in tonnes, is given by:

$$W = \rho_c \cdot V \cdot \frac{1}{F}$$

where:

F = 1,1 in general
1,05 for steel mill products

ρ_c = cargo density, in t/m^3; for bulk cargoes see S20.2.1; for steel products, ρ_c is to be taken as the density of steel

V = volume, in m^3, occupied by cargo at a level h_1

$$h_1 = \frac{X}{\rho_c \cdot g}$$

X = *for bulk cargoes* the lesser of X_1 and X_2 given by:

$$X_1 = \frac{Z + \rho \cdot g \cdot (E - h_f)}{1 + \frac{\rho}{\rho_c}(perm - 1)}$$

$$X_2 = Z + \rho \cdot g \cdot (E - h_f \cdot perm)$$

X = for steel products, X may be taken as X_1, using perm = 0

ρ = sea water density, in t/m^3

g = 9.81 m/s^2, gravity acceleration

E = ship immersion in m for flooded hold condition = d_f - 0,1D

d_f,D = as given in S20.2.2

h_f = flooding head, in m, as defined in S20.2.2

perm = cargo permeability, (i.e. the ratio between the voids within the cargo mass and the volume occupied by the cargo); it needs not be taken greater than 0.3.

Z = the lesser of Z_1 and Z_2 given by:

$$Z_1 = \frac{C_h}{A_{DB,h}}$$

$$Z_2 = \frac{C_e}{A_{DB,e}}$$

S20
cont'd

C_h = shear capacity of the double bottom, in kN, as defined in S20.3, considering, for each floor, the lesser of the shear strengths S_{f1} and S_{f2} (see S20.3.1) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (see S20.3.2)

C_e = shear capacity of the double bottom, in kN, as defined in S20.3, considering, for each floor, the shear strength S_{f1} (see S20.3.1) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (see S20.3.2)

$$A_{DB,h} = \sum_{i=1}^{i=n} S_i \cdot B_{DB,i}$$

$$A_{DB,e} = \sum_{i=1}^{i=n} S_i \cdot (B_{DB} - s_l)$$

n = number of floors between stools (or transverse bulkheads, if no stool is fitted)

S_i = space of ith-floor, in m

$B_{DB,i}$ = B_{DB} - s_l for floors whose shear strength is given by S_{f1} (see S20.3.1)

$B_{DB,i}$ = $B_{DB,h}$ for floors whose shear strength is given by S_{f2} (see S20.3.1)

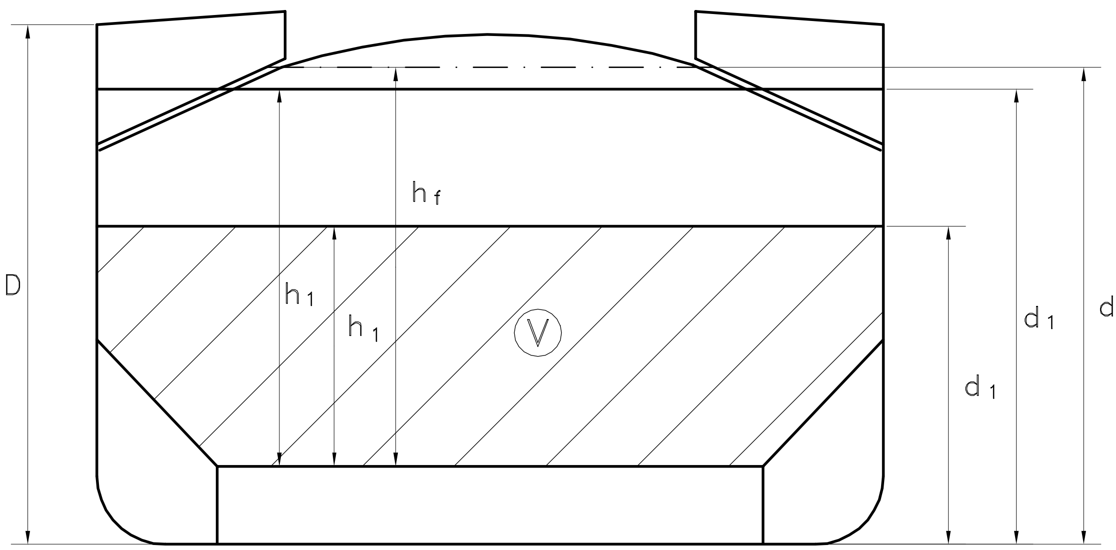
B_{DB} = breadth of double bottom, in m, between hoppers (see Figure 3)

$B_{DB,h}$ = distance, in m, between the two considered opening (see Figure 3)

s_l = spacing, in m, of double bottom longitudinals adjacent to hoppers

S20
cont'd

Figure 1



V = Volume of cargo

S20
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Figure 2

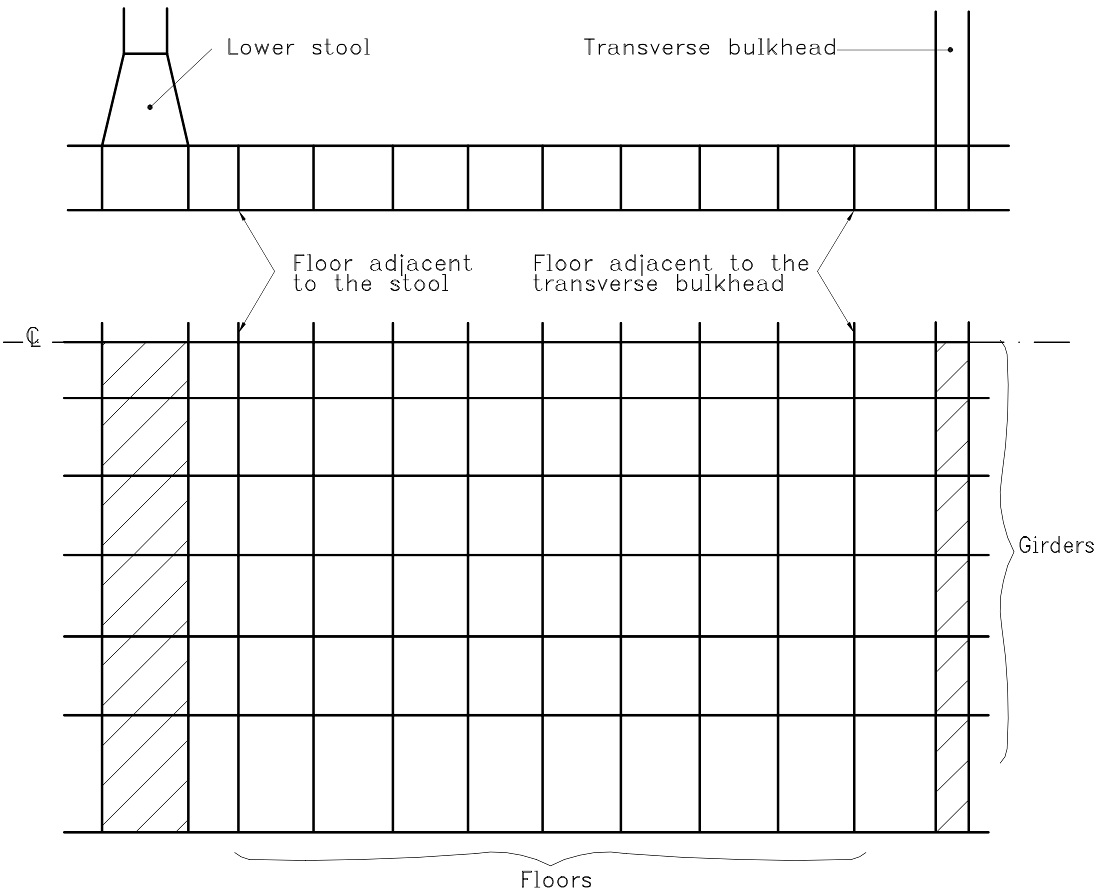

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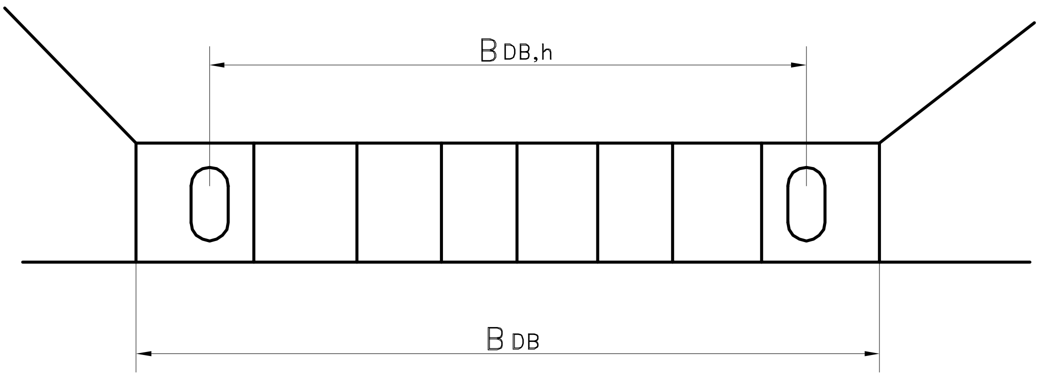
Figure 3



END

S 21 Evaluation of Scantlings of Hatch Covers and Hatch Coamings of Cargo Holds of Bulk Carriers, Ore Carriers and Combination Carriers (Rev. 4)

(1997)
(Rev. 1 2002)
(Rev.2 Nov.2002)
(Rev. 3 April 2003)
(Rev.4 July 2004)

S21.1 Application and definitions

These requirements apply to all bulk carriers, ore carriers and combination carriers, as defined in UR Z11, and are for all cargo hatch covers and hatch forward and side coamings on exposed decks in position 1, as defined in ILLC.

Rev. 3 of this UR applies to ships contracted for construction on or after 1 January 2004.

The strength requirements are applicable to hatch covers and hatch coamings of stiffened plate construction. The secondary stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

The spacing of primary supporting members parallel to the direction of secondary stiffeners is not to exceed 1/3 of the span of primary supporting members.

The secondary stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

These requirements are in addition to the requirements of the ILLC.

The net minimum scantlings of hatch covers are to fulfil the strength criteria given in:

- S21.3.3, for plating,
- S21.3.4, for secondary stiffeners,
- S21.3.5 for primary supporting members,

the critical buckling stress check in S21.3.6 and the rigidity criteria given in S21.3.7, adopting the load model given in S21.2.

The net minimum scantlings of hatch coamings are to fulfil the strength criteria given in:

- S21.4.2, for plating,
- S21.4.3, for secondary stiffeners,
- S21.4.4, for coaming stays,

adopting the load model given in S21.4.1.

The net thicknesses, t_{net}, are the member thicknesses necessary to obtain the minimum net scantlings required by S21.3 and S21.4.

The required gross thicknesses are obtained by adding the corrosion additions, t_s, given in S21.6, to t_{net}.

Material for the hatch covers and coamings is to be steel according to the requirements for ship's hull.

Note:
1. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.

S 21
(cont'd)

S21.2 Hatch cover load model

The pressure p, in kN/m^2, on the hatch covers panels is given by:

For ships of 100 m in length and above

$$p = 34.3 + \frac{p_{FP} - 34.3}{0.25} \bullet \left(0.25 - \frac{x}{L}\right) \geq 34.3, \quad \text{for hatch ways located at the freeboard deck}$$

where:

p_{FP} = pressure at the forward perpendicular
= 49.1 + (L-100)a

a = 0.0726 for type B freeboard ships

0.356 for ships with reduced freeboard

L = Freeboard length, in m, as defined in Regulation 3 of Annex I to the 1966 Load Line Convention as modified by the Protocol of 1988, to be taken not greater than 340 m

x = distance, in m, of the mid length of the hatch cover under examination from the forward end of L

Where a position 1 hatchway is located at least one superstructure standard height higher than the freeboard deck, the pressure p may be 34.3kN/m^2.

For ships less than 100 m in length

$$p = 15.8 + \frac{L}{3} \cdot \left(1 - \frac{5}{3} \cdot \frac{x}{L}\right) - 3.6 \cdot \frac{x}{L} \geq 0.195L + 14.9, \text{for hatch ways located at the freeboard deck}$$

Where two or more panels are connected by hinges, each individual panel is to be considered separately.

S21.3 Hatch cover strength criteria

S21.3.1 Allowable stress checks

The normal and shear stresses σ and τ in the hatch cover structures are not to exceed the allowable values, σ_a and τ_a, in N/mm^2, given by:

σ_a = 0.8 σ_F

τ_a = 0.46 σ_F

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

The normal stress in compression of the attached flange of primary supporting members is not to exceed 0.8 times the critical buckling stress of the structure according to the buckling check as given in S21.3.6.

The stresses in hatch covers that are designed as a grillage of longitudinal and transverse primary supporting members are to be determined by a grillage or a FE analysis.

When a beam or a grillage analysis is used, the secondary stiffeners are not to be included in the attached flange area of the primary members.

When calculating the stresses σ and τ, the net scantlings are to be used.

S 21
(cont'd)

S21.3.2 Effective cross-sectional area of panel flanges for primary supporting members

The effective flange area A_f, in cm^2, of the attached plating, to be considered for the yielding and buckling checks of primary supporting members, when calculated by means of a beam or grillage model, is obtained as the sum of the effective flange areas of each side of the girder web as appropriate:

$$A_F = \sum_{nf} (10 b_{ef} t)$$

where:

nf = 2 if attached plate flange extends on both sides of girder web

= 1 if attached plate flange extends on one side of girder web only

t = net thickness of considered attached plate, in mm

b_{ef} = effective breadth, in m, of attached plate flange on each side of girder web

= b_p , but not to be taken greater than 0.165 l

b_p = half distance, in m, between the considered primary supporting member and the adjacent one

l = span, in m, of primary supporting members

S21.3.3 Local net plate thickness

The local net plate thickness t, in mm, of the hatch cover top plating is not to be less than:

$$t = F_p \, 15.8 \, s \sqrt{\frac{p}{0.95 \, \sigma_F}}$$

but to be not less than 1% of the spacing of the stiffener or 6 mm if that be greater.

where:

F_p = factor for combined membrane and bending response

= 1.50 in general

= 1.90 σ/σ_a, for $\sigma/\sigma_a \geq 0.8$, for the attached plate flange of primary supporting members

s = stiffener spacing, in m

p = pressure, in kN/m^2 , as defined in S21.2

σ = as defined in S21.3.5

σ_a = as defined in S21.3.1.

S21.3.4 Net scantlings of secondary stiffeners

The required minimum section modulus, Z, in cm^3, of secondary stiffeners of the hatch cover top plate, based on stiffener net member thickness, are given by:

S 21
(cont'd)

$$Z = \frac{1000\ l^2\ s\ p}{12\ \sigma_a}$$

where:

l = secondary stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all secondary stiffener spans, the secondary stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the gross span, for each bracket.

s = secondary stiffener spacing, in m

p = pressure, in kN/m^2 , as defined in S21.2

σ_a= as defined in S21.3.1.

The net section modulus of the secondary stiffeners is to be determined based on an attached plate width assumed equal to the stiffener spacing.

S21.3.5 Net scantlings of primary supporting members

The section modulus and web thickness of primary supporting members, based on member net thickness, are to be such that the normal stress σ in both flanges and the shear stress τ, in the web, do not exceed the allowable values σ_a and τ_a, respectively, defined in S21.3.1.

The breadth of the primary supporting member flange is to be not less than 40% of their depth for laterally unsupported spans greater than 3.0 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

The flange outstand is not to exceed 15 times the flange thickness.

S21.3.6 Critical buckling stress check

S21.3.6.1 Hatch cover plating

The compressive stress σ in the hatch cover plate panels, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress σ_{C1}, to be evaluated as defined below:

$$\sigma_{C1} = \sigma_{E1} \qquad \text{when } \sigma_{E1} \le \frac{\sigma_F}{2}$$

$$= \sigma_F\left[1 - \sigma_F/(4\sigma_{E1})\right] \qquad \text{when } \sigma_{E1} > \frac{\sigma_F}{2}$$

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

$$\sigma_{E1} = 3.6E\left(\frac{t}{1000s}\right)^2$$

S 21
(cont'd)

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

= $2.06 \cdot 10^5$ for steel

t = net thickness, in mm, of plate panel

s = spacing, in m, of secondary stiffeners

The mean compressive stress σ in each of the hatch cover plate panels, induced by the bending of primary supporting members perpendicular to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress σ_{C2}, to be evaluated as defined below:

$$\sigma_{C2} = \sigma_{E2} \qquad \text{when } \sigma_{E2} \le \frac{\sigma_F}{2}$$

$$= \sigma_F\left[1 - \sigma_F/(4\sigma_{E2})\right] \qquad \text{when } \sigma_{E2} > \frac{\sigma_F}{2}$$

where:

σ_F = minimum upper yield stress, in N/mm^2, of the material

$$\sigma_{E2} = 0.9mE\left(\frac{t}{1000s_s}\right)^2$$

$$m = c\left[1 + \left(\frac{s_s}{l_s}\right)^2\right]^2 \frac{2.1}{\psi + 1.1}$$

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

= $2.06 \cdot 10^5$ for steel

t = net thickness, in mm, of plate panel

s_s = length, in m, of the shorter side of the plate panel

l_s = length, in m, of the longer side of the plate panel

ψ = ratio between smallest and largest compressive stress

c = 1.3 when plating is stiffened by primary supporting members

c = 1.21 when plating is stiffened by secondary stiffeners of angle or T type

c = 1.1 when plating is stiffened by secondary stiffeners of bulb type

c = 1.05 when plating is stiffened by flat bar

The biaxial compressive stress in the hatch cover panels, when calculated by means of FEM shell element model, is to be in accordance with each classification society's rule as deemed equivalent to the above criteria.

S21.3.6.2 Hatch cover secondary stiffeners

The compressive stress σ in the top flange of secondary stiffeners, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress σ_{CS}, to be evaluated as defined below:

S 21
(cont'd)

$$\sigma_{CS} = \sigma_{ES} \qquad \text{when } \sigma_{ES} \le \frac{\sigma_F}{2}$$

$$= \sigma_F\left[1 - \sigma_F/(4\sigma_{ES})\right] \qquad \text{when } \sigma_{ES} > \frac{\sigma_F}{2}$$

where:

σ_F = minimum upper yield stress, in N/mm^2, of the material

σ_{ES} = ideal elastic buckling stress, in N/mm^2, of the secondary stiffener,

= minimum between σ_{E3} and σ_{E4}

$$\sigma_{E3} = \frac{0.001\, E\, I_a}{A\, l^2}$$

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

= $2.06 \cdot 10^5$ for steel

I_a = moment of inertia, in cm^4, of the secondary stiffener, including a top flange equal to the spacing of secondary stiffeners

A = cross-sectional area, in cm^2, of the secondary stiffener, including a top flange equal to the spacing of secondary stiffeners

l = span, in m, of the secondary stiffener

$$\sigma_{E4} = \frac{\pi^2 E\, I_w}{10^4 I_p\, l^2}\left(m^2 + \frac{K}{m^2}\right) + 0.385\, E\, \frac{I_t}{I_p}$$

$$K = \frac{C\, l^4}{\pi^4 E\, I_w} 10^6$$

m = number of half waves, given by the following table:

	0 < K < 4	4 < K < 36	36 < K < 144	$(m-1)^2 m^2 < K \le m^2(m+1)^2$
m	1	2	3	m

I_w = sectorial moment of inertia, in cm^6, of the secondary stiffener about its connection with the plating

$$= \frac{h_w^3 t_w^3}{36} 10^{-6} \qquad \text{for flat bar secondary stiffeners}$$

$$= \frac{t_f b_f^3 h_w^2}{12} 10^{-6} \qquad \text{for "Tee" secondary stiffeners}$$

$$= \frac{b_f^3 h_w^2}{12(b_f + h_w)^2}\left[t_f\left(b_f^2 + 2b_f h_w + 4h_w^2\right) + 3t_w b_f h_w\right]10^{-6} \qquad \text{for angles and bulb secondary stiffener}$$

I_p = polar moment of inertia, in cm^4, of the secondary stiffener about its connection with the plating

$$= \frac{h_w^3 t_w}{3} 10^{-4} \qquad \text{for flat bar secondary stiffeners}$$

S 21
(cont'd)

$$= \left(\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f \right) 10^{-4}$$ for flanged secondary stiffeners

I_t = St Venant's moment of inertia, in cm^4, of the secondary stiffener without top flange

$$= \frac{h_w t_w^3}{3} 10^{-4}$$ for flat bar secondary stiffeners

$$= \frac{1}{3} \left[h_w t_w^3 + b_f t_f^3 \left(1 - 0.63 \frac{t_f}{b_f} \right) \right] 10^{-4}$$ for flanged secondary stiffeners

h_w, t_w = height and net thickness, in mm, of the secondary stiffener, respectively

b_f, t_f = width and net thickness, in mm, of the secondary stiffener bottom flange, respectively

s = spacing, in m, of secondary stiffeners

C = spring stiffness exerted by the hatch cover top plating $= \dfrac{k_p E t_p^3}{3s\left(1 + \dfrac{1.33 k_p h_w t_p^3}{1000 s t_w^3}\right)} 10^{-3}$

$k_p = 1 - \eta_p$ to be taken not less than zero;
for flanged secondary stiffeners, k_p need not be taken less than 0.1

$$\eta_p = \frac{\sigma}{\sigma_{E1}}$$

σ = as defined in S21.3.5
σ_{E1} = as defined in S21.3.6.1

t_p = net thickness, in mm, of the hatch cover plate panel.

For flat bar secondary stiffeners and buckling stiffeners, the ratio h/t_W is to be not greater than $15 \cdot k^{0.5}$, where:

h, t_W = height and net thickness of the stiffener, respectively

k = $235/\sigma_F$

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

S21.3.6.3 Web panels of hatch cover primary supporting members

This check is to be carried out for the web panels of primary supporting members, formed by web stiffeners or by the crossing with other primary supporting members, the face plate (or the bottom cover plate) or the attached top cover plate.

The shear stress τ in the hatch cover primary supporting members web panels is not to exceed 0.8 times the critical buckling stress τ_C, to be evaluated as defined below:

$$\tau_C = \tau_E \quad \text{when } \tau_E \le \frac{\tau_F}{2}$$

$$= \tau_F \left[1 - \tau_F / (4\tau_E) \right] \quad \text{when } \tau_E > \frac{\tau_F}{2}$$

S 21
(cont'd)

where:

σ_F = minimum upper yield stress, in N/mm^2, of the material

$$\tau_F = \sigma_F / \sqrt{3}$$

$$\tau_E = 0.9 k_t E \left[\frac{t_{pr,n}}{1000d} \right]^2$$

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

= $2.06 \cdot 10^5$ for steel

$t_{pr,n}$ = net thickness, in mm, of primary supporting member

k_t = $5.35 + 4.0 / (a / d)^2$

a = greater dimension, in m, of web panel of primary supporting member

d = smaller dimension, in m, of web panel of primary supporting member.

For primary supporting members parallel to the direction of secondary stiffeners, the actual dimensions of the panels are to be considered.

For primary supporting members perpendicular to the direction of secondary stiffeners or for hatch covers built without secondary stiffeners, a presumed square panel of dimension d is to be taken for the determination of the stress τ_C. In such a case, the average shear stress τ between the values calculated at the ends of this panel is to be considered.

S21.3.7 Deflection limit and connections between hatch cover panels

Load bearing connections between the hatch cover panels are to be fitted with the purpose of restricting the relative vertical displacements.

The vertical deflection of primary supporting members is to be not more than 0.0056 l, where l is the greatest span of primary supporting members.

S21.4 Hatch coamings and local details

S21.4.1 Load model

The pressure p_{coam}, in kN/m^2, on the No. 1 forward transverse hatch coaming is given by:

p_{coam} = 220, when a forecasrtle is fitted in accordance with UR S28

= 290 in the other cases

The pressure p_{coam}, in kN/m^2, on the other coamings is given by:

p_{coam} = 220

S 21
(cont'd)

S21.4.2 Local net plate thickness

The local net plate thickness t, in mm, of the hatch coaming plating is given by:

$$t = 14.9 s \sqrt{\frac{p_{coam}}{\sigma_{a,coam}} S_{coam}}$$

where:

s = secondary stiffener spacing, in m

p_{coam} = pressure, in kN/m^2, as defined in S21.4.1

S_{coam} = safety factor to be taken equal to 1.15

$\sigma_{a,coam}$ = 0.95 σ_F

The local net plate thickness is to be not less than 9.5 mm.

S21.4.3 Net scantlings of longitudinal and transverse secondary stiffeners

The required section modulus Z, in cm^3, of the longitudinal or transverse secondary stiffeners of the hatch coamings, based on net member thickness, is given by:

$$Z = \frac{1000\ S_{coam}\ l^2\ s\ p_{coam}}{m\ c_p\ \sigma_{a,coam}}$$

where:

m = 16 in general

= 12 for the end spans of stiffeners sniped at the coaming corners

S_{coam} = safety factor to be taken equal to 1.15

l = span, in m, of secondary stiffeners

s = spacing, in m, of secondary stiffeners

p_{coam} = pressure in kN/m^2 as defined in S21.4.1

c_p = ratio of the plastic section modulus to the elastic section modulus of the secondary stiffeners with an attached plate breadth, in mm, equal to 40 t, where t is the plate net thickness

= 1.16 in the absence of more precise evaluation,

$\sigma_{a,coam}$ =0.95 σ_F

S21.4.4 Net scantlings of coaming stays

The required minimum section modulus, Z, in cm^3, and web thickness, t_w, in mm of coamings stays designed as beams with flange connected to the deck or sniped and

S 21
(cont'd)

fitted with a bracket (see Figures 1 and 2) at their connection with the deck, based on member net thickness,are given by:

$$Z = \frac{1000\ H_C^2\ s\ p_{coam}}{2\ \sigma_{a,coam}}$$

$$t_W = \frac{1000\ H_C\ s\ p_{coam}}{h\ \tau_{a,coam}}$$

H_C = stay height, in m

s = stay spacing, in m

h = stay depth, in mm, at the connection with the deck

p_{coam}= pressure, in kN/m^2, as defined in S21.4.1

$\sigma_{a,coam}$ = 0.95 σ_F

$\tau_{a,coam}$ = 0.5 σ_F

For calculating the section modulus of coaming stays, their face plate area is to be taken into account only when it is welded with full penetration welds to the deck plating and adequate underdeck structure is fitted to support the stresses transmitted by it.

For other designs of coaming stays, such as, for examples, those shown in Figures 3 and 4, the stress levels in S21.3.1 apply and are to be checked at the highest stressed locations.

S21.4.5 Local details

The design of local details is to comply with the Society requirement for the purpose of transferring the pressures on the hatch covers to the hatch coamings and, through them, to the deck structures below. Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

Underdeck structures are to be checked against the load transmitted by the stays, adopting the same allowable stresses specified in S21.4.4.

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the Society requirements.

Double continuous welding is to be adopted for the connections of stay webs with deck plating and the weld throat is to be not less than 0.44 t_W, where t_W is the gross thickness of the stay web.

Toes of stay webs are to be connected to the deck plating with deep penetration double bevel welds extending over a distance not less than 15% of the stay width.

S21.5 Closing arrangements

S21.5.1 Securing devices

The strength of securing devices is to comply with the following requirements:

S 21
(cont'd)

Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements.

Arrangement and spacing are to be determined with due attention to the effectiveness for weather-tightness, depending upon the type and the size of the hatch cover, as well as on the stiffness of the cover edges between the securing devices.

The net sectional area of each securing device is not to be less than:

$A = 1.4\ a / f\ (cm^2)$

where:

a = spacing in m of securing devices, not being taken less than 2 m

$f = (\sigma_Y / 235)^e$

σ_Y = specified minimum upper yield stress in N/mm^2 of the steel used for fabrication, not to be taken greater than 70% of the ultimate tensile strength.

e = 0.75 for $\sigma_Y > 235$

= 1.0 for $\sigma_Y \leq 235$

Rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

Between cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by the securing devices.

For packing line pressures exceeding 5 N/mm, the cross section area is to be increased in direct proportion. The packing line pressure is to be specified.

The cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia, I, of edge elements is not to be less than:

$I = 6\ p\ a^4\ (cm^4)$

p = packing line pressure in N/mm, minimum 5 N/mm.

a = spacing in m of securing devices.

Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

S21.5.2 Stoppers

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.

With the exclusion of No.1 hatch cover, hatch covers are to be effectively secured, by

S 21
(cont'd)

means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2.

This pressure may be reduced to 175 kN/m^2 when a forecastle is fitted in accordance with UR S28.

The equivalent stress:

i. in stoppers and their supporting structures, and

ii. calculated in the throat of the stopper welds

is not to exceed the allowable value of 0.8 σ_Y.

S21.5.3 Materials and welding

Stoppers or securing devices are to be manufactured of materials, including welding electrodes, meeting relevant IACS requirements.

S21.6 Corrosion addition and steel renewal

S21.6.1 Hatch covers

For all the structure (plating and secondary stiffeners) of single skin hatch covers, the corrosion addition t_s is to be 2.0 mm.

For pontoon hatch covers, the corrosion addition is to be:

- 2.0 mm for the top and bottom plating
- 1.5 mm for the internal structures.

For single skin hatch covers and for the plating of pontoon hatch covers, steel renewal is required where the gauged thickness is less than t_{net} + 0.5 mm. Where the gauged thickness is within the range t_{net} + 0.5 mm and t_{net} + 1.0 mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. Coating is to be maintained in GOOD condition, as defined in UR Z10.2.1.2.

For the internal structure of pontoon hatch covers, thickness gauging is required when plating renewal is to be carried out or when this is deemed necessary, at the discretion of the Society Surveyor, on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is less than t_{net}.

S21.6.2 Hatch coamings

For the structure of hatch coamings and coaming stays, the corrosion addition t_s is to be 1.5 mm.

Steel renewal is required where the gauged thickness is less than t_{net} + 0.5 mm. Where the gauged thickness is within the range t_{net} + 0.5 mm and t_{net} + 1.0 mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. Coating is to be maintained in GOOD condition, as defined in UR Z10.2.1.2.

S 21
(cont'd)

Figure 1

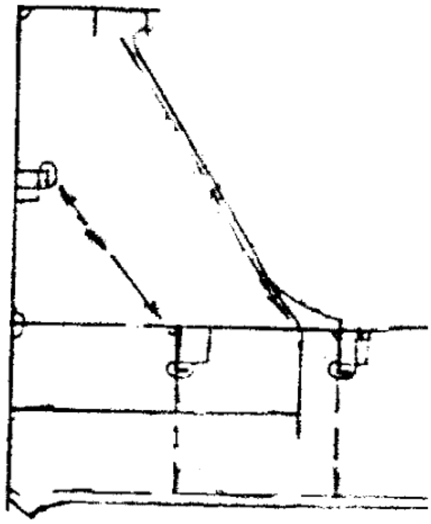


Figure 2

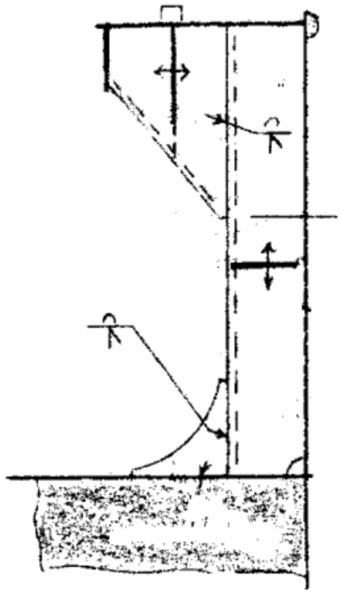


Figure 3

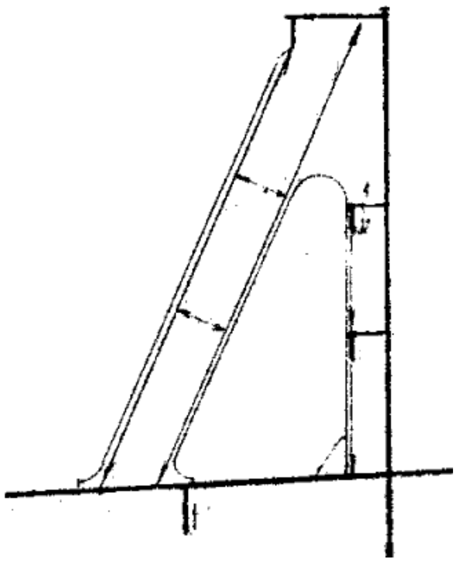
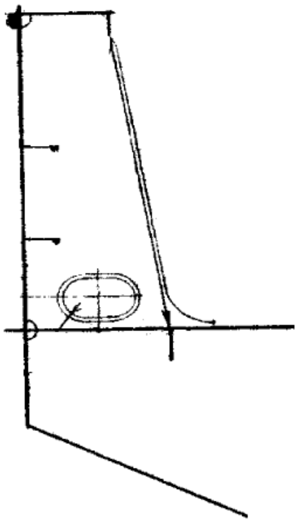


Figure 4



END

S22 Evaluation of Allowable Hold Loading of Cargo Hold No. 1 with Cargo Hold No. 1 Flooded, for Existing Bulk Carriers

(1997)
(Rev. 1 1997)
(Rev.2 Sept. 2000)
(Rev.3 July 2004)

S22.1 - Application and definitions

These requirements apply to all bulk carriers of 150 m in length and above, in the foremost hold, intending to carry solid bulk cargoes having a density of 1,78 t/m^3, or above, with single deck, topside tanks and hopper tanks, where:

(i) the foremost hold is bounded by the side shell only for ships which were contracted for construction prior to 1 July 1998, and have not been constructed in compliance with IACS Unified Requirement S20,

(ii) the foremost hold is double side skin construction less than 760 mm breadth measured perpendicular to the side shell in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 July 1999 and have not been constructed in compliance with IACS Unified Requirement S20 (Rev. 2, Sept. 2000).

Early completion of a special survey coming due after 1 July 1998 to postpone compliance is not allowed.

The loading in cargo hold No. 1 is not to exceed the allowable hold loading in the flooded condition, calculated as per S22.4, using the loads given in S22.2 and the shear capacity of the double bottom given in S22.3.

In no case, the allowable hold loading in flooding condition is to be taken greater than the design hold loading in intact condition.

S22.2 - Load model

S22.2.1 - General

The loads to be considered as acting on the double bottom of hold No. 1 are those given by the external sea pressures and the combination of the cargo loads with those induced by the flooding of hold No. 1.

The most severe combinations of cargo induced loads and flooding loads are to be used, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions;
- non homogeneous loading conditions;
- packed cargo conditions (such as steel mill products).

For each loading condition, the maximum bulk cargo density to be carried is to be considered in calculating the allowable hold limit.

S22.2.2 - Inner bottom flooding head

The flooding head h_f (see Figure 1) is the distance, in m, measured vertically with the ship in the upright position, from the inner bottom to a level located at a distance d_f, in m, from the baseline equal to:

- D in general
- 0,95 · D for ships less than 50,000 tonnes deadweight with Type B freeboard.

D being the distance, in m, from the baseline to the freeboard deck at side amidship (see Figure 1).

Note:

1 Changes introduced in Rev.2 are to be uniformly implemented by IACS Members and Assoiciates from 1 July 2001.

2 The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.

S22
cont'd

S22.3 - Shear capacity of the double bottom of hold No. 1

The shear capacity C of the double bottom of hold No. 1 is defined as the sum of the shear strength at each end of:

- all floors adjacent to both hoppers, less one half of the strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted (see Figure 2),
- all double bottom girders adjacent to both stools, or transverse bulkheads if no stool is fitted.

The strength of girders or floors which run out and are not directly attached to the boundary stool or hopper girder is to be evaluated for the one end only.

Note that the floors and girders to be considered are those inside the hold boundaries formed by the hoppers and stools (or transverse bulkheads if no stool is fitted). The hopper side girders and the floors directly below the connection of the bulkhead stools (or transverse bulkheads if no stool is fitted) to the inner bottom are not to be included.

When the geometry and/or the structural arrangement of the double bottom are such to make the above assumptions inadequate, to the Society's discretion, the shear capacity C of the double bottom is to be calculated according to the Society's criteria.

In calculating the shear strength, the net thicknesses of floors and girders are to be used. The net thickness t_{net}, in mm, is given by:

$$t_{net} = t - t_c$$

where:

t = as built thickness, in mm, of floors and girders

t_c = corrosion diminution, equal to 2 mm, in general; a lower value of tc may be adopted, provided that measures are taken, to the Society's satisfaction, to justify the assumption made.

S22.3.1 - Floor shear strength

The floor shear strength in way of the floor panel adjacent to hoppers S_{f1}, in kN, and the floor shear strength in way of the openings in the "outermost" bay (i.e. that bay which is closest to hopper) S_{f2}, in kN, are given by the following expressions:

$$S_{f1} = 10^{-3} \cdot A_f \cdot \frac{\tau_a}{\eta_1}$$

$$S_{f2} = 10^{-3} \cdot A_{f,h} \cdot \frac{\tau_a}{\eta_2}$$

where:

A_f = sectional area, in mm^2, of the floor panel adjacent to hoppers

$A_{f,h}$ = net sectional area, in mm^2, of the floor panels in way of the openings in the "outermost" bay

S22
cont'd

(i.e. that bay which is closest to hopper)

τ_a = allowable shear stress, in N/mm^2, to be taken equal to : $\sigma_F / \sqrt{3}$

σ_F = minimum upper yield stress, in N/mm^2, of the material

η_1 = 1,10

η_2 = 1,20
η_2 may be reduced, at the Society's discretion, down to 1,10 where appropriate reinforcements are fitted to the Society's satisfaction

S22.3.2 - Girder shear strength

The girder shear strength in way of the girder panel adjacent to stools (or transverse bulkheads, if no stool is fitted) S_{g1}, in kN, and the girder shear strength in way of the largest opening in the "outermost" bay (i.e. that bay which is closest to stool, or transverse bulkhead, if no stool is fitted) S_{g2}, in kN, are given by the following expressions:

$$S_{g1} = 10^{-3} \cdot A_g \cdot \frac{\tau_a}{\eta_1}$$

$$S_{g2} = 10^{-3} \cdot A_{g,h} \cdot \frac{\tau_a}{\eta_2}$$

where:

A_g = minimum sectional area, in mm^2, of the girder panel adjacent to stools (or transverse bulkheads, if no stool is fitted)

$A_{g,h}$ = net sectional area, in mm^2, of the girder panel in way of the largest opening in the "outermost" bay (i.e. that bay which is closest to stool, or transverse bulkhead, if no stool is fitted)

τ_a = allowable shear stress, in N/mm^2, as given in S22.3.1

η_1 = 1,10

η_2 = 1,15
η_2 may be reduced, at the Society's discretion, down to 1,10 where appropriate reinforcements are fitted to the Society's satisfaction

S22.4 - Allowable hold loading

The allowable hold loading W, in t, is given by:

$$W = \rho_c \cdot V \cdot \frac{1}{F}$$

where:

F = 1,05 in general
1,00 for steel mill products

ρ_c = cargo density, in t/m^3; for bulk cargoes see S22.2.1; for steel products, ρ_c is to be taken as the

S22
cont'd

density of steel

V = volume, in m^3, occupied by cargo at a level h_1

$$h_1 = \frac{X}{\rho_c \cdot g}$$

X = for bulk cargoes, the lesser of X_1 and X_2 given by

$$X_1 = \frac{Z + \rho \cdot g \cdot (E - h_f)}{1 + \frac{\rho}{\rho_c}\ (perm - 1)}$$

$$X_2 = Z + \rho \cdot g \cdot (E - h_f \cdot perm)$$

X = for steel products, X may be taken as X_1, using perm = 0

ρ = sea water density, in t/m^3

g = 9,81 m/s^2, gravity acceleration

E = d_f - 0,1 · D

d_f, D = as given in S22.2.2

h_f = flooding head, in m, as defined in S22.2.2

perm = permeability of cargo, to be taken as 0,3 for ore (corresponding bulk cargo density for iron ore may generally be taken as 3,0 t/m^3).

Z = the lesser of Z1 and Z2 given by:

$$Z_1 = \frac{C_h}{A_{DB,h}}$$

$$Z_2 = \frac{C_e}{A_{DB,e}}$$

C_h= shear capacity of the double bottom, in kN, as defined in S22.3, considering, for each floor, the lesser of the shear strengths S_{f1} and S_{f2} (see S22.3.1) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (see S22.3.2)

C_e= shear capacity of the double bottom, in kN, as defined in S22.3, considering, for each floor, the shear strength S_{f1} (see S22.3.1) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (see S22.3.2)

S22
cont'd

$$A_{DB,h} = \sum_{i=1}^{i=n} S_i \cdot B_{DB,i}$$

$$A_{DB,e} = \sum_{i=1}^{i=n} S_i \cdot B_{DB} - s$$

n = number of floors between stools (or transverse bulkheads, if no stool is fitted)

S_i = space of ith-floor, in m

$B_{DB,i} = B_{DB}$ - s for floors whose shear strength is given by Sf_1 (see S22.3.1)

$B_{DB,i} = B_{DB,h}$ for floors whose shear strength is given by Sf_2 (see S22.3.1)

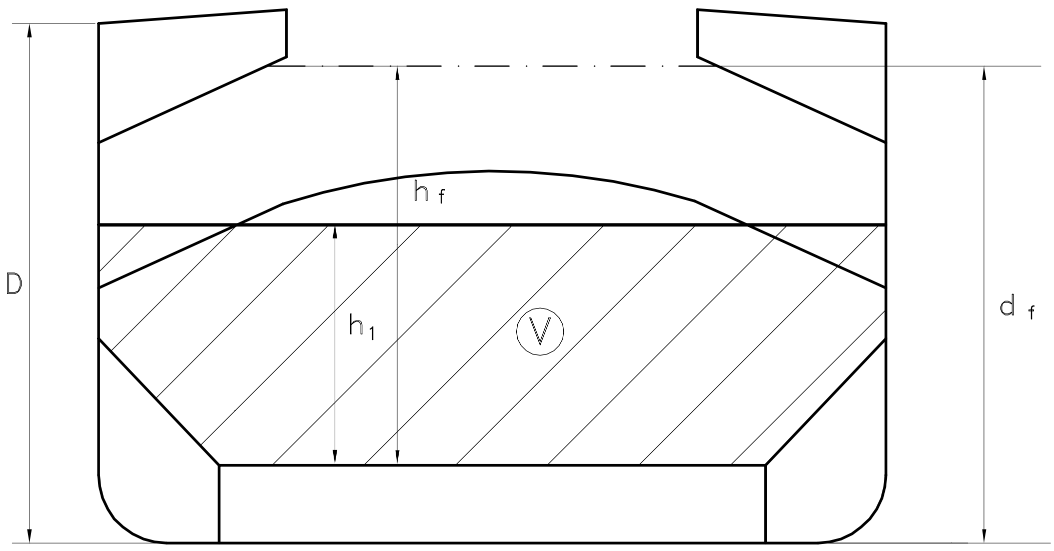
B_{DB} = breadth of double bottom, in m, between hoppers (see Figure 3)

$B_{DB,h}$= distance, in m, between the two considered opening (see Figure 3)

s = spacing, in m, of double bottom longitudinals adjacent to hoppers

S22
cont'd

Figure 1



V = Volume of cargo

S22
cont'd

Figure 2

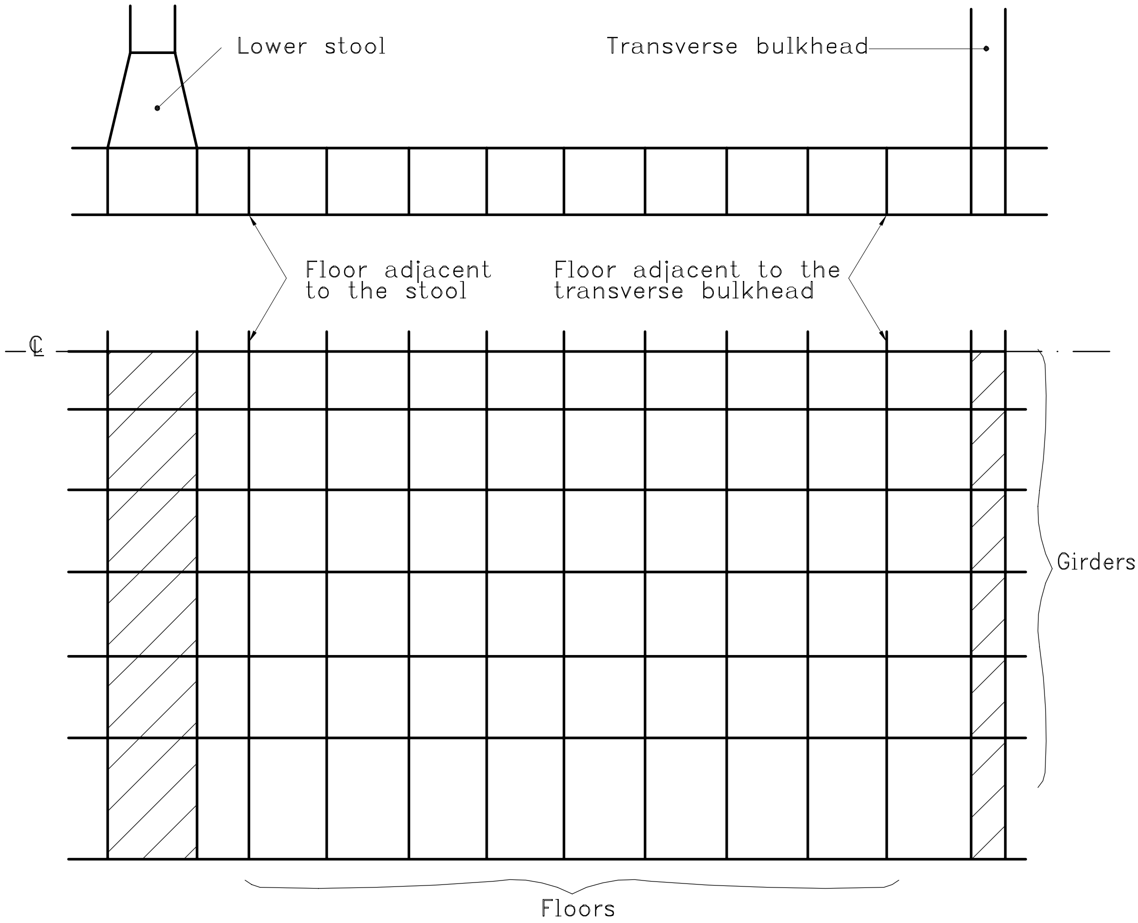
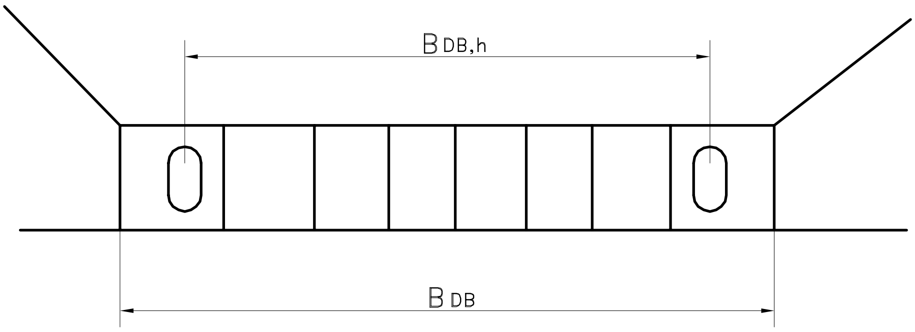


Figure 3



END

S23
(1997)
(Rev. 1 1997)
(Rev. 2 April 1998)
(Rev. 2.1 November 1998)
(Rev.3 Mar. 2002)
(Rev.3.1 Dec.2002)

Implementation of IACS Unified Requirements S19 and S22 for Existing Single Side Skin Bulk Carriers

S23.1 Application and Implementation Timetable*

a. Unified Requirements S19 and S22 are to be applied in conjunction with the damage stability requirements set forth in S23.2. Compliance is required:

i for ships which were 20 years of age or more on 1 July 1998, by the due date of the first intermediate, or the due date of the first special survey to be held after 1 July 1998, whichever comes first;

ii. for ships which were 15 years of age or more but less than 20 years of age on 1 July 1998, by the due date of the first special survey to be held after 1 July 1998, but not later than 1 July 2002;

iii. for ships which were 10 years of age or more but less than 15 years of age on 1 July 1998, by the due date of the first intermediate, or the due date of the first special survey to be held after the date on which the ship reaches 15 years of age but not later than the date on which the ship reaches 17 years of age;

iv. for ships which were 5 years of age or more but less than 10 years of age on 1 July 1998, by the due date, after 1 July 2003, of the first intermediate or the first special survey after the date on which the ship reaches 10 years of age, whichever occurs first;

v. for ships which were less than 5 years of age on 1 July 1998, by the date on which the ship reaches 10 years of age.

b. Completion prior to 1 July 2003 of an intermediate or special survey with a due date after 1 July 2003 cannot be used to postpone compliance. However, completion prior to 1 July 2003 of an intermediate survey the window for which straddles 1 July 2003 can be accepted.

S23.2 Damage Stability

a. Bulk carriers which are subject to compliance with Unified Requirements S19 and S22 shall, when loaded to the summer loadline, be able to withstand flooding of the foremost cargo hold in all loading conditions and remain afloat in a satisfactory condition of equilibrium, as specified in SOLAS regulation XII/4.2 to 4.6.

b. A ship having been built with an insufficient number of transverse watertight bulkheads to satisfy this requirement may be exempted from the application of Unified Requirements S19, S22 and this requirement provided the ship fulfills the requirement in SOLAS regulation XII/9.

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* See Annex for details.

S23
cont'd

Annex

1. Surveys to be held
The term "survey to be held" is interpreted to mean that the survey is "being held" until it is "completed".

2. Due dates and completion allowance

2.1 intermediate survey :

2.1.1 Intermediate survey carried out either at the second or third annual survey: 3 months after the due date (i.e. 2nd or 3rd anniversary) can be used to carry out and complete the survey;

2.1.2 Intermediate survey carried out between the second and third annual survey: 3 months after the due date of the 3rd Annual Survey can be used to carry out and complete the survey;

2.2 special survey : 3 months extension after the due date may be allowed subject to the terms/conditions of PR4;

2.3 ships controlled by "1 July 2002": same as for special survey;

2.4 ships controlled by "age 15 years" or "age 17 years": same as for special survey.

3. Intermediate Survey Interpretations/Applications

3.1 If the 2nd anniversary is prior to or on 1 July 1998 and the intermediate survey is completed prior to or on 1 July 1998, the ship need not comply until the next special survey.

3.2 If the 2nd anniversary is prior to or on 1 July 1998 and the intermediate survey is completed within the window of the 2nd annual survey but after 1 July 1998, the ship need not comply until the next special survey.

3.3 If the 2nd anniversary is prior to or on 1 July 1998 and the intermediate survey is completed outside the window of the 2nd annual survey and after 1 July 1998, it is taken that the intermediate survey is held after 1 July 1998 and between the second and third annual surveys. Therefore, the ship shall comply no later than 3 months after the 3rd anniversary.

3.4 If the 2nd anniversary is after 1 July 1998 and the intermediate survey is completed within the window of the 2nd annual survey but prior to or on 1 July 1998, the ship need not comply until the next special survey

3.5 If the 3rd anniversary is prior to or on 1 July 1998 and the intermediate survey is completed prior to or on 1 July 1998, the ship need not comply until the next special survey.

3.6 If the 3rd anniversary is prior to or on 1 July 1998 and the intermediate survey is completed within the window of the 3rd annual survey but after 1 July 1998, the ship need not comply until the next special survey.

3.7 If the 3rd anniversary is after 1 July 1998 and the intermediate survey is completed within the window prior to or on 1 July 1998, the ship need not comply until the next special survey.

4. Special Survey Interpretations/Applications

4.1 If the due date of a special survey is after 1 July 1998 and the special survey is completed within the 3 month window prior to the due date and prior to or on 1 July 1998, the ship need not comply until the next relevant survey (i.e. special survey for ships under 20 years of age on 1 July 1998, intermediate survey for ships 20 years of age or more on 1 July 1998).

5. Early Completion of an Intermediate Survey (coming due after 1 July 1998 to postpone compliance is not allowed):

5.1 Early completion of an intermediate survey means completion of the survey prior to the opening of the window (i.e. completion more than 3 months prior to the 2nd anniversary since the last special survey).

5.2 The intermediate survey may be completed early and credited from the completion date but in such a case the ship will still be required to comply not later than 3 months after the 3rd anniversary.

6. Early Completion of a Special Survey (coming due after 1 July 1998 to postpone compliance is not allowed):

6.1 Early completion of a special survey means completion of the survey more than 3 months prior to the due date of the special survey.

6.2 The special survey may be completed early and credited from the completion date, but in such a case the ship will still be required to comply by the due date of the special survey.

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S24
(September
1998)
(Deleted
Jan2004)

Detection of Water Ingress into Cargo Holds of Bulk Carriers

URS24 superceded by UI SC 179 and SC 180

Deleted on 1 January 2004

▶

S25
(June 2002)
(Rev.1 Feb. 2003)
(Corr.1, May 2004)
(Rev.2 July 2004)

Harmonised Notations and Corresponding Design Loading Conditions for Bulk Carriers

1 Preamble

1.1 This document is an outcome of IACS SC/BCS with a view to providing improved transparency with regard to the cargo carrying capabilities of bulk carriers by assigning harmonised notations and applying corresponding unified design loading conditions among the IACS classification societies.

1.2 This document is not intended to prevent any other loading conditions to be included in the loading manual for which calculations are to be submitted as required by the relevant UR, nor is it intended to replace in any way the required loading manual/instrument.

1.3 A bulk carrier 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.

2 Application

2.1 This resolution is applicable to "Bulk Carrier" as defined in UR Z11.2.2, having length as defined in UR S2.1 of 150 m or above and contracted for new construction(1) on or after 1 July 2003.

2.2 The loading conditions listed under Section 4 are to be used for the checking of rules criteria regarding longitudinal strength(2), local strength, capacity and disposition of ballast tanks and stability. The loading conditions listed under Section 5 are to be used for the checking of rule criteria regarding local strength.

2.3 For the purpose of applying the conditions given in this document, maximum draught is to be taken as moulded summer load line draught.

3 Harmonized notations and annotations

Bulk Carriers are to be assigned one of the following notations.

BC-A : for bulk carriers designed to carry dry bulk cargoes of cargo density 1.0 tonne/m^3 and above with specified holds empty at maximum draught in addition to BC-B conditions.

BC-B : for bulk carriers designed to carry dry bulk cargoes of cargo density of 1.0 tonne/m^3 and above with all cargo holds loaded in addition to BC-C conditions.

BC-C : for bulk carriers designed to carry dry bulk cargoes of cargo density less than 1.0 tonne/m^3.

Note (1) The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.

(2) As required by URs S7, S11 and S17

S25
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The following additional notations and annotations are to be provided giving further detailed description of limitations to be observed during operation as a consequence of the design loading condition applied during the design in the following cases:

i. additional notations;
{maximum cargo density (in tonnes/m^3)} for notations BC-A and BC-B if the maximum cargo density is less than 3.0 tonnes/m^3 ;
{no MP} for all notations when the vessel has not been designed for loading and unloading in multiple ports in accordance with the conditions specified in Section 5.3.

ii. annotations;
{allowed combination of specified empty holds} for notation BC-A.

4 Design loading conditions (General)

4.1 BC-C

Homogeneous cargo loaded condition where the cargo density corresponds to all cargo holds, including hatchways, being 100% full at maximum draught with all ballast tanks empty.

4.2 BC-B

As required for BC-C, plus:

Homogeneous cargo loaded condition with cargo density 3.0 tonnes/m^3, and the same filling rate (cargo mass/hold cubic capacity) in all cargo holds at maximum draught with all ballast tanks empty.

In cases where the cargo density applied for this design loading condition is less than 3.0 tonnes/m^3, the maximum density of the cargo that the vessel is allowed to carry is to be indicated with the additional notation {maximum cargo density x.y tonnes/m^3}.

4.3 BC-A

As required for BC-B, plus:

At least one cargo loaded condition with specified holds empty, with cargo density 3.0 tonnes/m^3, and the same filling rate (cargo mass/hold cubic capacity) in all loaded cargo holds at maximum draught with all ballast tanks empty.

The combination of specified empty holds shall be indicated with the annotation {holds a, b,…. may be empty}.

In such cases where the design cargo density applied is less than 3.0 tonnes/m^3, the maximum density of the cargo that the vessel is allowed to carry shall be indicated within the annotation, e.g. {holds a, b,…. may be empty, with maximum cargo density x.y tonnes/m^3}.

S25
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4.4 Ballast conditions (applicable to all notations)

4.4.1 Ballast tank capacity and disposition

All bulk carriers are to have ballast tanks of sufficient capacity and so disposed to at least fulfill the following requirements.

4.4.1(a)Normal ballast condition

Normal ballast condition for the purpose of this Unified Requirement is a ballast (no cargo) condition where:

i. the ballast tanks may be full, partially full or empty. Where partially full option is exercised, the conditions in S11.2.1.3 of UR S11, Rev.3 are to be complied with,

ii. any cargo hold or holds adapted for the carriage of water ballast at sea are to be empty,

iii. the propeller is to be fully immersed, and

iv. the trim is to be by the stern and is not to exceed 0.015L, where L is the length between perpendiculars of the ship.

In the assessment of the propeller immersion and trim, the draughts at the forward and after perpendiculars may be used.

4.4.1(b) Heavy ballast condition

Heavy ballast condition for the purpose of this Unified Requirement is a ballast (no cargo) condition where:

i. the ballast tanks may be full, partially full or empty. Where partially full option is exercised, the conditions in S11.2.1.3 of UR S11, Rev.3 are to be complied with,

ii. at least one cargo hold adapted for carriage of water ballast at sea, where required or provided, is to be full,

iii. the propeller immersion I/D is to be at least 60% where
   I = the distance from propeller centerline to the waterline
   D = propeller diameter, and

iv. the trim is to be by the stern and is not to exceed 0.015L, where L is the length between perpendiculars of the ship,

v. the moulded forward draught in the heavy ballast condition is not to be less than the smaller of 0.03L or 8 m.

S25
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4.4.2 Strength requirements

All bulk carriers are to meet the following strength requirements:

4.4.2(a) Normal ballast condition

i. the structures of bottom forward are to be strengthened in accordance with the Rules of the Society against slamming for the condition of 4.4.1(a) at the lightest forward draught,

ii. the longitudinal strength requirements are to be met for the condition of 4.4.1(a), and

iii. in addition, the longitudinal strength requirements are to be met with all ballast tanks 100 % full.

4.4.2(b) Heavy ballast condition

i. the longitudinal strength requirements are to be met for the condition of 4.4.1(b),

ii. in addition to the conditions in 4.4.2(b)i, the longitudinal strength requirements are to be met under a condition with all ballast tanks 100 % full and one cargo hold adapted and designated for the carriage of water ballast at sea, where provided, 100 % full, and

iii. where more than one hold is adapted and designated for the carriage of water ballast at sea, it will not be required that two or more holds be assumed 100 % full simultaneously in the longitudinal strength assessment, unless such conditions are expected in the heavy ballast condition. Unless each hold is individually investigated, the designated heavy ballast hold and any/all restrictions for the use of other ballast hold(s) are to be indicated in the loading manual.

4.5 Departure and arrival conditions

Unless otherwise specified, each of the design loading conditions defined in 4.1 to 4.4 is to be investigated for the arrival and departure conditions as defined below.

Departure condition:	with bunker tanks not less than 95 % full and other consumables 100 %
Arrival condition:	with 10% of consumables.

S25
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5. Design loading conditions (for local strength)

5.1 Definitions

The maximum allowable or minimum required cargo mass in a cargo hold, or in two adjacently loaded holds, is related to the net load on the double bottom. The net load on the double bottom is a function of draft, cargo mass in the cargo hold, as well as the mass of fuel oil and ballast water contained in double bottom tanks.
The following definitions apply:

M_H: the actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught.

M_{Full}: the cargo mass in a cargo hold corresponding to cargo with virtual density (homogeneous mass/hold cubic capacity, minimum 1.0 tonne/m^3) filled to the top of the hatch coaming. M_{Full} is in no case to be less than M_H.

M_{HD}: the maximum cargo mass allowed to be carried in a cargo hold according to design loading condition(s) with specified holds empty at maximum draft.

5.2 General conditions applicable for all notations

5.2.1 Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught.

5.2.2 Any cargo hold is to be capable of carrying minimum 50% of M_H, with all double bottom tanks in way of the cargo hold being empty, at maximum draught.

5.2.3 Any cargo hold is to be capable of being empty, with all double bottom tanks in way of the cargo hold being empty, at the deepest ballast draught.

5.3 Condition applicable for all notations, except when notation {no MP} is assigned

5.3.1 Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of maximum draught.

5.3.2 Any cargo hold is to be capable of being empty with all double bottom tanks in way of the cargo hold being empty, at 83% of maximum draught.

5.3.3 Any two adjacent cargo holds are to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of the maximum draught. This requirement to the mass of cargo and fuel oil in double bottom tanks in way of the cargo hold applies also to the condition where the adjacent hold is filled with ballast, if applicable.

S25
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5.3.4 Any two adjacent cargo holds are to be capable of being empty, with all double bottom tanks in way of the cargo hold being empty, at 75% of maximum draught.

5.4 Additional conditions applicable for BC-A notation only

5.4.1 Cargo holds, which are intended to be empty at maximum draught, are to be capable of being empty with all double bottom tanks in way of the cargo hold also being empty.

5.4.2 Cargo holds, which are intended to be loaded with high density cargo, are to be capable of carrying M_{HD} plus 10% of M_H, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom being empty in way of the cargo hold, at maximum draught.

In operation the maximum allowable cargo mass shall be limited to M_{HD}.

5.4.3 Any two adjacent cargo holds which according to a design loading condition may be loaded with the next holds being empty, are to be capable of carrying 10% of M_H in each hold in addition to the maximum cargo load according to that design loading condition, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught.

In operation the maximum allowable mass shall be limited to the maximum cargo load according to the design loading conditions.

5.5 Additional conditions applicable for ballast hold(s) only

5.5.1 Cargo holds, which are designed as ballast water holds, are to be capable of being 100% full of ballast water including hatchways, with all double bottom tanks in way of the cargo hold being 100% full, at any heavy ballast draught. For ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty.

5.6 Additional conditions applicable during loading and unloading in harbour only

5.6.1 Any single cargo hold is to be capable of holding the maximum allowable sea-going mass at 67% of maximum draught, in harbour condition.

5.6.2 Any two adjacent cargo holds are to be capable of carrying M_{Full} ,with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of maximum draught, in harbour condition.

S25
cont'd

5.6.3 At reduced draught during loading and unloading in harbour, the maximum allowable mass in a cargo hold may be increased by 15% of the maximum mass allowed at the maximum draught in sea-going condition, but shall not exceed the mass allowed at maximum draught in the sea-going condition. The minimum required mass may be reduced by the same amount.

5.7 Hold mass curves

Based on the design loading criteria for local strength, as given in 5.2 to 5.6 (except 5.5.1) above, hold mass curves are to be included in the loading manual and the loading instrument, showing maximum allowable and minimum required mass as a function of draught, in sea-going condition as well as during loading and unloading in harbour (See IACS UR S1A).

At other draughts than those specified in the design loading conditions above, the maximum allowable and minimum required mass is to be adjusted for the change in buoyancy acting on the bottom. Change in buoyancy is to be calculated using water plane area at each draught.
Hold mass curves for each single hold, as well as for any two adjacent holds, are to be included.

END

S 26
(Nov. 2002)
(Rev.1, Nov 2003)
(Rev.2 July 2004)

STRENGTH AND SECURING OF SMALL HATCHES ON THE EXPOSED FORE DECK

1. General

1.1 The strength of, and securing devices for, small hatches fitted on the exposed fore deck are to comply with the requirements of this UR.

1.2 Small hatches in the context of this UR are hatches designed for access to spaces below the deck and are capable to be closed weather-tight or watertight, as applicable. Their opening is normally 2.5 square meters or less.

1.3 Hatches designed for use of emergency escape are to comply with the requirements of this UR, excepting 5.1 (i) and (ii), 6.3 and 7.

2. Application

2.1 For ships that are contracted for construction on or after 1 January 2004 on the exposed deck over the forward 0.25L, applicable to:

All ship types of sea going service of length 80 m or more, where
the height of the exposed deck in way of the hatch is less than 0.1L or 22 m above the summer load waterline, whichever is the lesser.

2.2 For ships that are contracted for construction prior to 1 January 2004 only for hatches on the exposed deck giving access to spaces forward of the collision bulkhead, and to spaces which extend over this line aft-wards, applicable to:

Bulk carriers, ore carriers, and combination carriers (as defined in UR Z11) and general dry cargo ships (excluding container vessels, vehicle carriers, Ro-Ro ships and woodchip carriers), of length 100m or more.

2.3 The ship length L is as defined in UR S2.

3. Implementation

3.1 Ships that are described in paragraph 2.1 that are contracted for construction on or after 1 January 2004 are to comply by the time of delivery.

3.2 Ships described in paragraph 2.2 that are contracted for construction prior to 1 January 2004 are to comply:

i) for ships which will be 15 years of age or more on 1 January 2004 by the due date of the first intermediate or special survey after that date;

ii) for ships which will be 10 years of age or more on 1 January 2004 by the due date of the first special survey after that date;

iii) for ships which will be less than 10 years of age on 1 January 2004 by the date on which the ship reaches 10 years of age.

Completion prior to 1 January 2004 of an intermediate or special survey with a due date after 1 January 2004 cannot be used to postpone compliance.
However, completion prior to 1 January 2004 of an intermediate survey the window for which straddles 1 January 2004 can be accepted.

Note:
1. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.

4. Strength

4.1 For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with Table 1, and Figure 1. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in 6.1, see Figure 1. Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener, see Figure 2.

4.2 The upper edge of the hatchway coamings is to be suitably reinforced by a horizontal section, normally not more than 170 to 190 mm from the upper edge of the coamings.

4.3 For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement is to be according to the requirements of each Society.

4.4 For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

5. Primary Securing Devices

5.1 Small hatches located on exposed fore deck subject to the application of this UR are to be fitted with primary securing devices such that their hatch covers can be secured in place and weather-tight by means of a mechanism employing any one of the following methods:

i) Butterfly nuts tightening onto forks (clamps),
ii) Quick acting cleats, or
iii) Central locking device.

5.2 Dogs (twist tightening handles) with wedges are not acceptable.

6. Requirements for Primary Securing

6.1 The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device in accordance with Figure 1, and of sufficient capacity to withstand the bearing force.

6.2 The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.

6.3 For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimize the risk of butterfly nuts being dislodged while in use; by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is not to be less than 16 mm. An example arrangement is shown in Figure 2.

6.4 For small hatch covers located on the exposed deck forward of the fore-most cargo hatch, the hinges are to be fitted such that the predominant direction of green sea will cause the cover to close, which means that the hinges are normally to be located on the fore edge.

S 26
cont'd

6.5 On small hatches located between the main hatches, for example between Nos. 1 and 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

7. Secondary Securing Device

Small hatches on the fore deck are to be fitted with an independent secondary securing device e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

Table 1 : Scantlings for Small Steel Hatch Covers on the Fore Deck

Nominal size (mm x mm)	Cover plate thickness (mm)	Primary stiffeners	Secondary stiffeners
		Flat Bar (mm x mm); number	
630 x 630	8	-	-
630 x 830	8	100 x 8 ; 1	-
830 x 630	8	100 x 8 ; 1	-
830 x 830	8	100 x 10 ; 1	-
1030 x 1030	8	120 x 12 ; 1	80 x 8 ; 2
1330 x 1330	8	150 x 12 ; 2	100 x 10 ; 2

S 26
cont'd

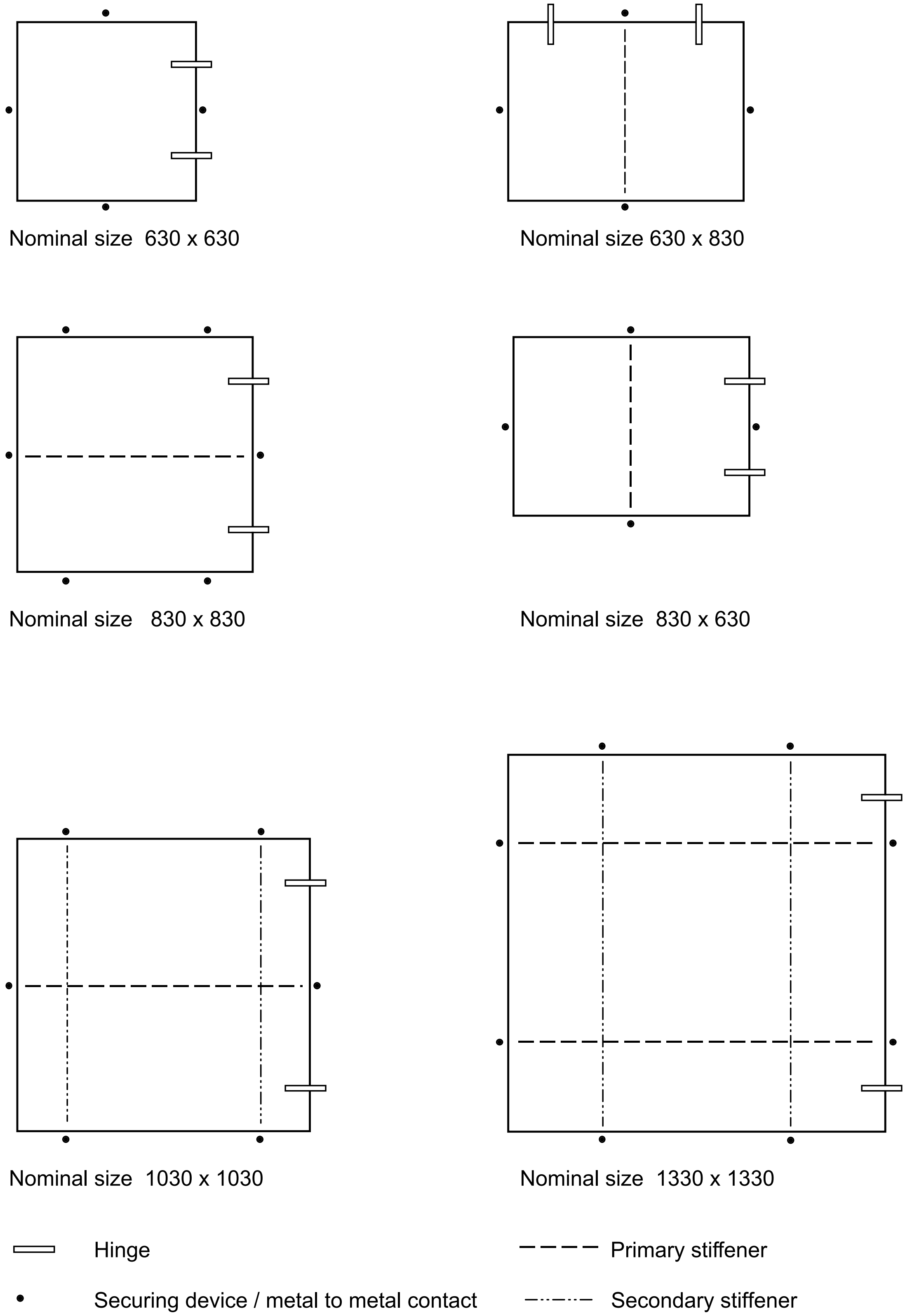

Figure 1. Arrangement of Stiffeners

S 26
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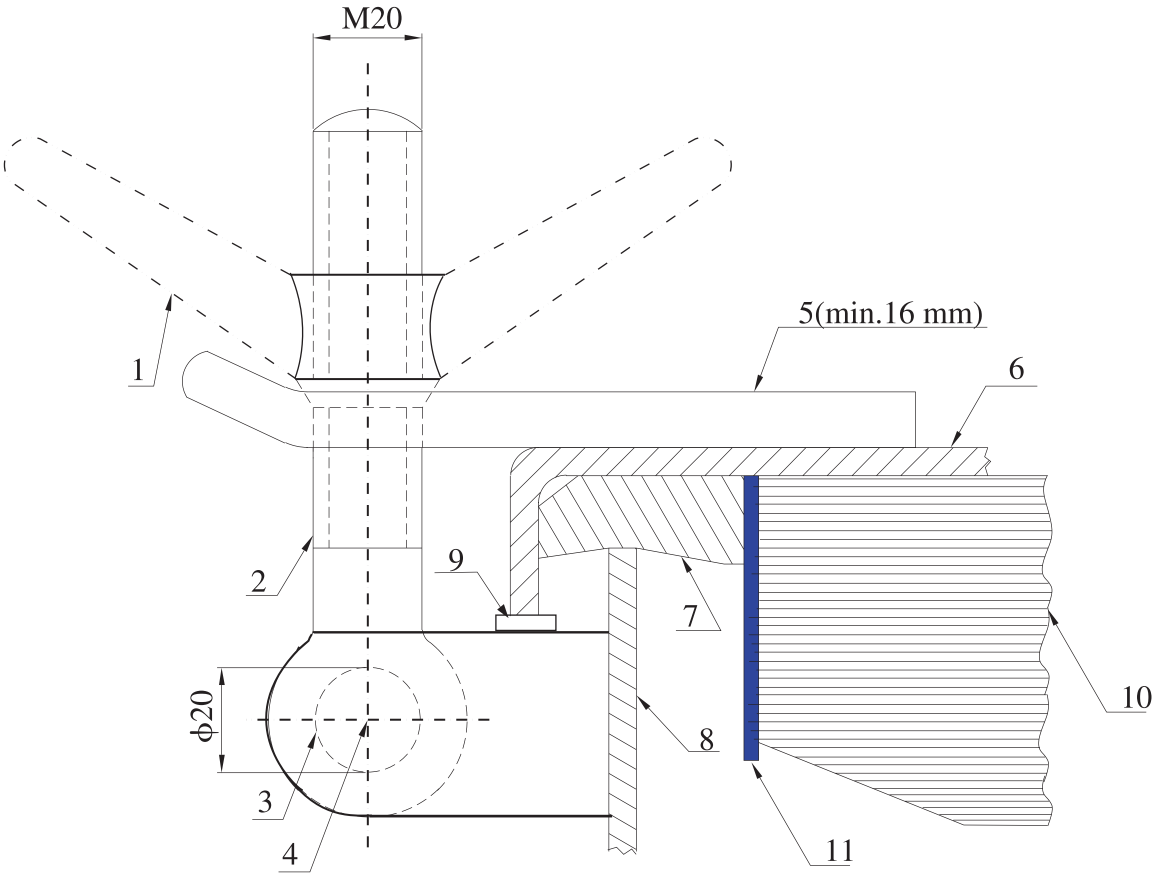

1: butterfly nut
2: bolt
3: pin
4: center of pin
5: fork (clamp) plate
6: hatch cover
7: gasket
8: hatch coaming
9: bearing pad welded on the bracket of a toggle bolt for metal to metal contact
10: stiffener
11: inner edge stiffener

(Note: Dimensions in millimeters)

Figure 2. Example of a Primary Securing Method

END

S 27
(Nov. 2002)
(Rev.1 March 2003)
(Corr.1 July 2003)
(Rev.2 Nov. 2003)
(Rev.3 July 2004)

STRENGTH REQUIREMENTS FOR FORE DECK FITTINGS AND EQUIPMENT

1. General

1.1 This UR S 27 provides strength requirements to resist green sea forces for the following items located within the forward quarter length:

air pipes, ventilator pipes and their closing devices, the securing of windlasses.

1.2 For windlasses, these requirements are additional to those appertaining to the anchor and chain performance criteria of each Society.

1.3 Where mooring winches are integral with the anchor windlass, they are to be considered as part of the windlass.

2. Application

2.1 For ships that are contracted for construction on or after 1January 2004 on the exposed deck over the forward 0.25L, applicable to:

All ship types of sea going service of length 80 m or more, where the height of the exposed deck in way of the item is less than 0.1L or 22 m above the summer load waterline, whichever is the lesser.

2.2 For ships that are contracted for construction prior to 1January 2004 only for air pipes, ventilator pipes and their closing devices on the exposed deck serving spaces forward of the collision bulkhead, and to spaces which extend over this line aft-wards, applicable to:

Bulk carriers, ore carriers, and combination carriers (as defined in UR Z11) and general dry cargo ships (excluding container vessels, vehicle carriers, Ro-Ro ships and woodchip carriers), of length100m or more.

2.3 The ship length L is as defined in UR S2.

3. Implementation

3.1 Ships that are described in paragraph 2.1 that are contracted for construction on or after 1 January 2004 are to comply by the time of delivery.

3.2 Ships described in paragraph 2.2 that are contracted for construction prior to 1 January 2004 are to comply:

i) for ships which will be 15 years of age or more on 1 January 2004 by the due date of the first intermediate or special survey after that date;

ii) for ships which will be 10 years of age or more on 1 January 2004 by the due date of the first special survey after that date;

iii) for ships which will be less than 10 years of age on 1 January 2004 by the date on which the ship reaches 10 years of age.

Note:
1. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.

Completion prior to 1 January 2004 of an intermediate or special survey with a due date after 1 January 2004 cannot be used to postpone compliance. However, completion prior to 1 January 2004 of an intermediate survey the window for which straddles 1 January 2004 can be accepted.

4. Applied Loading

4.1 Air pipes, ventilator pipes and their closing devices

4.1.1 The pressures p, in kN/m^2 acting on air pipes, ventilator pipes and their closing devices may be calculated from:

$$p = 0.5 \rho V^2 C_d C_s C_p$$

where:

ρ = density of sea water (1.025 t/m^3)
V = velocity of water over the fore deck (13.5 m/sec)
C_d = shape coefficient
= 0.5 for pipes, 1.3 for air pipe or ventilator heads in general, 0.8 for an air pipe or ventilator head of cylinderical form with its axis in the vertical direction.
C_s = slamming coefficient (3.2)
C_p = protection coefficient:
(0.7) for pipes and ventilator heads located immediately behind a breakwater or forecastle,
(1.0) elsewhere and immediately behind a bulwark.

4.1.2 Forces acting in the horizontal direction on the pipe and its closing device may be calculated from 4.1.1 using the largest projected area of each component.

4.2 Windlasses

4.2.1 The following pressures and associated areas are to be applied (see Figure 1):

- 200 kN/m^2 normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction,
- 150 kN/m^2 parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of f times the projected area in this direction,
  where f is defined as:
  $f = 1 + B/H$, but not greater than 2.5
  where:
  B = width of windlass measured parallel to the shaft axis,
  H = overall height of windlass.

4.2.2 Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by N bolt groups, each containing one or more bolts, see Figure 2.

4.2.3 The axial force R_i in bolt group (or bolt) i, positive in tension, may be calculated from:

$$R_{xi} = P_x h x_i A_i / I_x$$
$$R_{yi} = P_y h y_i A_i / I_y$$

S 27
cont'd

and $R_i = R_{xi} + R_{yi} - R_{si}$

where:

P_x = force (kN) acting normal to the shaft axis
P_y = force (kN) acting parallel to the shaft axis, either inboard or outboard whichever gives the greater force in bolt group *i*
h = shaft height above the windlass mounting(cm)
x_i , y_i = *x* and *y* coordinates of bolt group *i* from the centroid of all *N* bolt groups, positive in the direction opposite to that of the applied force(cm)
A_i = cross sectional area of all bolts in group *i* (cm^2)
I_x = $\Sigma A_i x_i^2$ for *N* bolt groups
I_y = $\Sigma A_i y_i^2$ for *N* bolt groups
R_{si} = static reaction at bolt group *i*, due to weight of windlass.

4.2.4 Shear forces F_{xi} , F_{yi} applied to the bolt group *i*, and the resultant combined force F_i may be calculated from:

$$F_{xi} = (P_x - \alpha g M) / N$$

$$F_{yi} = (P_y - \alpha g M) / N$$

and

$$F_i = (F_{xi}^2 + F_{yi}^2)^{0.5}$$

where:

α = coefficient of friction (0.5)
M = mass of windlass (tonnes)
g = gravity acceleration (9.81 m/sec^2)
N = number of bolt groups.

4.2.5 Axial tensile and compressive forces in 4.2.3 and lateral forces in 4.2.4 are also to be considered in the design of the supporting structure.

5. Strength Requirements

5.1 Air pipes, ventilator pipes and their closing devices

5.1.1 These requirements are additional to IACS Unified Requirement P3 and Unified Interpretation LL36 **(Footnote *)**.

5.1.2 Bending moments and stresses in air and ventilator pipes are to be calculated at critical positions: at penetration pieces, at weld or flange connections, at toes of supporting brackets. Bending stresses in the net section are not to exceed 0.8 σ_y, where σ_y is the specified minimum yield stress or 0.2% proof stress of the steel at room temperature. Irrespective of corrosion protection, a corrosion addition to the net section of 2.0 mm is then to be applied.

Footnote *: This does not mean that closing devices of air pipes on all existing ships subject to S27 need to be upgraded to comply with UR P3.

S 27
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5.1.3 For standard air pipes of 760 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 1. Where brackets are required, three or more radial brackets are to be fitted. Brackets are to be of gross thickness 8 mm or more, of minimum length 100 mm, and height according to Table 1 but need not extend over the joint flange for the head. Bracket toes at the deck are to be suitably supported.

5.1.4 For other configurations, loads according to 4.1 are to be applied, and means of support determined in order to comply with the requirements of 5.1.2. Brackets, where fitted, are to be of suitable thickness and length according to their height. Pipe thickness is not to be taken less than as indicated in IACS UI LL 36.

5.1.5 For standard ventilators of 900 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 2. Brackets, where required are to be as specified in 5.1.3.

5.1.6 For ventilators of height greater than 900 mm, brackets or alternative means of support are to be fitted according to the requirements of each Society. Pipe thickness is not to be taken less than as indicated in IACS UI LL 36.

5.1.7 All component parts and connections of the air pipe or ventilator are to be capable of withstanding the loads defined in 4.1

5.1.8 Rotating type mushroom ventilator heads are unsuitable for application in the areas defined in 2.

5.2 Windlass Mounts

5.2.1 Tensile axial stresses in the individual bolts in each bolt group i are to be calculated. The horizontal forces F_{xi} and F_{yi} are normally to be reacted by shear chocks. Where "fitted" bolts are designed to support these shear forces in one or both directions, the von Mises equivalent stresses in the individual bolts are to be calculated, and compared to the stress under proof load. Where pour-able resins are incorporated in the holding down arrangements, due account is to be taken in the calculations.

The safety factor against bolt proof strength is to be not less than 2.0.

5.2.2 The strength of above deck framing and hull structure supporting the windlass and its securing bolt loads as defined in 4.2 is to be according to the requirements of each Society.

S 27
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Table 1 : 760 mm Air Pipe Thickness and Bracket Standards

Nominal pipe diameter (mm)	Minimum fitted gross thickness, LL36(c) (mm)	Maximum projected area of head (cm^2)	Height (1) of brackets (mm)
40A(3)	6.0	-	520
50A(3)	6.0	-	520
65A	6.0	-	480
80A	6.3	-	460
100A	7.0	-	380
125A	7.8	-	300
150A	8.5	-	300
175A	8.5	-	300
200A	8.5(2)	1900	300 (2)
250A	8.5(2)	2500	300 (2)
300A	8.5(2)	3200	300 (2)
350A	8.5(2)	3800	300 (2)
400A	8.5(2)	4500	300 (2)

(1) Brackets (see 5.1.3) need not extend over the joint flange for the head.
(2) Brackets are required where the as fitted (gross) thickness is less than 10.5 mm, or where the tabulated projected head area is exceeded.
(3) Not permitted for new ships - reference UR P1.
Note: For other air pipe heights, the relevant requirements of section 5 are to be applied.

Table 2 : 900 mm Ventilator Pipe Thickness and Bracket Standards

Nominal pipe diameter (mm)	Minimum fitted gross thickness, LL 36(c) (mm)	Maximum projected area of head (cm^2)	Height of brackets (mm)
80A	6.3	-	460
100A	7.0	-	380
150A	8.5	-	300
200A	8.5	550	-
250A	8.5	880	-
300A	8.5	1200	-
350A	8.5	2000	-
400A	8.5	2700	-
450A	8.5	3300	-
500A	8.5	4000	-

Note: For other ventilator heights, the relevant requirements of section 5 are to be applied.

S 27
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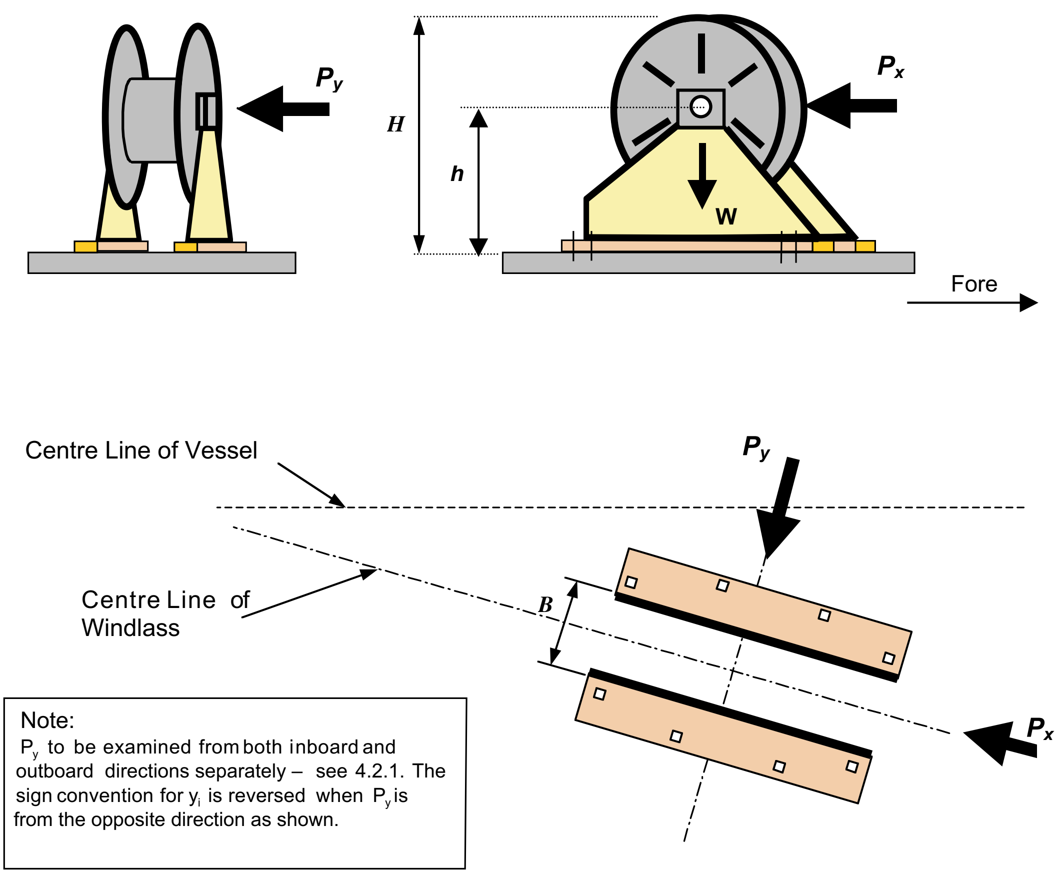


Figure 1. Direction of Forces and Weight

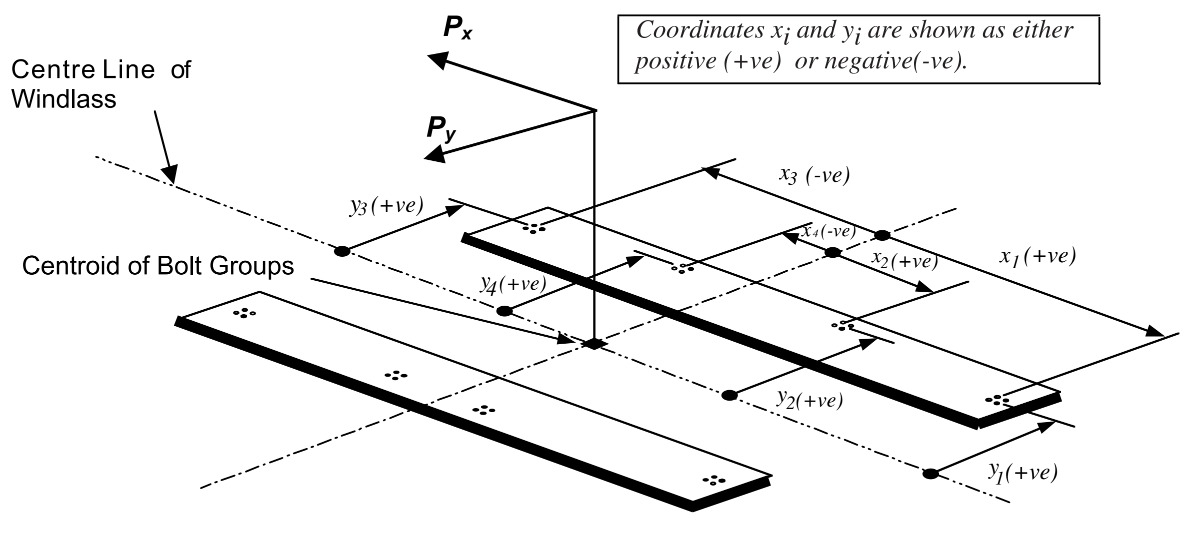


Figure 2. Sign Convention

END

S 28 Requirements for the Fitting of a Forecastle for Bulk Carriers, Ore Carriers and Combination Carriers

(May 2003) (Rev.1 July 2004)

S28.1 Application and definitions

These requirements apply to all bulk carriers, ore carriers and combination carriers, as defined in UR Z11, which are contracted for construction on or after 1 January 2004.

Such ships are to be fitted with an enclosed forecastle on the freeboard deck.

The required dimensions of the forecastle are defined in S28.2.

The structural arrangements and scantlings of the forecastle are to comply with the relevant Society's requirements.

S28.2 Dimensions

The forecastle is to be located on the freeboard deck with its aft bulkhead fitted in way or aft of the forward bulkhead of the foremost hold, as shown in Figure 1.

The forecastle height H_F above the main deck is to be not less than:

- the standard height of a superstructure as specified in the International Convention on Load Line 1966 and its Protocol of 1988, or
- H_C + 0.5 m, where H_C is the height of the forward transverse hatch coaming of cargo hold No.1,

whichever is the greater.

All points of the aft edge of the forecastle deck are to be located at a distance l_F :

$$l_F \le 5\sqrt{H_F - H_C}$$

from the hatch coaming plate in order to apply the reduced loading to the No.1 forward transverse hatch coaming and No.1 hatch cover in applying S21.4.1 and S21.5.2, respectively, of UR S21(Rev.3).

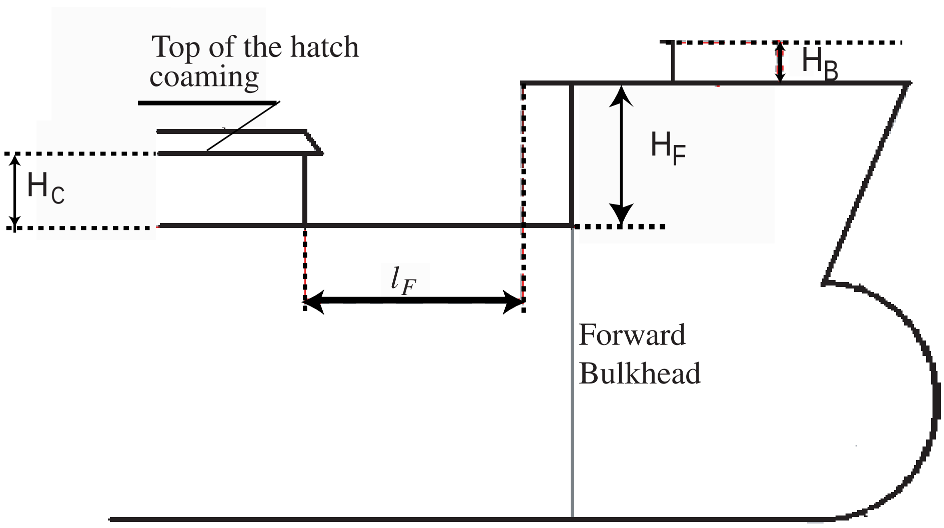
A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its upper edge at centre line is not less than H_B / tan20º forward of the aft edge of the forecastle deck, where H_B is the height of the breakwater above the forecastle (see Figure 1).

Note:

1. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.

S 28
(cont'd)

Figure 1



END

S30 (Jan. 2003) (Corr.1 May 2003) (Rev.1, August 2003)

Cargo Hatch Cover Securing Arrangements for Bulk Carriers not Built in accordance with UR S21 (Rev.3)

1. Application and Implementation

1.1 These requirements apply to all bulk carriers, as defined in UR Z11.2.2, which were not built in accordance with UR S21(Rev.3) and are for steel hatch cover securing devices and stoppers for cargo hold hatchways No.1 and No.2 which are wholly or partially within 0.25L of the fore perpendicular, except pontoon type hatch cover.

1.2 All bulk carriers not built in accordance with UR S21 (Rev.3) are to comply with the requirements of this UR in accordance with the following schedule:

i. For ships which will be 15 years of age or more on 1 January 2004 by the due date of the first intermediate or special survey after that date;

ii. For ships which will be 10 years of age or more on 1January 2004 by the due date of the first special survey after that date;

iii. For ships which will be less than 10 years of age on 1 January 2004 by the date on which the ship reaches 10 years of age.

1.3 Completion prior to 1 January 2004 of an intermediate or special survey with a due date after 1 January 2004 cannot be used to postpone compliance. However, completion prior to 1 January 2004 of an intermediate survey the window for which straddles 1 January 2004 can be accepted.

2. Securing Devices

2.1 The strength of securing devices is to comply with the following requirements:

2.1.1 Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements.

Arrangement and spacing are to be determined with due attention to the effectiveness for weather-tightness, depending upon the type and the size of the hatch cover, as well as on the stiffness of the cover edges between the securing devices.

2.1.2 The net sectional area of each securing device is not to be less than:

$A = 1.4\ a / f\ (cm^2)$

where:

a = spacing between securing devices not to be taken less than 2 meters

$f = (\sigma_Y\ /\ 235)^e$

σ_Y = specified minimum upper yield stress in N/mm^2 of the steel used for fabrication, not to be taken greater than 70% of the ultimate tensile strength.

e = 0.75 for $\sigma_Y > 235$

= 1.0 for $\sigma_Y \leq 235$

▶

S30
(Cont'd)

Rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

2.1.3 Between cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by the securing devices.

For packing line pressures exceeding 5 N/mm, the cross section area is to be increased in direct proportion. The packing line pressure is to be specified.

2.1.4 The cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia, I, of edge elements is not to be less than:

I = 6 p a^4 (cm^4)

p = packing line pressure in N/mm, minimum 5 N/mm

a = spacing in m of securing devices.

2.1.5 Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

2.1.6 Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

2.1.7 Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

3. Stoppers

3.1 No. 1 and 2 hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.

3.2 No. 2 hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

3.3 No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2.

This pressure may be reduced to 175 kN/m^2 if a forecastle is fitted.

3.4 The equivalent stress:

i. in stoppers and their supporting structures, and
ii. calculated in the throat of the stopper welds is not to exceed the allowable value of 0.8 σ_Y.

4. Materials and Welding

4.1 Where stoppers or securing devices are fitted to comply with this UR, they are to be manufactured of materials, including welding electrodes, meeting relevant IACS requirements.

◄◄

S 31
(Nov. 2002)
(Rev.1 June 2003)
(Corr.1 July 2003)
(Corr.2 Nov.2003)
(Corr.3 Jan2004)
(Rev.2 July 2004)

Renewal Criteria for Side Shell Frames and Brackets in Single Side Skin Bulk Carriers and Single Side Skin OBO Carriers not Built in accordance with UR S12 Rev.1 or subsequent revisions

S31.1 Application and definitions

These requirements apply to the side shell frames and brackets of cargo holds bounded by the single side shell of bulk carriers constructed with single deck, topside tanks and hopper tanks in cargo spaces intended primarily to carry dry cargo in bulk, which were not built in accordance with UR S12 Rev. 1 or subsequent revisions.

In addition, these requirements also apply to the side shell frames and brackets of cargo holds bounded by the single side shell of Oil/Bulk/Ore(OBO) carriers, as defined in UR Z11 but of single side skin construction.

For the purpose of this UR, "ships" means both "bulk carriers" and "OBO carriers" as defined above, unless otherwise specified.

Bulk Carriers subject to these requirements are to be assessed for compliance with the requirements of this UR and steel renewal, reinforcement or coating, where required in accordance with this UR, is to be carried out in accordance with the following schedule and at subsequent intermediate and special surveys.

i. For bulk carriers which will be 15 years of age or more on 1 January 2004 by the due date of the first intermediate or special survey after that date;

ii. For bulk carriers which will be 10 years of age or more on 1January 2004 by the due date of the first special survey after that date;

iii. For bulk carriers which will be less than 10 years of age on 1 January 2004 by the date on which the ship reaches 10 years of age.

Completion prior to 1 January 2004 of an intermediate or special survey with a due date after 1 January 2004 cannot be used to postpone compliance. However, completion prior to 1 January 2004 of an intermediate survey the window for which straddles 1 January 2004 can be accepted.

OBO carriers subject to these requirements are to be assessed for compliance with the requirements of this UR and steel renewal, reinforcement or coating, where required in accordance with this UR, is to be carried out in accordance with the following schedule and at subsequent intermediate and special surveys.

i. For OBO carriers which will be 15 years of age or more on 1 July 2005 by the due date of the first intermediate or special survey after that date;
ii. For OBO carriers which will be 10 years of age or more on 1July 2005 by the due date of the first special survey after that date;
iii. For OBO carriers which will be less than 10 years of age on 1 July 2005 by the date on which the ship reaches 10 years of age.

Completion prior to 1 July 2005 of an intermediate or special survey with a due date after 1 July 2005 cannot be used to postpone compliance. However, completion prior to 1 July 2005 of an intermediate survey the window for which straddles 1 July 2005 can be accepted.

Note: This UR is to be applied to bulk carriers and OBO carriers of single side skin construction, as defined above, in conjunction with UR Z10.2(Rev.15, 2003 and Corr.1, 2004). Z10.2.1.1.5 refers.

S 31
(Cont'd)

These requirements define steel renewal criteria or other measures to be taken for the webs and flanges of side shell frames and brackets as per S31.2.

Reinforcing measures of side frames are also defined as per S31.2.3.

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

S31.1.1 Ice strengthened ships

S31.1.1.1 Where ships are reinforced to comply with an ice class notation, the intermediate frames are not to be included when considering compliance with S31.

S31.1.1.2 The renewal thicknesses for the additional structure required to meet the ice strengthening notation are to be based on the class society's requirements.

S31.1.1.3 If the ice class notation is requested to be withdrawn, the additional ice strengthening structure, with the exception of tripping brackets (see S31.2.1.2.1.b and S31.2.3), is not to be considered to contribute to compliance with S31.

S31.2 Renewal or other measures

S31.2.1 Criteria for renewal or other measures

S31.2.1.1 Symbols used in S31.2.1

t_M = thickness as measured, in mm

t_{REN} = thickness at which renewal is required. See S31.2.1.2

$t_{REN,d/t}$ = thickness criteria based on d/t ratio. See S31.2.1.2.1

$t_{REN,S}$ = thickness criteria based on strength. See S31.2.1.2.2

S 31
(Cont'd)

t_{COAT} = 0.75 t_{S12}

t_{S12} = thickness in mm as required by UR S12 (Rev.3) in S12.3 for frame webs and in S12.4 for upper and lower brackets

t_{AB} = thickness as built, in mm

t_C = See Table 1 below

Table 1 - t_C values, in mm

Ship's length L, in m	Holds other than No. 1		Hold No. 1	
	Span and upper brackets	Lower brackets	Span and upper brackets	Lower brackets
≤ 100	2.0	2.5	2.0	3.0
150	2.0	3.0	3.0	3.5
≥ 200	2.0	3.0	3.0	4.0
Note: For intermediate ship lengths, t_C is obtained by linear interpolation between the above values.				

S31.2.1.2 Criteria for webs (Shear and other checks)

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

t_{REN} is the greatest of:

(a) $t_{COAT} - t_C$

(b) 0,75 t_{AB}

(c) $t_{REN,d/t}$

(d) $t_{REN,S}$ (where required by S31.2.1.2.2))

S31.2.1.2.1 Thickness criteria based on d/t ratio

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

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

where:

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

for lower brackets (see *a)* below):
87 $k^{0.5}$ for symmetrically flanged frames
73 $k^{0.5}$ for asymmetrically flanged frames

S 31
(Cont'd)

k = 1,0 for ordinary hull structural steel and according to UR S4 for higher tensile steel.

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

a) Lower brackets

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

- The web depth of lower bracket may be measured from the intersection of the sloped bulkhead of the hopper tank and the side shell plate, perpendicularly to the face plate of the lower bracket (see Figure 3).
- Where stiffeners are fitted on the lower bracket plate, the web depth may be taken as the distance between the side shell and the stiffener, between the stiffeners or between the outermost stiffener and the face plate of the brackets, whichever is the greatest.

b) Tripping bracket alternative

When t_M is less than $t_{REN,d/t}$ at section b) of the side frames, tripping brackets in accordance with S31.2.3 may be fitted as an alternative to the requirements for the web depth to thickness ratio of side frames, in which case $t_{REN,d/t}$ may be disregarded in the determination of t_{REN} in accordance with S31.2.1.2.

c) Immediately abaft collision bulkhead

For the side frames located immediately abaft the collision bulkheads, whose scantlings are increased in order that their moment of inertia is such to avoid undesirable flexibility of the side shell, when their web as built thickness t_{AB} is greater than $1,65 \cdot t_{REN,S}$, the thickness $t_{REN,d/t}$ may be taken as the value $t'_{REN,d/t}$ obtained from the following equation:

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

where $t_{REN,S}$ is obtained from S31.3.3.

S31.2.1.2.2 Thickness criteria based on shear strength check

Where t_M in the lower part of side frames, as defined in Figure 1, is equal to or less than t_{COAT}, $t_{REN,S}$ is to be determined in accordance with S31.3.3.

S31.2.1.2.3 Thickness of renewed webs of frames and lower brackets

Where steel renewal is required, the renewed webs are to be of a thickness not less than t_{AB}, $1,2t_{COAT}$ or $1,2t_{REN}$, whichever is the greatest.

S31.2.1.2.4 Criteria for other measures

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

S 31
(Cont'd)

a) sand blasting, or equivalent, and coating (see S31.2.2),

b) fitting tripping brackets (see S31.2.3), when the above condition occurs for any of the side frame zones A, B, C and D, shown in Figure 1, and

c) maintaining the coating in "as-new" condition (i.e. without breakdown or rusting) at Special and Intermediate Surveys.

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

S31.2.1.3 Criteria for frames and brackets (Bending check)

Where the length or depth of the lower bracket does not meet the requirements in S12(Rev.3), a bending strength check in accordance with S31.3.4 is to be carried out and renewals or reinforcements of frames and/or brackets effected as required therein.

S31.2.2 Thickness measurements, steel renewal, sand blasting and coating

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

Representative thickness measurements are to be taken for each zone and are to be assessed against the criteria in S31.2.1.

In case of integral brackets, when the criteria in S31.2.1 are not satisfied for zone A or B, steel renewal, sand blasting and coating, as applicable, are to be done for both zones A and B.

In case of separate brackets, when the criteria in S31.2.1 are not satisfied for zone A or B, steel renewal, sand blasting and coating is to be done for each one of these zones, as applicable.

When steel renewal is required for zone C according to S31.2.1, it is to be done for both zones B and C. When sand blasting and coating is required for zone C according to S31.2.1, it is to be done for zones B, C and D.

When steel renewal is required for zone D according to S31.2.1, it needs only to be done for this zone. When sand blasting and coating is required for zone D according to S31.2.1, it is to be done for both zones C and D.

Special consideration may be given by the Society to zones previously renewed or re-coated, if found in "as-new" condition (i.e., without breakdown or rusting).

When adopted, on the basis of the renewal thickness criteria in S31.2.1, in general coating is to be applied in compliance with the requirements of UR Z9, as applicable.

Where, according to the requirements in S31.2.1, a limited number of side frames and brackets are shown to require coating over part of their length, the following criteria apply.

a) The part to be coated includes:

S 31
(Cont'd)

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

b) Epoxy coating or equivalent is to be applied.

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

S31.2.3 Reinforcing measures

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

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

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

S31.2.4 Weld throat thickness

In case of steel renewal the welded connections are to comply with UR S12.7 of UR S12(Rev.3).

S31.2.5 Pitting and grooving

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

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

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

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

S31.3 Strength check criteria

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

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

S31.3.1 Load model

S31.3.1.1 Forces

The forces $P_{fr,a}$ and $P_{fr,b}$, in kN, to be considered for the strength checks at sections a)

S 31
(Cont'd)

and b) of side frames (specified in Figure 2; in the case of separate lower brackets, section b) is at the top of the lower bracket), are given by:

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

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

where:

P_s = still water force, in kN

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

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

P_1 = wave force, in kN, in head sea

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

P_2 = wave force, in kN, in beam sea

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

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

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

s = frame spacing, in m

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

$p_{1,U}$, $p_{1,L}$ = wave pressure, in kN/m^2, as defined in S31.3.1.2.1) below for the upper and lower end of the side frame span h, respectively

$p_{2,U}$, $p_{2,L}$ = wave pressure, in kN/m^2, as defined in S31.3.1.2.2) below for the upper and lower end of the side frame span h, respectively

S31.3.1.2 Wave Pressure

1) Wave pressure p_1

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

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

$$P_{11} = 3k_S C + k_f$$

S 31
(Cont'd)

- The wave pressure p1, in kN/m^2, above the water line is given by:

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

2) *Wave pressure p_2*

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

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

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

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

where:

p_{1wl}	=	p_1 wave sea pressure at the waterline
p_{2wl}	=	p_2 wave sea pressure at the waterline
L	=	Rule length, in m, as defined in UR S2
B	=	greatest moulded breadth, in m
C_B	=	block coefficient, as defined in UR S2, but not to be taken less than 0.6
T	=	maximum design draught, in m

C = coefficient

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

= 10.75 for 300 m < L

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

k = 1.2 for ships without bilge keel

= 1.0 for ships with bilge keel

k_r = roll radius of gyration. If the actual value of k_r is not available
= 0.39 B for ships with even distribution of mass in transverse section (e.g. alternate heavy cargo loading or homogeneous light cargo loading)

S 31
(Cont'd)

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

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

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

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

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

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

Between the above specified points, k_s is to be interpolated linearly.

k_f = 0.8 C

S31.3.2 Allowable stresses

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

$\sigma_a = 0.90\ \sigma_F$
$\tau_a = 0.40\ \sigma_F$

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

S31.3.3 Shear strength check

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

The thickness $t_{REN,S}$, in mm, is the greater of the thicknesses $t_{REN,Sa}$ and $t_{REN,Sb}$ obtained from the shear strength check at sections a) and b) (see Figure 2 and S31.3.1) given by the following, but need not be taken in excess of $0.75t_{S12}$.

– at section a): $t_{REN,Sa} = \frac{1000 k_s P_{fr,a}}{d_a \sin\phi \tau_a}$

– at section b): $t_{REN,Sb} = \frac{1000 k_s P_{fr,b}}{d_b \sin\phi \tau_a}$

where:

k_S = shear force distribution factor, to be taken equal to 0,6

$P_{fr,a}$, $P_{fr,b}$ = pressures forces defined in S31.3.1.1

d_a, d_b = bracket and frame web depth, in mm, at sections a) and b), respectively (see Figure 2); in case of separate (non integral) brackets, d_b is to be taken as the minimum web depth deducing possible scallops

ϕ = angle between frame web and shell plate

τ_a = allowable shear stress, in N/mm^2, defined in S31.3.2.

S 31
(Cont'd)

S31.3.4 Bending strength check

Where the lower bracket length or depth does not meet the requirements in UR S12(Rev.3), the actual section modulus, in cm^3, of the brackets and side frames at sections a) and b) is to be not less than:

- at section a):

$$Z_a = \frac{1000 P_{fr,a} h}{m_a \sigma_a}$$

- at section b)

$$Z_b = \frac{1000 P_{fr,a} h}{m_b \sigma_a}$$

where:

$P_{fr,a}$ = pressures force defined in S31.3.1.1

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

σ_a = allowable normal stress, in N/mm^2, defined in S31.3.2

m_a, m_b = bending moment coefficients defined in Table 2

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

- t_{REN}, for the web thickness
- the minimum thicknesses allowed by the Society renewal criteria for flange and attached plating.

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

If the actual section moduli at sections a) and b) are less than the values Z_a and Z_b, the frames and brackets are to be renewed or reinforced in order to obtain actual section moduli not less than 1,2 Z_a and 1,2 Z_b, respectively.

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

Table 2 – Bending moment coefficients m_a and m_b

	m_a	m_b		
		h_B = 0.08 h	h_B = 0.1 h	h_B = 0.125 h
Empty holds of ships approved to operate in non homogeneous loading conditions	10	17	19	22
Other cases	12	20	22	26

Note 1: Non homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for each hold, exceeds 1.20 corrected for different cargo densities.

Note 2: For intermediate values of the bracket length h_B, the coefficient m_b is obtained by linear interpolation between the table values.

S 31
(Cont'd)

Figure 1 – Lower part and zones of side frames

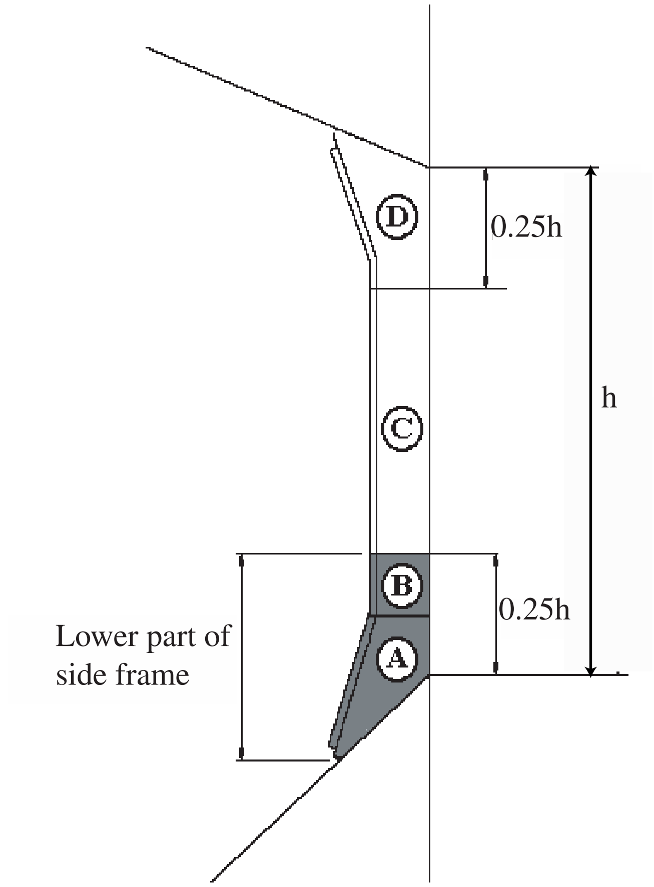
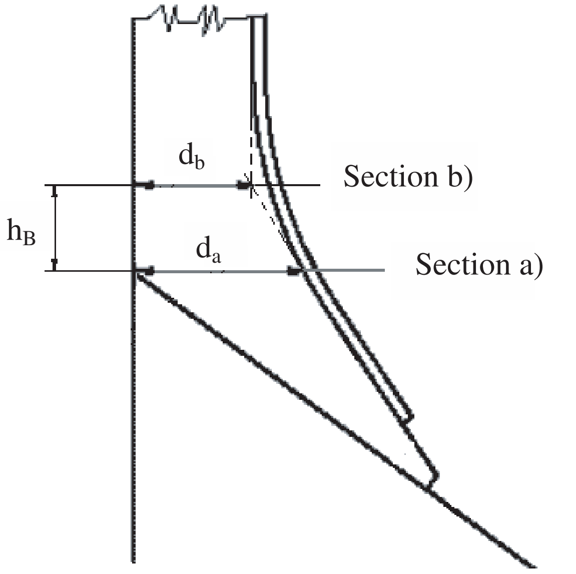


Figure 2 – Sections a) and b)



d_a = lower bracket web depth for determining $t_{REN,S}$

d_b = frame web depth

h_B = lower bracket length

S 31
(Cont'd)

Figure 3 – Definition of the lower bracket web depth for determining $t_{REN,d/t}$

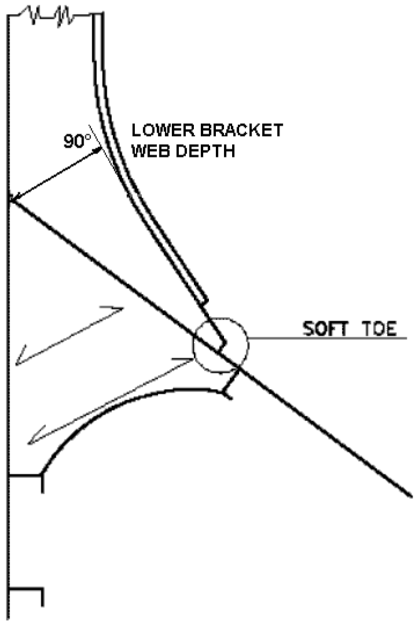
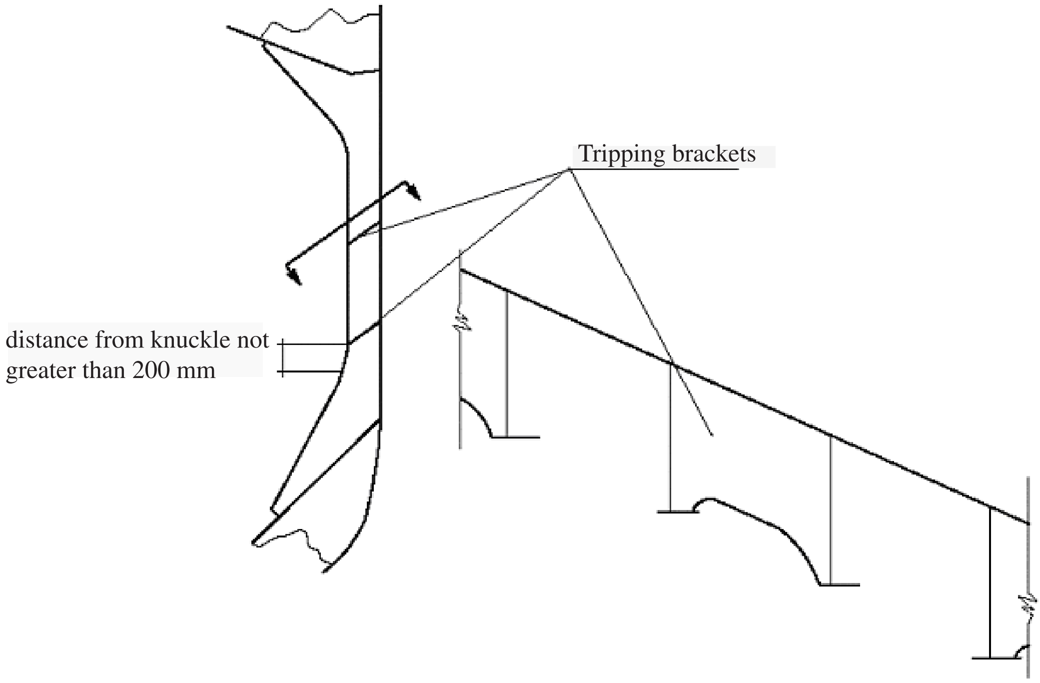


Figure 4 – Tripping brackets



S31
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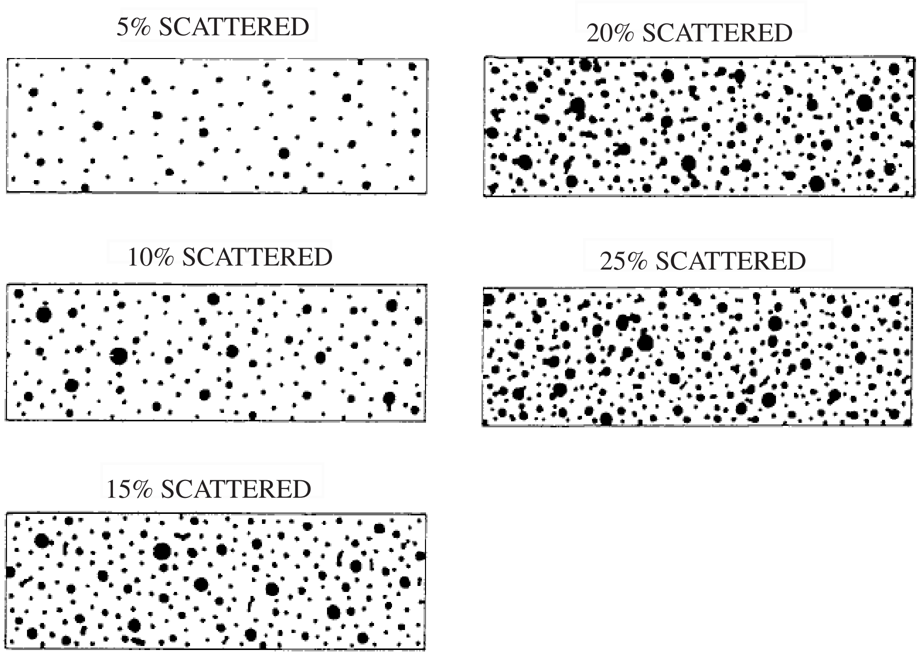
Figure 5 - Pitting intensity diagrams (from 5% to 25% intensity)



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