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IACS Req. 1998/Rev. 2007
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 50% 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”.
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.
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
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.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.
### ANNEX 1
**Guidance on Typical Loading Sequence Summary Form**

<table>
<thead>
<tr>
<th>Port Condition at commencement of loading/discharging</th>
<th>Total mass of cargo to be loaded/discharged: loading/discharging</th>
<th>Dock water</th>
<th>Maximum Average Loading/discharging rate:</th>
<th>Number of Maximum Average loaders/dischargers:</th>
<th>Ballasting/Deballasting rate:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Height of hold, h (m)</th>
<th>Loading/discharging operations may have to be paused to allow for ballasting/deballasting in order to keep actual values within limits.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hold content at commencement of loading/discharging</th>
<th>Ballast content at commencement of loading/discharging</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Values at end of pour (from harbour to sea)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hold</td>
</tr>
<tr>
<td>1 Upper</td>
</tr>
<tr>
<td>2 Upper</td>
</tr>
<tr>
<td>3 Upper</td>
</tr>
<tr>
<td>4 Upper</td>
</tr>
<tr>
<td>5 Upper</td>
</tr>
<tr>
<td>6 Upper</td>
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<tr>
<td>7 Upper</td>
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<tr>
<td>8 Upper</td>
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<tr>
<td>9 Upper</td>
</tr>
<tr>
<td>10 Upper</td>
</tr>
<tr>
<td>.. Upper</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Draft Survey</th>
<th>Total cargo</th>
<th>Remaining cargo</th>
<th>Total amount (for loading): onboard (t): to be loaded (t): of bunkers onboard (t):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hold content at end of loading/discharging</th>
<th>Ballast content at end of loading/discharging</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Values at end of loading/discharging (sea)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hold</td>
</tr>
<tr>
<td>1 Upper</td>
</tr>
<tr>
<td>2 Upper</td>
</tr>
<tr>
<td>3 Upper</td>
</tr>
<tr>
<td>4 Upper</td>
</tr>
<tr>
<td>5 Upper</td>
</tr>
<tr>
<td>6 Upper</td>
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<tr>
<td>7 Upper</td>
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<tr>
<td>8 Upper</td>
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<tr>
<td>9 Upper</td>
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<td>10 Upper</td>
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<td>11 Upper</td>
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<td>12 Upper</td>
</tr>
<tr>
<td>13 Upper</td>
</tr>
<tr>
<td>14 Upper</td>
</tr>
<tr>
<td>15 Upper</td>
</tr>
</tbody>
</table>

**Net load on double bottom =**

\[(Mh/V) * h - T\]  (t/m²)

**Approved by:**

\[\text{Net load on double bottom} = \frac{\text{mass in hold} + \text{mass in DB}}{\text{total volume of hold}} \times \text{height of hold from inner bottom to top of coaming} - \text{draught} \quad \text{t/m²} \]

\[\text{Net load in two adjacent holds} = \frac{\text{mass in hold} + \text{mass in DB}}{\text{total volume of hold}} \times \text{draught} \quad \text{t} \]

\[\text{Net load on DB} = \frac{\text{mass in hold} + \text{mass in DB}}{\text{total volume of hold}} \times \text{draught} \quad \text{t/m²} \]

Place, date, stamp and sign.
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.
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 strength, 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.
**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/mm\(^2\) (MPa)

\[
a = 2.0 + \frac{L_1}{120} \text{ for lowest tier of unprotected fronts}
\]

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.

\[
a = 1.0 + \frac{L_1}{120} \text{ for 2nd tier of unprotected fronts}
\]

\[
a = 0.5 + \frac{L_1}{120} \text{ for 3rd tier of unprotected fronts}
\]

\[
a = 0.7 + \frac{L_1}{1000} - 0.8 \frac{L_1}{L} \text{ for aft ends aft of amidships}
\]

\[
a = 0.5 + \frac{L_1}{1000} - 0.4 \frac{L_1}{L} \text{ for aft ends forward of amidships}
\]

\( L, L_1 = \text{length of ships in metres, } L_1 \text{ need not be taken greater than 300 m} \)
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.

\[ f = \frac{L}{100} e^{-\frac{L}{150}} \left[ 1 - \left( \frac{L}{150} \right) \right] \] for \( L < 150 \) m
\[ f = \frac{L}{100} e^{-\frac{L}{300}} \] for \( 150 \) 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>
<thead>
<tr>
<th>( L ) (m)</th>
<th>( p ) (N/mm(^2) or MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lowest tier of unprotected fronts</td>
</tr>
<tr>
<td>( L \leq 50 )</td>
<td>0.03</td>
</tr>
<tr>
<td>( 50 &lt; L &lt; 250 )</td>
<td>0.025 + 10 ( -^2L )</td>
</tr>
<tr>
<td>( L \geq 250 )</td>
<td>0.05</td>
</tr>
</tbody>
</table>

S3.3 Stiffener modulus

\[ W = 350s^3p \]

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 \( l_{\text{min}} = 2.0 \) 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:

\( 5.0 + L/100 \) for lowest tier

\( 4.0 + L/100 \) 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.
Criteria for the use of high tensile steel with minimum yield stress of 315 N/mm$^2$, 355 N/mm$^2$ and 390 N/mm$^2$

\[ k = \begin{cases} 
0.78 & \text{for steel with } Y = 315 \text{ N/mm}^2 \\
0.72 & \text{for steel with } Y = 355 \text{ N/mm}^2 \\
0.68 & \text{for steel with } Y = 390 \text{ N/mm}^2 
\end{cases} \]

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

\[ I_{\text{min}} = 3 W_{\text{min}} L \text{ (cm}^4\text{)} \]

\[ Y = \text{minimum yield stress} \]

\[ L = \text{Rule length of ship (m)} \]

\[ W_{\text{min}} = \text{minimum mild steel section modulus (cm}^2\text{) as given for a new ship in S7. Any reduction for corrosion control is not to be taken account of.} \]
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 - \( \Sigma b \)) (where \( B \) = breadth of ship, \( \Sigma b \) = 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°.

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.
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

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

Notes:

[1] Not to be less than grade E/EH within 0.4L amidships in ships with length exceeding 250 metres.
[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.
Table 2 Material Grade Requirements for Classes I, II and III

<table>
<thead>
<tr>
<th>Class</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness, in mm</td>
<td>MS</td>
<td>HT</td>
<td>MS</td>
</tr>
<tr>
<td>t ≤ 15</td>
<td>A</td>
<td>AH</td>
<td>A</td>
</tr>
<tr>
<td>15 &lt; t ≤ 20</td>
<td>A</td>
<td>AH</td>
<td>A</td>
</tr>
<tr>
<td>20 &lt; t ≤ 25</td>
<td>A</td>
<td>AH</td>
<td>B</td>
</tr>
<tr>
<td>25 &lt; t ≤ 30</td>
<td>A</td>
<td>AH</td>
<td>D</td>
</tr>
<tr>
<td>30 &lt; t ≤ 35</td>
<td>B</td>
<td>AH</td>
<td>D</td>
</tr>
<tr>
<td>35 &lt; t ≤ 40</td>
<td>B</td>
<td>AH</td>
<td>D</td>
</tr>
<tr>
<td>40 &lt; t ≤ 50</td>
<td>D</td>
<td>DH</td>
<td>E</td>
</tr>
</tbody>
</table>

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 -20°C), 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 tD, 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, PRIMARY and SPECIAL). For non-exposed structures and structures below the lowest ballast water line, see S6.1.
Table 3 - Application of Material Classes and Grades - Structures Exposed at Low Temperatures

<table>
<thead>
<tr>
<th>Structural member category</th>
<th>Material class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Within 0.4 L amidships</td>
</tr>
<tr>
<td><strong>SECONDARY:</strong></td>
<td></td>
</tr>
<tr>
<td>Deck plating exposed to weather, in general</td>
<td>I</td>
</tr>
<tr>
<td>Side plating above BWL</td>
<td></td>
</tr>
<tr>
<td>Transverse bulkheads above BWL</td>
<td></td>
</tr>
<tr>
<td><strong>PRIMARY:</strong></td>
<td></td>
</tr>
<tr>
<td>Strength deck plating [1]</td>
<td>II</td>
</tr>
<tr>
<td>Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings</td>
<td></td>
</tr>
<tr>
<td>Longitudinal bulkhead above BWL</td>
<td></td>
</tr>
<tr>
<td>Top wing tank bulkhead above BWL</td>
<td></td>
</tr>
<tr>
<td><strong>SPECIAL:</strong></td>
<td></td>
</tr>
<tr>
<td>Sheer strake at strength deck [2]</td>
<td>III</td>
</tr>
<tr>
<td>Stringer plate in strength deck [2]</td>
<td></td>
</tr>
<tr>
<td>Deck strake at longitudinal bulkhead [3]</td>
<td></td>
</tr>
<tr>
<td>Continuous longitudinal hatch coamings [4]</td>
<td></td>
</tr>
</tbody>
</table>

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 $t_D < -55^\circ C$, materials are to be specially considered by each Classification Society.
Table 4 - Material Grade Requirements for Classes, I, II and III at Low Temperatures

### Class I

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

Ø = Not applicable

### Class II

<table>
<thead>
<tr>
<th>Plate thickness, in mm</th>
<th>-20°/25°C MS</th>
<th>-26°/35°C MS</th>
<th>-36°/45°C MS</th>
<th>-46°/55°C MS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HT</td>
<td>HT</td>
<td>HT</td>
<td>HT</td>
</tr>
<tr>
<td>t ≤ 10</td>
<td>B</td>
<td>AH</td>
<td>D</td>
<td>DH</td>
</tr>
<tr>
<td>10 &lt; t ≤ 20</td>
<td>D</td>
<td>DH</td>
<td>E</td>
<td>EH</td>
</tr>
<tr>
<td>20 &lt; t ≤ 25</td>
<td>E</td>
<td>EH</td>
<td>E</td>
<td>EH</td>
</tr>
<tr>
<td>25 &lt; t ≤ 30</td>
<td>E</td>
<td>EH</td>
<td>Ø</td>
<td>FH</td>
</tr>
<tr>
<td>30 &lt; t ≤ 35</td>
<td>E</td>
<td>EH</td>
<td>Ø</td>
<td>FH</td>
</tr>
<tr>
<td>35 &lt; t ≤ 45</td>
<td>E</td>
<td>EH</td>
<td>Ø</td>
<td>FH</td>
</tr>
<tr>
<td>45 &lt; t ≤ 50</td>
<td>E</td>
<td>EH</td>
<td>Ø</td>
<td>FH</td>
</tr>
</tbody>
</table>

Ø = Not applicable

### Class III

<table>
<thead>
<tr>
<th>Plate thickness, in mm</th>
<th>-20°/25°C MS</th>
<th>-26°/35°C MS</th>
<th>-36°/45°C MS</th>
<th>-46°/55°C MS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HT</td>
<td>HT</td>
<td>HT</td>
<td>HT</td>
</tr>
<tr>
<td>t ≤ 10</td>
<td>D</td>
<td>DH</td>
<td>E</td>
<td>EH</td>
</tr>
<tr>
<td>10 &lt; t ≤ 20</td>
<td>D</td>
<td>DH</td>
<td>Ø</td>
<td>FH</td>
</tr>
<tr>
<td>20 &lt; t ≤ 25</td>
<td>E</td>
<td>EH</td>
<td>Ø</td>
<td>FH</td>
</tr>
<tr>
<td>25 &lt; t ≤ 30</td>
<td>E</td>
<td>EH</td>
<td>Ø</td>
<td>FH</td>
</tr>
<tr>
<td>30 &lt; t ≤ 35</td>
<td>E</td>
<td>EH</td>
<td>Ø</td>
<td>FH</td>
</tr>
<tr>
<td>35 &lt; t ≤ 40</td>
<td>E</td>
<td>EH</td>
<td>Ø</td>
<td>FH</td>
</tr>
<tr>
<td>40 &lt; t ≤ 50</td>
<td>Ø</td>
<td>FH</td>
<td>Ø</td>
<td>Ø</td>
</tr>
</tbody>
</table>

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.
S6.3 Design temperature $t_D$

The design temperature $t_D$ is to be taken as the lowest mean daily average air temperature 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†

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

$$W_{\text{min}} = cL^2B (C_b + 0.7) k \text{ (cm}^3\text{)}$$

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 $= 0.9 \ c_n$
$c_n =$
- $10.75$ – for $90 \leq L \leq 300$ m
- $10.75 \left(\frac{L - 350}{150}\right)^\alpha$ for $300 < L < 350$ m
- $10.75$ – for $350 \leq L \leq 500$ 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.
Bow doors and inner doors

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: \( \sigma_e = \sqrt{\sigma^2 + 3\tau^2} = \frac{150}{k} \text{ N/mm}^2 \)

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.

S8.2.1c 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 \( \sigma_F \) 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:

\[ P_e = 2.75 \lambda C_{\mu} (0.22 + 0.15 \tan \alpha)(0.4 V \sin \beta + 0.6 L^{0.5})^2 \]

where:

- \( V \) contractual ship’s speed, in knots,
- \( L \) ship’s length, in m, but need not be taken greater than 200 metres,
- \( \lambda \) coefficient depending on the area where the ship is intended to be operated:

\( \lambda=1 \) for seagoing ships,
\( \lambda=0.8 \) for ships operated in coastal waters,
\( \lambda=0.5 \) 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.

\[
C_H = \begin{cases} 
0.0125 \ L & \text{for } L < 80m \\
1 & \text{for } L \geq 80m 
\end{cases}
\]

\(\alpha\)  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,

\(\beta\)  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 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,

\(\ell\)  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,

\(P_e\)  external pressure, in kN/m², as given in S8.3.1a with angles \(\alpha\) and \(\beta\) defined as follows:

\(\alpha\)  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,

\(\beta\)  entry angle measured at the same point as \(\alpha\).

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:

\[
M_y = F_x a + 10Wc - F_z b
\]
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/m² is to be taken into account.

S8.3.2 Inner doors

S8.3.2a The design external pressure \( p_e \), in kN/m², 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/m², 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.

S8.4.2c The stiffener webs are to have a net sectional area, in cm², not less than:

\[ A = \frac{Qk}{10} \]
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 \( M_{yo} > 0 \). Moreover, the closing moment \( M_y \) as given in S8.3.1c is to be not less than:

\[
M_{yo} = 10Wc + 0.1\left(a^2 + b^2\right)^{0.5} \left(F_x^2 + F_z^2\right)^{0.5}
\]
S8.6.2  *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  $0.7F_X$ 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.

S8.6.2h  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.

S8.6.2i  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.
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.
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.

S8.7.2g 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 or unauthorized access by passengers thereto, can be detected whilst the ship is underway.
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
  - manufacturer’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 $\alpha$ and $\beta$
Fig. 2 Bow Door of Visor Type

Fig. 3 Thrust Bearing
Side Shell Doors and Stern Doors

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 pivoted 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**

- **Ro-ro spaces**: 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:

\[
\begin{align*}
\text{shear stress} & : \quad \tau = \frac{80}{k} \text{ N/mm}^2 \\
\text{bending stress} & : \quad \sigma = \frac{120}{k} \text{ N/mm}^2 \\
\text{equivalent stress} & : \quad \sigma_e = \sqrt{\sigma^2 + 3\tau^2} = \frac{150}{k} \text{ N/mm}^2
\end{align*}
\]

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.
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 $\frac{F}{\sigma_F}$, where $\sigma_F$ 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/kN/mm², 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: $F_e = Ap_e + F_p$
. internal force: $F_i = F_o + 10W$

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

. external force: $F_e = Ap_e$
. internal force: $F_i = F_o + 10W + F_p$

(iii) Design forces for primary members:

. external force: $F_e = Ap_e$
. internal force: $F_i = F_o + 10W$

where:

- $A$ area, in m², 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 5A (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/m², 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, $p_e$ is not to be taken less than:

\[P_e = 0.6AC_H(0.8 + 0.6L^{0.5})^2\]

$\lambda$ coefficient depending on the area where the ship is intended to be operated.
\[ \lambda = \begin{cases} 1 & \text{for sea going ships,} \\ 0.8 & \text{for ships operated in coastal waters,} \\ 0.5 & \text{for ships operated in sheltered waters.} \end{cases} \]

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.

\[ \begin{align*}
CH & = 0.0125 L & \text{for } L < 80m \\
& = 1 & \text{for } L \geq 80m \\
L & \text{ship's length, in m, but need not be taken greater than 200 metres,} \\
T & \text{draught, in m, at the highest subdivision load line,} \\
Z_G & \text{height of the centre of area of the door, in m, above the baseline.} \\
\end{align*} \]

S9.4 Scanlings 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.
**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.
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 located partly or totally below the freeboard deck with a clear opening area greater than 6m² 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 6m², 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.
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
  - manufacturer’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:

\[
\begin{align*}
\alpha &= 0 \text{ degree} \\
\beta &= 90 \text{ degrees} \\
V &= 2 \text{ knots}
\end{align*}
\]
S10 Rudders, sole pieces and rudder horns

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/mm². The following requirements are based on a material's yield stress of 235 N/mm². If material is used having a yield stress differing from 235 N/mm² the material factor is to be determined as follows:

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

with

\[ e = 0.75 \text{ for } \sigma_F > 235 \text{ N/mm}^2 \]

\[ e = 1.00 \text{ for } \sigma_F \leq 235 \text{ N/mm}^2 \]

\[ \sigma_F = \text{yield stress (N/mm}^2\text{) of material used, and is not to be taken greater than 0.7}\sigma_T \text{ or 450 N/mm}^2\text{, whichever is the smaller value} \]

\[ \sigma_T = \text{tensile strength of material used} \]

1.3.2 Before significant reductions in rudder stock diameter due to the application of steels with yield stresses exceeding 235 N/mm² 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.
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:

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

Where:
- $C_R$ = rudder force [N];
- $A$ = area of rudder blade [$m^2$];
- $V$ = 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:
  $$V_{min} = \frac{(V + 20)}{3}.$$ 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 $\lambda$ of the rudder area;
  $$K_1 = \frac{\lambda + 2}{3}, \text{ with } \lambda \text{ not to be taken greater than } 2;$$
- $\lambda = \frac{b}{A_t}$, 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 $b$ [$m^2$];
- $K_3 = 0.8$ for rudders outside the propeller jet;
  $$= 1.15 \text{ for rudders behind a fixed propeller nozzle;}$$
  $$= 1.0 \text{ otherwise; }$$
- $K_{th} = \frac{C_R (C_{th})}{C_R (C_{th} = 1.0)}$, $C_{th}$ = 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

**Diagram**: Mean breadth and height of rudder

$$c = \frac{x_2 + x_3 - x_1}{2}; \text{ mean breadth of rudder}$$

$$b = \frac{z_3 + z_4 - z_2}{2}; \text{ mean height of rudder}$$
<table>
<thead>
<tr>
<th>Profile type</th>
<th>K_2 ahead condition</th>
<th>K_2 astern condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>NACA-00</td>
<td>1,1</td>
<td>0,80</td>
</tr>
<tr>
<td>Göttingen-profiles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>hollow profiles</td>
<td>1,35</td>
<td>0,90</td>
</tr>
<tr>
<td>flat side profiles</td>
<td>1,1</td>
<td>0,90</td>
</tr>
</tbody>
</table>
2.1.2 The rudder torque is to be calculated for both the ahead and astern condition according to the formula:

\[ Q_R = C_R \cdot r \quad [\text{Nm}] \]

\[ r = c \cdot (\alpha - k) \quad [\text{m}] \]

- \( c \) = mean breadth of rudder area [m], see Fig. 1
- \( \alpha = 0.33 \) for ahead condition
- \( \alpha = 0.66 \) for astern condition
- \( k \) = balance factor as follows
- \( k = A_r / A \), where \( A_r \) = portion of the rudder blade area situated ahead of the centre line of the rudder stock
- \( r_{\text{min}} = 0.1 \cdot c \) [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).

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

\[ r_1 = c_1 \cdot (\alpha - k_1) \quad [\text{m}] \]
\[ r_2 = c_2 \cdot (\alpha - k_2) \quad [\text{m}] \]

- \( c_1, c_2 \) = mean breadth of partial areas \( A_1, A_2 \), determined, where applicable, in accordance with Fig. 1 in S10.2.1.1
- \( k_1 = A_{1f} / A_1 \)
- \( k_2 = A_{2f} / A_2 \)
- \( \alpha = 0.33 \) for ahead condition
- \( \alpha = 0.66 \) for astern condition

Fig. 2
For parts of a rudder behind a fixed structure such as rudder horn
\[ \alpha = 0.25 \text{ for ahead condition} \]
\[ \alpha = 0.55 \text{ for astern condition} \]

The resulting force of each part may be taken as:
\[ CR_1 = C_R \frac{A_1}{A} [N] \]
\[ CR_2 = C_R \frac{A_2}{A} [N] \]

The resulting torque of each part may be taken as:
\[ Q_{R1} = C_{R1} \cdot r_1 [Nm] \]
\[ Q_{R2} = C_{R2} \cdot r_2 [Nm] \]

The total rudder torque is to be calculated for both the ahead and astern condition according to the formula:
\[ Q_R = Q_{R1} + Q_{R2} [Nm] \]

For ahead condition \( Q_R \) is not to be taken less than
\[ Q_{R_{\text{min}}} = 0.1 \cdot C_R \cdot \frac{A_1 \cdot c_1 + A_2 \cdot c_2}{A} \]

**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:
\[ d_r = 4.2 \sqrt[3]{\frac{Q_R}{K}} [mm] \]

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

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.
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:

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

Bending stress:  \(\sigma_b = \frac{M}{d c^3} \quad \text{[N/mm}^2\text{]}\)

Torsional stress:  \(\tau_t = \frac{Q R}{d c^3} \quad \text{[N/mm}^2\text{]}\)

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

$$d_c = \frac{6}{4/3 \sqrt{[M/QR]^2}} \quad \text{[mm]}$$

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 \(\sigma_b\)  \(110 \text{ N/mm}^2\)
   (ii) shear stress \(\tau\)  \(50 \text{ N/mm}^2\)
   (iii) equivalent stress \(\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}\)  \(120 \text{ N/mm}^2\)

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

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:

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

\(d = \text{summer loadline draught [m] of the ship;\)}

\(C_R = \text{rudder force [Nm] according to S10.2.1.1;}\)

\(A = \text{rudder area [m}^2\text{];}\)

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

\(s = \text{smallest unsupported width of plating in [m];}\)

\(b = \text{greatest unsupported width of plating in [m].}\)

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.
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:

$$ t_b = 1.5 s V + 2.5 \text{ [mm]} $$

$$ s = \text{spacing of stiffening arms in [m], not to exceed 1 m;} $$

$$ v = \text{speed in knots, see S10.2.1.1.} $$

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

$$ Z_a = 0.5 s C_1^2 V^2 \text{ [cm³];} $$

$$ C_1 = \text{horizontal distance from the aft edge of the rudder to the centreline of the rudder stock, in meters} $$

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:

$$ d_b = 0.62 \sqrt{d^2 K_b/n e_m K_s} \text{ [mm]} $$

$$ d = \text{stock diameter, the greater of the diameters } d_t \text{ or } d_c \text{ according to S10.3 and S10.4.3 [mm];} $$

$$ n = \text{total number of bolts, which is not to be less than 6;} $$

$$ e_m = \text{mean distance [mm] of the bolt axes from the centre of the bolt system;} $$

$$ K_s = \text{material factor for the stock as given in S10.1.3.1;} $$

$$ K_b = \text{material factor for the bolts as given in S10.1.3.1.} $$

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

$$ t_f = d_b \sqrt{K_f / K_s} $$

$$ K_f = \text{material factor for flange as given in S10.1.3.1;} $$

$$ t_{f \text{ min}} = 0.9 \cdot d_b; $$

$$ d_b = \text{bolt diameter calculated for a number of bolts not exceeding 8.} $$

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.
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: \(d_n \geq 1.2 \cdot d_g\), 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

\[
d_b = 0.81 \frac{d}{\sqrt{n \times \sqrt{k_b / k_s}}}
\]

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 \(0.67 d_b\).
**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

\[ d_p = 0.35 \sqrt[3]{B \ k_p} \]

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:

\[ A_b = \frac{P}{q_a} \text{ [mm}^2\text{]} \]

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:

<table>
<thead>
<tr>
<th>Bearing material</th>
<th>( q_a ) [N/mm(^2)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>lignum vitae</td>
<td>2.5</td>
</tr>
<tr>
<td>white metal, oil lubricated</td>
<td>4.5</td>
</tr>
<tr>
<td>synthetic material with hardness between 60 and 70 Shore D(^1)</td>
<td>5.5</td>
</tr>
<tr>
<td>steel(^2) and bronze and hot-pressed bronze-graphite materials</td>
<td>7.0</td>
</tr>
</tbody>
</table>

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 metallic bearing 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.
S10.9 Strength of sole pieces and of rudder horns

9.1 Sole piece

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

\[ Z_z = \frac{M_b}{K} / 80 \text{ [cm}^3\text{]} \]

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:

\[ A_s = \frac{B_1}{48} \text{ [mm}^2\text{]} \]

\[ K = \text{material factor as given S10.1.3.1 or UR S4 respectively.} \]

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:

\[ \sigma_r = \sqrt{\sigma_b^2 + 3 \tau^2} \text{ [N/mm}^2\text{]} \]

\[ \sigma_b = \frac{M_b}{Z_z(x)} \text{ [N/mm}^2\text{]} \]

\[ \tau = \frac{B_1}{A_s} \text{ [N/mm}^2\text{]} \]

\[ M_b = \text{bending moment at the section considered [Nm]} \]

\[ M_s = \text{supporting force in the pintle bearing [N] (normally } B_1 = \frac{C_i}{2}. \]

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:

\[ M_b = \text{bending moment} = B_1 \cdot z \text{ [Nm]} \]

\[ M_{p_{\text{max}}} = B_1 \cdot d \text{ [Nm]} \]

\[ q = \text{shear force} = B_1 \text{ [N]} \]

\[ M_{t}(z) = \text{torsional moment} = B_1 \cdot e(z) \text{ [Nm]} \]

\[ \text{see Fig. 6} \]
An estimate for $B_1$ is

$$B_1 = C_r \frac{b}{(1_{20} + 1_{30})} \quad [N].$$

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:

$$Z_x = \frac{M_b}{K} / 67 \quad [cm^3].$$

The shear stress is not to be larger than:

$$\tau = \frac{48}{K} \quad [N/mm^2].$$

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:

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

$$\sigma_b = \frac{M_b}{Z_x} \quad [N/mm^2]$$

$$\tau = B_1 / A_h \quad [N/mm^2]$$

$$\tau_T = \frac{M_T}{10^3 / 2 \cdot A_T \cdot t_h} \quad [N/mm^2]$$

$A_h$ = 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

$$D_p \leq L_p \leq 1.2 \cdot D_p.$$ 

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 $0.25 \cdot D_p$. 

---

Annex
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 \([\text{cm}^4]\).

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 \( l_{50} \) 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**

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

for \( C_{R}, C_{R1}, C_{R2}, \) see S10.2.2

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.
4. Estimates for spade rudders

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

\[ M_b = C_R (l_{30} + (l_{10} \cdot (c_1 + c_2)/3 \cdot (c_1 + c_2))) \quad [Nm]; \]
\[ B_1 = M_b/l_{30} \quad [N]; \]
\[ B_2 = C_R + B_3 \quad [N]. \]

Fig. 1: Rudder supported by sole piece

Fig. 2: Semi-spade rudder
Fig. 3: Spade rudder
Longitudinal strength standard

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 \( L/B \leq 5, \quad B/D \geq 2.5 \)
(ii) Length \( L \geq 500 \text{ m} \)
(iii) Block coefficient \( C_B < 0.6 \)
(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, \( M_S \) (kN·m), and still water shear forces, \( F_S \) (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 \( M_S \) and \( F_S \) are as shown in Fig. 1.

\[
M_S: \quad \begin{array}{c}
\text{Aft} \\
\downarrow \\
(+) \\
\end{array} \quad \begin{array}{c}
\text{Fore} \\
\end{array}
\]

\[
F_S: \quad \begin{array}{c}
\text{Aft} \\
\downarrow \\
(+) \\
\end{array} \quad \begin{array}{c}
\text{Fore} \\
\end{array}
\]

Fig. 1 Sign Conventions of \( M_S \) and \( F_S \)

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 \( M_S \) and \( F_S \) 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.

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

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. Changes introduced in Rev.5 of this UR are to be uniformly applied by IACS Societies on ships contracted for construction on or after 1 July 2006.
– 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.

To demonstrate compliance with all filling levels between empty and full, 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
• full
• partially filled at intended level

Where multiple tanks are intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks are to be investigated.

However, for conventional ore carriers with large wing water ballast tanks in cargo area, where empty or full ballast water filling levels of one or maximum two pairs of these tanks lead to the ship’s trim exceeding one of the following conditions, it is sufficient to demonstrate compliance with maximum, minimum and intended partial filling levels of these one or maximum two pairs of ballast tanks such that the ship’s condition does not exceed any of these trim limits. Filling levels of all other wing ballast tanks are to be considered between empty and full. The trim conditions mentioned above are:

• trim by stern of 3% of the ship’s length, or
• trim by bow of 1.5% of ship’s length, or
• any trim that cannot maintain propeller immersion \((I/D)\) not less than 25%, where;
  \(I\) = the distance from propeller centerline to the waterline
  \(D\) = propeller diameter
(see the following figure)

The maximum and minimum filling levels of the above mentioned pairs of side ballast tanks are to be indicated in the loading manual.

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.

S11.2.1.5 Sequential ballast water exchange
Requirements of S11.2.1.3 and S11.2.1.4 are not applicable to ballast water exchange using the sequential method.

**S11.2 Wave loads**

*S11.2.2.1 Wave bending moment*

The wave bending moments, \(M_w\), at each section along the ship length are given by the following formulae:

\[
M_w (+) = + 190 M C L^2 B Cb \times 10^3 \quad \text{(kN - m)} \quad \text{... For positive moment}
\]

\[
M_w (+) = - 110 M C L^2 B (C + 0.7) \times 10^3 \quad \text{(kN - m)} \quad \text{... For negative moment}
\]
where, $M = \text{Distribution factor given in Fig. 2}$

$C = 10.75 - \left[ \frac{300 - L}{100} \right]^{0.5}$ for $90 \leq L \leq 300$

or $10.75$ for $300 \leq L \leq 350$

or $10.75 - \left[ \frac{L - 350}{150} \right]^{0.5}$ for $350 \leq L \leq 500$

$L = \text{Length of the ships in metres, defined by S2}$

$B = \text{Greatest moulded breadth in metres}$

$Cb = \text{Block coefficient, defined by S2, but not to be taken less than 0.6}$

**S11 2.2.2 Wave shear force**

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

$F_w (+) = +30 F_1 C L B (Cb + 0.7) \times 10^{-2}$ (kN) ... For positive shear force

$F_w (-) = -30 F_2 C L B (Cb + 0.7) \times 10^{-2}$ (kN) ... For negative shear force

Where, $F_1, F_2 = \text{Distribution factors given in Figs. 3 and 4}$

$C, L, B, Cb = \text{As specified in S11.2.2.1}$
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 \( M_s \) given in S11.2.1.1 and the wave bending moments \( M_w \) given in S11.2.2.1, respectively:

\[
\frac{|M_s + M_w|}{\sigma} \times 10^3 \ (cm^3)
\]

where, \( \sigma = \) permissible 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.

S11.3.2 Moment of inertia

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

\[ I_{min} = 3CLB (Cb + 0.7) \ (cm^4) \]

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
calculated shear stress is not to exceed 110/k (N/mm²).

**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 \( F_s \) given in S11.2.1.1 and the wave shear forces \( F_w \) given in S11.2.2.2, respectively:

\[
t = \frac{0.5 \left| F_s + F_w \right| S}{I} \times 10^2 \text{ (mm)}
\]

where,
- \( I \) = Moment of inertia in \( \text{cm}^4 \) about the horizontal neutral axis at the section under consideration
- \( S \) = First moment in \( \text{cm}^3 \), 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
- \( \tau \) = permissible shear stress = 110/k (N/mm²)
- \( k \) = As specified in S11.3.1.1 (i)

(ii) The value of \( F_s \) 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:

\[
t = \frac{\left| (0.5 - \phi) (F_s + F_w) + \Delta F_{sh} \right| S}{I} \times 10^2 \text{ (mm)}
\]

For longitudinal bulkheads:

\[
t = \frac{\phi (F_s + F_w) + \Delta F_{bl}}{I} \times 10^2 \text{ (mm)}
\]

where,
- \( \phi \) = ratio of shear force shared by the longitudinal bulkhead to the total shear force, and given by each Classification Society.
- \( \Delta F_{sh}, \Delta F_{bl} = \) 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
- \( S, I, \tau = \) As specified in S11.4.2 (i)
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:

\[ \sigma_E = 0.9m \left( \frac{t_b}{1000s} \right)^2 \text{ (N/mm}^2\text{)} \]

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

\[ m = \frac{8.4}{\Psi + 1.1} \text{ for } (0 \leq \Psi \leq 1) \]

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

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

where

\[ E = \text{modulus of elasticity of material} \]

\[ E = 2.06 \times 10^5 \text{ N/mm}^2 \text{ for steel} \]

\[ t_b = \text{net thickness, in mm, of plating, considering standard deductions equal to the values given in the table here after:} \]
<table>
<thead>
<tr>
<th>Structure</th>
<th>Standard deduction (mm)</th>
<th>Limit values min-max (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Compartments carrying dry bulk cargoes</td>
<td>0.05 t</td>
<td>0.5 - 1</td>
</tr>
<tr>
<td>- One side exposure to ballast and/or liquid cargo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- One side exposure to ballast and/or liquid cargo</td>
<td>0.10 t</td>
<td>2 - 3</td>
</tr>
<tr>
<td>Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Two side exposure to ballast and/or liquid cargo</td>
<td>0.15 t</td>
<td>2 - 4</td>
</tr>
<tr>
<td>Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. Shear

The ideal elastic buckling stress is given by:

\[
\tau_E = 0.9k_E \frac{I_b}{1000 \ell} \quad (\text{N/mm}^2)
\]

\[
K = 5.34 + 4 \left( \frac{s}{\ell} \right)^2
\]

E, \( t_b \), \( s \) and \( \ell \) are given in 1.

---

**S11**

---

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:

\[
\sigma_E = 0.001E \frac{I_a}{A \ell^2} \quad (\text{N/mm}^2)
\]

\( I_a \) = moment of inertia, in \( \text{cm}^4 \), of longitudinal, including plate flange and calculated with thickness as specified in S 11.5.2.1.1,

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

\( \ell \) = 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:

\[
\sigma_E = \frac{\pi^2EI_m}{10^4 I_p \ell^2} \left( \frac{K}{m^2} + \frac{K}{m^2} \right) + 0.385E \frac{I_a}{I_p} \quad (\text{N/mm}^2)
\]

\[
K = \frac{C\ell^4}{\pi^4EI_w} \times 10^6
\]
m = number of half waves, given by the following table:

<table>
<thead>
<tr>
<th></th>
<th>0 &lt; K &lt; 4</th>
<th>4 &lt; K &lt; 36</th>
<th>36 &lt; K &lt; 144</th>
<th>(m-1) m² &lt; K ≤ m² (m+1)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>m</td>
</tr>
</tbody>
</table>

Iₐ = St Venant's moment of inertia, in cm⁴, of profile (without plate flange)

\[
Iₐ = \frac{hₜtₘ}{3} 10^{-4} \quad \text{for flat bars (slabs)}
\]

\[
Iₐ = \frac{1}{3} \left[ hₜtₘ^3 + bₕtₙ^3 \left( 1 - 0.63 \frac{tₙ}{bₕ} \right) \right] 10^{-4} \quad \text{for flanged profiles}
\]

Iₚ = polar moment of inertia, in cm⁴, of profile about connection of stiffener to plate

\[
Iₚ = \frac{hₜtₘ}{3} 10^{-4} \quad \text{for flat bars (slabs)}
\]

\[
Iₚ = \left( \frac{hₜtₘ}{3} + hₚ²bₕtₙ \right) 10^{-4} \quad \text{for flanged profiles}
\]

Iₕ = sectorial moment of inertia, in cm⁶, of profile about connection of stiffener to plate

\[
Iₕ = \frac{hₜtₘ}{36} 10^{-6} \quad \text{for flat bars (slabs)}
\]

\[
Iₕ = \frac{tₙbₕ²hₜ^2}{12} 10^{-6} \quad \text{for "Tee" profiles}
\]

\[
Iₕ = \frac{bₕ²hₚ²}{12(bₕ + hₚ)} \left[ tₙ \left( bₕ² + 2bₕhₚ + 4hₚ² \right) + 3tₙbₕhₚ \right] 10^{-6} \quad \text{for angles and bulb profiles}
\]

hₜ = web height, in mm,

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

bₕ = flange width, in mm,

tₙ = 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  

\[ \ell \quad = \text{span of profile, in m,} \]

\[ s \quad = \text{spacing of profiles, in m,} \]

\[ C = \text{spring stiffness exerted by supporting plate p} \]

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

\[ k_p = 1 - \eta_p \text{ not to be taken less than zero} \]

\[ t_p = \text{plate thickness, in mm, considering standard deductions as specified in S 11.5.2.1.1.} \]

\[ \eta_p = \frac{\sigma_a}{\sigma_{E_p}} \]

\[ \sigma_a = \text{calculated compressive stress. For longitudinals, see S 11.5.4.1,} \]

\[ \sigma_{E_p} = \text{elastic buckling stress of supporting plate as calculated in S 11.5.2.1,} \]

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:

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

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

\[ \frac{b_f}{t_f} \leq 15 \]

\[ b_f = \text{flange width, in mm, for angles, half the flange width for T-sections.} \]

\[ t_f = \text{as built flange thickness.} \]

S 11.5.3 Critical buckling stresses

S 11.5.3.1 Compression

The critical buckling stress in compression \( \sigma_c \) is determined as follows:
S11 - cont'd

\[ \sigma_c = \sigma_E \quad \text{when} \quad \sigma_E \leq \frac{\sigma_F}{2} \]

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

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

\( \sigma_E \) = ideal elastic buckling stress calculated according to S 11.5.2.

S 11.5.3.2 Shear

The critical buckling stress in shear \( \tau_c \) is determined as follows:

\[ \tau_c = \tau_E \quad \text{when} \quad \tau_E \leq \frac{\tau_E}{2} \]

\[ = \tau_E \left(1 - \frac{\tau_E}{4\tau_E}\right) \quad \text{when} \quad \tau_E > \frac{\tau_E}{2} \]

\( \tau_F = \frac{\sigma_F}{\sqrt{3}} \)

\( \sigma_F \) = as given in S 11.5.3.1,

\( \tau_E \) = 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:

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

\[ = \text{minimum} \frac{30}{k} \text{ N/mm}^2 \]

\( M_s \) = 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 cm\(^4\), 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.
S 11.5.4.2  Shear stresses

1. Ships without effective longitudinal bulkheads

For side shell

\[ \tau_s = \frac{0.51 F_s + F_w}{t} \cdot \frac{S}{I} \cdot 10^2 \text{ N/mm}^2 \]

For longitudinal bulkheads

\[ \tau_s = \frac{(0.5 \phi)(F_s + F_w) + \Delta F_{sh}}{t} \cdot \frac{S}{I} \cdot 10^2 \text{ N/mm}^2 \]

\[ F_s, F_w, t, s, I \text{ as specified in S 11.4.2} \]

2. Ships with two effective longitudinal bulkheads

For side shell

\[ \tau_s = \frac{\phi(F_s + F_w) + \Delta F_{sh}}{t} \cdot \frac{S}{I} \cdot 10^2 \text{ N/mm}^2 \]

For longitudinal bulkheads

\[ \tau_s = \frac{\phi(F_s + F_w) + \Delta F_{sh}}{t} \cdot \frac{S}{I} \cdot 10^2 \text{ N/mm}^2 \]

\[ F_s, F_w, \Delta F_{sh}, \Delta F_{bl}, t, S, I \text{ as specified in S 11.4.3.} \]

S 11.5.5 Scantling criteria

S 11.5.5.1 Buckling Stress

The design buckling stress \( \sigma_c \) 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

\[ \beta = 1 \quad \text{for plating and for web plating of stiffeners (local buckling)} \]

\[ \beta = 1.1 \quad \text{for stiffeners} \]

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

\[ \tau_c \geq \tau_a \]
S11  Longitudinal strength standard

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 \( L/B \leq 5, \quad B/D \geq 2.5 \)
(ii) Length \( L \geq 500 \text{ m} \)
(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.

\[ Ms: \]

\[ Fs: \]

Fig. 1 Sign Conventions of \( MS \) and \( Fs \)
S11.2.1 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 $M_s$ and $F_s$ 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, $M_w$, at each section along the ship length are given by the following formulae:

\[
M_w (+) = + 190 M C L^2 B Cb \times 10^{-3} \text{ (kN} \cdot \text{m)} \quad \text{... For positive moment}
\]

\[
M_w (+) = - 110 M C L^2 B (C_b + 0.7) \times 10^{-3} \text{ (kN} \cdot \text{m)} \quad \text{... For negative moment}
\]

where, $M = \text{Distribution factor given in Fig. 2}$

\[
C = \begin{cases} 
10.75 - \left[ \frac{300 - L}{100} \right]^{1.5} & \text{for } 90 \leq L \leq 300 \\
10.75 & \text{for } 300 < L < 350 \\
10.75 - \left[ \frac{L - 350}{150} \right]^{1.5} & \text{for } 350 \leq L \leq 500
\end{cases}
\]

$L = \text{Length of the ships in metres, defined by S2}$

$B = \text{Greatest moulded breadth in metres}$

$C_b = \text{Block coefficient, defined by S2, but not to be taken less than 0.6}$
The wave shear forces, $F_w$, at each section along the length of the ship are given by the following formulae:

\[
F_w(+) = +30 F_1 C L B (C_b + 0.7) \times 10^{-2} \text{ (kN)} \quad \text{... For positive shear force}
\]

\[
F_w(-) = -30 F_2 C L B (C_b + 0.7) \times 10^{-2} \text{ (kN)} \quad \text{... For negative shear force}
\]

Where, $F_1, F_2$ = Distribution factors given in Figs. 3 and 4

$C, L, B, C_b$ = As specified in S11.2.2.1

---

**Fig. 2 Distribution factor $M$**

**Fig. 3 Distribution factor $F_1$**
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 $M_s$ given in S11.2.1.1 and the wave bending moments $M_w$ given in S11.2.2.1, respectively:

$$\frac{|M_s + M_w|}{\sigma} \times 10^3 \ (cm^3)$$

where, 

$\sigma = 175 / k \ (N/mm^2)$

$k = 1.0$ 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.

S11.3.2 Moment of inertia

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

$$I_{min} = 3CL^3 B \ (Cb + 0.7) \ (cm^4)$$

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
calculated shear stress is not to exceed 110/k (N/mm²).

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 $F_s$ given in S11.2.1.1 and the wave shear forces $F_w$ given in S11.2.2.2, respectively:

$$t = \frac{0.5 \left| F_s + F_w \right|}{\tau} \frac{S}{I} \times 10^2 \quad \text{(mm)}$$

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

$\tau = 110/k$ (N/mm²)

$k =$ As specified in S11.3.1.1 (i)

(ii) The value of $F_s$ 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:

$$t = \frac{\left| 0.5 - \phi \right| (F_s + F_w) + \Delta F_{sh}}{\tau} \frac{S}{I} \times 10^2 \quad \text{(mm)}$$

For longitudinal bulkheads:

$$t = \frac{\phi (F_s + F_w) + \Delta F_{bl}}{\tau} \frac{S}{I} \times 10^2 \quad \text{(mm)}$$

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

$\Delta F_{sh}, \Delta F_{bl} =$ 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

$S, I, \tau =$ As specified in S11.4.2 (i)
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:

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

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

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

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

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

where

- \(E\) = modulus of elasticity of material
- \(= 2.06 \times 10^5 \text{ N/mm}^2\) for steel
- \(t_b\) = net thickness, in mm, of plating, considering standard deductions equal to the values given in the table here after:
<table>
<thead>
<tr>
<th>Structure</th>
<th>Standard deduction (mm)</th>
<th>Limit values min-max (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Compartments carrying dry bulk cargoes</td>
<td>0.05 t</td>
<td>0.5 - 1</td>
</tr>
<tr>
<td>- One side exposure to ballast and/or liquid cargo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- One side exposure to ballast and/or liquid cargo</td>
<td>0.10 t</td>
<td>2 - 3</td>
</tr>
<tr>
<td>Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Two side exposure to ballast and/or liquid cargo</td>
<td>0.15 t</td>
<td>2 - 4</td>
</tr>
<tr>
<td>Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Two side exposure to ballast and/or liquid cargo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
s = shorter side of plate panel, in m,
\( \ell \) = 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,
\( \Psi \) = ratio between smallest and largest compressive \( \sigma \) stress when linear variation across panel.

2. Shear
The ideal elastic buckling stress is given by:

\[
\tau_E = 0.9 K_t E \left( \frac{t_b}{1000 s} \right)^2 \quad (\text{N/mm}^2)
\]

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

\( E, t_b, s \) and \( \ell \) are given in 1.

S11.5.2.2 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:

\[
\sigma_E = 0.001 E \frac{I_a}{A \ell^2} \quad (\text{N/mm}^2)
\]

\( I_a \) = 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,
\( \ell \) = 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:

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

\[
K = \frac{C \ell^4}{\pi^4 E I_w} \times 10^6
\]
m = number of half waves, given by the following table:

<table>
<thead>
<tr>
<th></th>
<th>0 &lt; K &lt; 4</th>
<th>4 &lt; K &lt; 36</th>
<th>36 &lt; K &lt; 144</th>
<th>(m-1)²m² &lt; K ≤ m²(m+1)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>m</td>
</tr>
</tbody>
</table>

Iₜ = St Venant’s moment of inertia, in cm⁴, of profile (without plate flange)

for flat bars (slabs)

\[ Iₜ = \frac{h_w t_w^3}{3} 10^{-4} \]

for flanged profiles

\[ Iₜ = \left( \frac{h_w t_w^3}{3} + h_w^2 b_f t_f \right) 10^{-4} \]

Iₚ = polar moment of inertia, in cm⁴, of profile about connection of stiffener to plate

for flat bars (slabs)

\[ Iₚ = \frac{h_w^3 t_w}{3} 10^{-4} \]

for flanged profiles

\[ Iₚ = \left( \frac{h_w^3 t_w}{3} + h_w^2 b_f t_f \right) 10^{-4} \]

Iₗ = sectional moment of inertia, in cm⁶, of profile about connection of stiffener to plate

for flat bars (slabs)

\[ Iₗ = \frac{h_w^3 t_w}{36} 10^{-6} \]

for "Tee" profiles

\[ Iₗ = \frac{b_f h_w^2}{12} 10^{-6} \]

for angles and bulb profiles

\[ Iₗ = \frac{b_f h_w^2}{12(b_f + h_w)^2} \left[ t_f \left( b_f^2 + 2 b_f h_w + 4 h_w^2 \right) + 3 t_w b_f h_w \right] 10^{-6} \]

hₜ = web height, in mm,

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

bₕ = flange width, in mm,

bₕ = 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.
$S11$

$S11$ cont’d

| $\ell$ | = span of profile, in m, |
| $s$ | = spacing of profiles, in m, |

$C = \text{spring stiffness exerted by supporting plate p}$

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

$k_p = 1 - \eta_p \text{not to be taken less than zero}$

$t_p = \text{plate thickness, in mm, considering standard deductions as specified in S 11.5.2.1.1.}$

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

$\sigma_a = \text{calculated compressive stress. For longitudinals, see S 11.5.4.1,}$

$\sigma_{Ep} = \text{elastic buckling stress of supporting plate as calculated in S 11.5.2.1,}$

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:

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

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

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

$b_f = \text{flange width, in mm, for angles, half the flange width for T-sections.}$

$t_f = \text{as built flange thickness.}$

$S11$ cont’d

$S11.5.3 \text{ Critical buckling stresses}$

$S11.5.3.1 \text{ Compression}$

The critical buckling stress in compression $\sigma_e$ is determined as follows:
$\sigma_c = \sigma_e$ (when $\sigma_e \leq \frac{\sigma_F}{2}$)

$= \sigma_F \left(1 - \frac{\sigma_e}{4\sigma_F}\right)$ (when $\sigma_e > \frac{\sigma_F}{2}$)

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

$\sigma_E$ = ideal elastic buckling stress calculated according to S 11.5.2.

S 11.5.3.2 Shear

The critical buckling stress in shear $\tau_c$ is determined as follows:

$\tau_c = \tau_e$ (when $\tau_e \leq \frac{\tau_E}{2}$)

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

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

$\sigma_F$ = as given in S 11.5.3.1,

$\tau_E$ = ideal elastic buckling stress in shear calculated according to S 11.5.2.1.2.

S 11.5.4 Working stress

S 11.5.4.1 Longitudinal compressive stresses

The compressive stresses are given in the following formula:

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

$= \text{minimum} \frac{30}{k}$ N/mm$^2$

$M_s$ = 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 cm$^4$, 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.
S 11.5.2 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
   \[ \tau_a = \frac{\phi (F_s + F_w) + \Delta F_{b/\ell}}{t} \cdot \frac{S}{I} \cdot 10^2 \text{ N/mm}^2 \]
   \( F_s, F_w, \Delta F_{sh}, \Delta F_{b/\ell}, t, S, I \) as specified in S 11.4.3.

S 11.5.5 Scantling criteria

S 11.5.5.1 Buckling Stress

The design buckling stress \( \sigma_c \) 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

\[ \beta = 1 \quad \text{for plating and for web plating of stiffeners (local buckling)} \]

\[ \beta = 1.1 \quad \text{for stiffeners} \]

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

\[ \tau_c \geq \tau_a \]
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 \( t_{w,\text{min}} \) in mm, given by:

\[
t_{w,\text{min}} = C \left( 7,0 + 0,03 \cdot L \right)
\]

\[C = \begin{array}{l}
1.15 \text{ for the frame webs in way of the foremost hold;} \\
1.0 \text{ for the frame webs in way of other holds.}
\end{array}
\]

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 \( t_{w,\text{min}} + 2 \) 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 \( t_{w,\text{min}} \).

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.
S12.5 - 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):

- \( 0.44 \cdot t \) in zone “a”
- \( 0.4 \cdot t \) 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 \( t_{p,\text{min}} \) in mm, given by:

\[
t_{p,\text{min}} = \sqrt{L}
\]
Figure 1

\[ SM_{\text{UPPER}} = 2 \cdot SM_f \]

Zone "a"

Zone "b"

\[ SM_{\text{LOWER}} = 2 \cdot SM_f \]

Zone "a"

Upper Wing Tank

Lower Wing Tank

0.25h

0.25h

\[ t = \text{the lesser of} \ t_1 \text{or} \ t_2 \]
Figure 4

Tripping brackets to be fitted in way of foremost hold
S13  Strength of bottom forward in oil tankers

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).
Testing Procedures of Watertight Compartments

S14 - General

S14.1 - 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 m³ 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.
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 $0.15 \times 10^5$ Pa is to be applied during the test.

Prior to inspection, it is recommended that the air pressure in the tank is raised to $0.20 \times 10^5$ 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 $0.20 \times 10^5$ 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 $2 \times 10^5$ 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
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.
<table>
<thead>
<tr>
<th>Item number</th>
<th>Structure to be tested</th>
<th>Type of testing</th>
<th>Structural test pressure</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Double bottom tanks</td>
<td>Structural testing [1]</td>
<td>The greater of the following:&lt;br&gt;• head of water up to the top of overflow&lt;br&gt;• head of water up to the margin line</td>
<td>Tank boundaries tested from at least one side</td>
</tr>
<tr>
<td>2</td>
<td>Double side tanks</td>
<td>Structural testing [1]</td>
<td>The greater of the following:&lt;br&gt;• head of water up to the top of overflow&lt;br&gt;• 2.4 m head of water above highest point of tank</td>
<td>Tank boundaries tested from at least one side</td>
</tr>
<tr>
<td>3</td>
<td>Tank bulkheads, deep tanks</td>
<td>Structural testing [1]</td>
<td>The greater of the following [2]:&lt;br&gt;• head of water up to the top of overflow&lt;br&gt;• 2.4 m head of water above highest point of tank</td>
<td>Tank boundaries tested from at least one side</td>
</tr>
<tr>
<td></td>
<td>Fuel oil bunkers</td>
<td>Structural testing</td>
<td>• setting pressure of the safety relief valves, where relevant</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Ballast holds in bulk carriers</td>
<td>Structural testing [1]</td>
<td>The greater of the following:&lt;br&gt;• head of water up to the top of overflow&lt;br&gt;• 0.90 m head of water above top of hatch</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Fore peak and after peak used as tank</td>
<td>Structural testing</td>
<td>The greater of the following:&lt;br&gt;• head of water up to the top of overflow&lt;br&gt;• 2.4 m head of water above highest point of tank</td>
<td>Test of the after peak carried out after the stern tube has been fitted</td>
</tr>
<tr>
<td></td>
<td>Fore peak not used as tank</td>
<td>Refer to SOLAS Ch. II.1 Reg. 14</td>
<td><strong>Note:</strong> Refer to SOLAS Ch. II.1 Reg. 14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>After peak not used as tank</td>
<td>Leak testing</td>
<td><strong>Note:</strong> Leak testing</td>
<td></td>
</tr>
</tbody>
</table>

**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 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.

[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.
### Table 1 - General testing requirements

<table>
<thead>
<tr>
<th>Item number</th>
<th>Structure to be tested</th>
<th>Type of testing</th>
<th>Structural test pressure</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Cofferdams</td>
<td>Structural testing</td>
<td>The greater of the following:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• head of water up to the top of overflow</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• 2.4 m head of water above highest point of tank</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Watertight bulkheads</td>
<td>Refer to SOLAS Ch. II.1 Reg. 14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Watertight doors below freeboard or bulkhead deck</td>
<td>Refer to SOLAS Ch. II.1 Reg. 18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Double plate rudders</td>
<td>Leak testing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Shaft tunnel clear of deep tanks</td>
<td>Hose testing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Shell doors</td>
<td>Hose testing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Watertight hatchcovers of tanks in bulk-carriers</td>
<td>Hose testing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Watertight hatchcovers of tanks in combination carriers</td>
<td>Structural testing</td>
<td>The greater of the following:</td>
<td>At least every 2nd hatch cover are to be tested</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• 2.4 m head of water above the top of hatchcover</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• setting pressure of the safety relief valves, where relevant</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Weathertight hatchcovers and closing appliances</td>
<td>Hose testing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note:

[1] Leak or hydro pneumatic 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.

[2] Leak or hydro pneumatic 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.

[3] 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.
<table>
<thead>
<tr>
<th>Item number</th>
<th>Structure to be tested</th>
<th>Type of testing</th>
<th>Structural test pressure</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Chain locker (if aft of collision bulkhead)</td>
<td>Structural testing</td>
<td>Head of water up to the top</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Independent tanks</td>
<td>Structural testing</td>
<td>Head of water up to the top of overflow, but not less than 0,9 m</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Ballast ducts</td>
<td>Structural testing</td>
<td>Ballast pump maximum pressure</td>
<td></td>
</tr>
</tbody>
</table>
### Table 2 - Additional testing requirements for spaces within the cargo area of certain types of ships

<table>
<thead>
<tr>
<th>Item number</th>
<th>Types of ships</th>
<th>Structure to be tested</th>
<th>Testing requirements</th>
<th>Structural test pressure</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Liquefied gas carriers</td>
<td>Integral tanks</td>
<td>Refer to UR G1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hull structure supporting membrane or semi-membrane tanks</td>
<td>Refer to UR G1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Independent tanks type A</td>
<td>Refer to UR G1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Independent tanks type B</td>
<td>Refer to UR G1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Independent tanks type C</td>
<td>Refer to UR G2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2 - Additional testing requirements for spaces within the cargo area of certain types of ships (cont’d)

<table>
<thead>
<tr>
<th>Item number</th>
<th>Types of ships</th>
<th>Structure to be tested</th>
<th>Testing requirements</th>
<th>Structural test pressure</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Edible liquid carriers</td>
<td>Independent tanks</td>
<td>Structural testing</td>
<td>Head of water up to the top of overflow without being less than 0.9 m</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Chemical carriers</td>
<td>Integral or independent tanks</td>
<td>Structural testing of cargo tanks boundaries from at least one side</td>
<td>The greater of the following:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• 2.4 m head of water above highest point of tank</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• setting pressure of the safety relief valves, where relevant</td>
<td></td>
</tr>
</tbody>
</table>
Side Shell Doors and Stern Doors

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-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 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 reassessed 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.
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 permissible 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.
S17 - Longitudinal Strength of Hull Girder in flooded condition for Bulk Carriers (Rev.7)

S17.1 - General

Revision 7 of this UR is to be complied with in respect of the flooding of any cargo hold of bulk carriers, as defined in UR Z11.2.2, with notation BC-A or BC-B, as defined in UR S25, in accordance with Note 2.

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.

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/m³ is to be used. For cement, a minimum permeability of 0.3 with a corresponding bulk density of 1.3 t/m³ 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. 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. Revision 7 of this UR is to be applied by IACS Societies to ships contracted for construction from a date commencing not later than 1 July 2006.
S17.4 - Stress assessment

The actual hull girder bending stress $\sigma_{fld}$ in N/mm$^2$, at any location is given by:

$$\sigma_{fld} = \frac{M_{sf} + 0.8 \cdot M_{w}}{W} \cdot 10^3$$

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

$W$ = section modulus, in cm$^3$, for the corresponding location in the hull girder.

The shear strength of the side shell and the inner hull (longitudinal bulkhead) if any, at any location of the ship, is to be checked according to the requirements specified in UR S11.4 in which $F_S$ and $F_W$ are to be replaced respectively by $F_{SF}$ and $F_{WF}$, where:

$F_{SF}$ = still water shear force, in kN, in the flooded conditions for the section under consideration

$F_{WF}$ = 0.8 $F_W$

$F_W$ = wave shear force, in kN, as given in UR S11.2.2.2 for the section under consideration

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.
Evaluation of Scantlings of Corrugated Transverse Watertight Bulkheads in Bulk Carriers Considering Hold Flooding

S18.1 - Application and definitions

Revision 7 of this UR is to be complied with in respect of the flooding of any cargo hold of bulk carriers, as defined in UR Z11.2.2, of 150 m in length and above, with single deck, topside tanks and hopper tanks, and of single side or double side skin construction, intending to carry solid bulk cargoes having a density of 1.0 t/m³, or above, with vertically corrugated transverse watertight bulkheads, in accordance with Note 2.

The net thickness $t_{\text{net}}$ 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 $t_{\text{net}}$.

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. 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. Revision 7 of this UR is to be applied by IACS Societies to ships contracted for construction from a date commencing not later than 1 July 2006.
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/m³, 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/m³ 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/m³ 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/m², is given by:

\[
p_c = \rho_c \cdot g \cdot h_1 \cdot \tan^2 \gamma
\]

where:
\( \rho_c \) = bulk cargo density, in t/m³
\( g \) = 9.81 m/s², 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 cont’d

\[ \gamma = 45° - \left( \varphi / 2 \right) \]

\[ \varphi = \text{angle of repose of the cargo, in degrees, that may generally be taken as } 35° \text{ for iron ore and } 25° \text{ for cement} \]

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:

- \( \rho_c \), \( g \), \( d_1 \), \( \gamma \) = 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/m², is given by:

\[ p_{c,f} = \rho \cdot g \cdot h_f \]

where:

- \( \rho \) = sea water density, in t/m³
- \( g \) = 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 \( d_1 \) from the baseline, the pressure \( p_{c,f} \), in kN/m², 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:

- \( \rho \), \( h_f \) = as given above
- \( \rho_c \), \( g \), \( h_1 \), \( \gamma \) = as given in S18.2.3
- \( \text{perm} \) = 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/m³), coal cargoes and for cement (corresponding bulk cargo density for cement may generally be taken as 1.3 t/m³)
The force $F_{c,f}$, in kN, acting on a corrugation is given by:

$$
F_{c,f} = s_1 \left[ \frac{\rho \cdot g \cdot (d_f - d_1)^2}{2} + \frac{\rho \cdot g \cdot (d_f - d_1) + (p_{c,f})_{le}}{2} \cdot (d_1 - h_{DB} - h_{LS}) \right]
$$

where:

- $\rho$ = 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:

- $\rho_c, g, h_1, \gamma$ = 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:

$$
p_{c,f} = \rho \cdot g \cdot h_1 + \left[ (\rho_c \cdot h_1 - \rho \cdot (1 - \text{perm}) \cdot h_f) \right] g \cdot \tan^2 \gamma
$$

where:

- $\rho, h_f, \text{perm}$ = as given in a) above
- $\rho_c, g, h_1, \gamma$ = as given in S18.2.3

$$
F_{c,f} = s_1 \left[ \rho_c \cdot g \cdot \left( \frac{(d_1 - d_f)^2}{2} \cdot \tan^2 \gamma + \frac{(d_1 - d_f) \cdot \tan^2 \gamma + (p_{c,f})_{le}}{2} \cdot (d_f - h_{DB} - h_{LS}) \right) \right]
$$

The force $F_{c,f}$, in kN, acting on a corrugation is given by:

where:

- $s_1, \rho_c, g, d_1, \gamma, h_{DB}, h_{LS}$ = as given in S18.2.3
- $d_f$ = as given in S18.2.2
(p_{c,f})_{le} = \text{pressure, in kN/m}^2, \text{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 \( p_f \) induced by the flooding head \( h_f \) is to be considered.

The force \( F_f \), in kN, acting on a corrugation is given by:

\[
F_f = s_1 \cdot \rho \cdot g \cdot \frac{(d_f - h_{DB} - h_{LS})^2}{2}
\]

where:

- \( s_1, g, h_{DB}, h_{LS} \) = as given in S18.2.3
- \( \rho \) = 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:
\[ M = \frac{F \cdot \ell}{8} \]

where:

- \( F \) = resultant force, in kN, as given in S18.2.5
- \( \ell \) = 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 \( \varphi \) 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\( \cdot \)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\( \cdot \)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.
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. Scallop 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 than 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. Scallop 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 $\tau$

The bending capacity is to comply with the following relationship:

$$10^3 \frac{M}{0.5 \cdot Z_{le} \cdot \sigma_{a,j} + Z_m \cdot \sigma_{a,m}} \leq 0.95$$

where:

$M$ = bending moment, in kN·m, as given in S18.3.1

$Z_{le}$ = section modulus of one half pitch corrugation, in cm³, at the lower end of corrugations, to be
calculated according to S18.4.3.

\[ Z_m = \text{section modulus of one half pitch corrugation, in cm}^3, \text{ at the mid-span of corrugations, to be calculated according to S18.4.4.} \]

\[ \sigma_{a,le} = \text{allowable stress, in N/mm}^2, \text{ as given in S18.4.5, for the lower end of corrugations} \]

\[ \sigma_{a,m} = \text{allowable stress, in N/mm}^2, \text{ as given in S18.4.5, for the mid-span of corrugations} \]

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 shedder 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:

\[ Z_g = \text{section modulus of one half pitch corrugation, in cm}^3, \text{ of the corrugations calculated, according to S18.4.4, in way of the upper end of shedder or gusset plates, as applicable} \]

\[ Q = \text{shear force, in kN, as given in S18.3.2} \]

\[ h_g = \text{height, in m, of shedders or gusset plates, as applicable (see Figures 3a, 3b, 4a and 4b)} \]

\[ s_1 = \text{as given in S18.2.3} \]

\[ p_g = \text{resultant pressure, in kN/m}^2, \text{ as defined in S18.2.5, calculated in way of the middle of the shedders or gusset plates, as applicable} \]
Stresses $\tau$ 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 $(\sin \varphi)$, $\varphi$ 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 $\Theta$ in Figures 3a and 3b), the area of flange plates, in cm², may be increased by:

$$\left(2.5 \cdot a \cdot t_f \cdot t_{sh}\right)$$

(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 $\Theta$ in Figures 4a and 4b), the area of flange plates, in cm², 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 $2.5 \cdot a \cdot t_f$

- $s_{gu}$ = 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 45° 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 45°, the effectiveness of the web may be obtained by linear interpolation between 30% for 0° and 100% for 45°.
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 $\sigma$ and $\tau$ are not to exceed the allowable values $\sigma_a$ and $\tau_a$, in N/mm$^2$, given by:

$$\sigma_a = \sigma_F$$

$$\tau_a = 0.5\sigma_F$$

$\sigma_F = \text{the minimum upper yield stress, in N/mm}^2, \text{of the material.}$

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:

$$C_e = \begin{cases} 
1,0 & \text{for } \beta \leq 1,25 \\
\frac{225}{\beta} - \frac{125}{\beta^2} & \text{for } \beta > 1,25 
\end{cases}$$

$$C_e = 1.0 \quad \text{for } \beta \leq 1,25$$

$$\beta = 10^3 \cdot \frac{a}{t_f} \cdot \sqrt{\frac{\sigma_F}{E}}$$

$t_f = \text{net flange thickness, in mm}$

$a = \text{width, in m, of the corrugation flange (see Figure 2a)}$

$\sigma_F = \text{minimum upper yield stress, in N/mm}^2, \text{of the material}$

$E = \text{modulus of elasticity of the material, in N/mm}^2, \text{to be assumed equal to } 2,06 \cdot 10^5 \text{ for steel.}$

S18.4.6.2 - Shear

The buckling check is to be performed for the web plates at the corrugation ends.

The shear stress $\tau$ is not to exceed the critical value $\tau_c$, in N/mm$^2$, obtained by the following:
\[ \tau_C = \tau_E \quad \text{when } \tau_E \leq \frac{\tau_F}{2} \]

\[ = \tau_F \left( 1 - \frac{\tau_F}{4\tau_E} \right) \quad \text{when } \tau_E > \frac{\tau_F}{2} \]

where:

\[ \tau_F = \frac{\sigma_F}{\sqrt{3}} \]

\[ \sigma_F = \text{minimum upper yield stress, in } \text{N/mm}^2, \text{ of the material} \]

\[ \tau_E = 0.9k_tE \left( \frac{t}{1000c} \right)^2 \quad (\text{N/mm}^2) \]

\[ k_t, E, t \text{ and } c \text{ are given by:} \]

\[ k_t = 6.34 \]

\[ E = \text{modulus of elasticity of material as given in S18.4.6.1} \]

\[ t = \text{net thickness, in mm, of corrugation web} \]

\[ c = \text{width, in m, of corrugation web (See Figure 2a)} \]

**S18.4.7 - Local net plate thickness**

The bulkhead local net plate thickness \( t \), in mm, is given by:

\[ t = 14.9 \cdot s_w \cdot \sqrt{\frac{105 \cdot p}{\sigma_F}} \]

where:

\[ s_w = \text{plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is the greater (see Figure 2a)} \]

\[ p = \text{resultant pressure, in kN/m}^2, \text{ as defined in S18.2.5, at the bottom of each strake of plating; in all cases, the net thickness of the lowest strake is to be determined using the resultant pressure at the top of the lower stool, or at the inner bottom, if no lower stool is fitted or at the top of shedders, if shedder or gusset/shedder plates are fitted.} \]

\[ \sigma_F = \text{minimum upper yield stress, in } \text{N/mm}^2, \text{ of the material}. \]

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 \( t_{\text{w}} \), in mm, given by:

\[ t_{\text{w}} = 14.9 \cdot s_{\text{n}} \cdot \sqrt{\frac{105 \cdot p}{\sigma_F}} \]

\( s_{\text{n}} \) 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
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\[ t_w = 14.9 \cdot s_w \cdot \sqrt{\frac{105 \cdot p}{\sigma_F}} \]

and

\[ t_w = \sqrt{\frac{440 \cdot s_w^2 \cdot 105 \cdot p - t_{np}^2}{\sigma_F}} \]

where \( t_{np} \) is actual net thickness of the narrower plating and not to be greater than

\[ 14.9 \cdot s_w \cdot \sqrt{\frac{105 \cdot p}{\sigma_F}} \]

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 \( t_{net} + 0.5 \text{ mm} \).

Where the gauged thickness is within the range \( t_{net} + 0.5 \text{ mm} \) and \( t_{net} + 1.0 \text{ mm} \), coating (applied in accordance with the coating manufacturer’s requirements) or annual gauging may be adopted as an alternative to steel renewal.
Figure 1

V = Volume of cargo

P = Calculation point
Figure 2a

n = neutral axis of the corrugations

S = max [sec]
Note  For the definition of $\ell$, 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
Figure 3a
Symmetric shedder plates

Figure 3b
Asymmetric shedder plates
Figure 5  Permitted distance, $d$, from edge of stool top plate to surface of corrugation flange

$d \geq t_f$

* $t_f$: As-Built Flange Thickness
Figure 6

Root Face (f): 3 mm to T/3 mm
Groove Angle (α): 40° to 60°
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/m³, 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.
S19.2.2 - 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 \( d_1 \) and \( d_f \), \( d_1 \) (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
- \( \rho_c \) = 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.
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/m², is given by:

\[
p_{c,f} = \rho \cdot g \cdot h_f
\]

where:

- \( \rho \) = sea water density, in t/m³
- \( g \) = 9.81 m/s², 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/m², is given by:

\[
p_{c,f} = \rho \cdot g \cdot h_f + \left[ \rho_c - \rho \cdot (1 - \text{perm}) \right] \cdot g \cdot h_1 \cdot \tan^2 \gamma
\]

where:

- \( \rho, \ g, \ h_f \) = as given above
- \( \rho_c \) = bulk cargo density, in t/m³
- \( \text{perm} \) = 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/m³).
- \( h_1 \) = 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)
- \( \gamma \) = \( 45^\circ - (\phi/2) \)
- \( \phi \) = angle of repose of the cargo, in degrees, and may generally be taken as \( 35^\circ \) for iron ore.

The force \( F_{c,f} \), in kN, acting on a corrugation is given by:

\[
F_{c,f} = s_1 \left( \frac{\rho \cdot g \cdot (d_f - d_1)^2}{2} + \frac{\rho \cdot g \cdot (d_f - d_1) \cdot (p_{c,f})_{le} \cdot (d_f - h_{DB} - h_{1,s})}{2} \right)
\]
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where:

\( s_1 \) = spacing of corrugations, in m (see Figure 2a)

\( \rho, g, d_1, h_{DB} \) = as given above

\( d_f \) = as given in S19.2.2

\( (p_{c,f})_{le} \) = pressure, in kN/m², 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/m², is given by:

\[
p_{c,f} = \rho_c \cdot g \cdot h_1 \cdot \tan^2 \gamma
\]

where:

\( \rho_c, g, h_1, \gamma \) = 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/m², is given by:

\[
p_{c,f} = \rho \cdot g \cdot h_f + \left[ \rho_c \cdot h_1 - \rho \cdot (1 - \text{perm}) \cdot h_f \right] \cdot g \cdot \tan^2 \gamma
\]

where:

\( \rho, g, h_f, \rho_c, h_1, \text{perm}, \gamma \) = as given in a) above

The force \( F_{c,f} \), in kN, acting on a corrugation is given by:

\[
F_{c,f} = s_1 \left( \rho_c \cdot g \cdot \frac{(d_1 - d_f)^2}{2} \cdot \tan^2 \gamma + \frac{\rho_c \cdot g \cdot (d_1 - d_f) \cdot \tan^2 \gamma + (p_{c,f})_{le} \cdot (d_f - h_{DB} - h_{LS})}{2} \right)
\]

where:

\( s_1, \rho_c, g, \gamma, (p_{c,f})_{le}, h_{LS} \) = as given in a) above

\( d_1, h_{DB} \) = as given in S19.2.3.1

\( d_f \) = as given in S19.2.2.
S19.2.3.2 - 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:

$$F_f = s_1 \cdot \rho \cdot g \cdot \frac{(d_1 - h_{DB} - h_{LS})^2}{2}$$

where:

$s_1, \rho, g, h_{LS} =$ 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/m², is given by:

$$p_c = \rho_c \cdot g \cdot h_1 \cdot \tan^2 \gamma$$

where:

$\rho_c, g, h_1, \gamma =$ as given in S19.2.3.1 a)

The force $F_c$, in kN, acting on a corrugation is given by:

$$F_c = \rho_c \cdot g \cdot s_1 \cdot \frac{(d_1 - h_{DB} - h_{LS})^2}{2} \cdot \tan^2 \gamma$$

where:

$\rho_c, g, s_1, h_{LS}, \gamma =$ 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/m², to be considered for the scantlings of the bulkhead is given by:

$$p = \rho_{c,f} - 0.8 \cdot \rho_c$$
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/m², 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/m², 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
S19.3.2 - 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:

$F = \text{as given in S19.2.5}$

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 $\phi$ shown in Figure 2a if less than $50^\circ$, 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 $\tau$

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:

$\sigma_{a,le} = \text{allowable stress, in N/mm}^2, \text{as given in S19.4.5, for the lower end of corrugations}$

$\sigma_{a,m} = \text{allowable stress, in N/mm}^2, \text{as given in S19.4.5, for the mid-span of corrugations.}$

In no case $Z_{m}$ is to be taken greater than the lesser of 1.15·$Z_{le}$ and 1.15·$Z'_{le}$ for calculation of the
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
- $\sigma_a$ = allowable stress, in N/mm$^2$, as given in S19.4.5.

Stresses $\tau$ 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 $(\sin \phi)$, $\phi$ 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.
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 $O$ in Figures 3a and 3b), the area of flange plates, in cm$^2$, may be increased by

$$\left( 2.5 \cdot a \cdot \sqrt{t_f \cdot t_{sh}} \cdot \frac{F_{sh}}{\sigma_{sh}} \right)$$

(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
- $\sigma_{sh}$ = minimum upper yield stress, in N/mm$^2$, of the material used for the shedder plates
- $\sigma_{fl}$ = 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 $O$ in Figures 4a and 4b), the area of flange plates, in cm$^2$, may be increased by $(7 \cdot h_g \cdot t_gu)$ where:

$$\left( \frac{10}{7} \cdot s_{gu} \right)$$

- $h_g$ = height of gusset plate in m, see Figures 4a and 4b, not to be taken greater than $7 \cdot h_g$.
- $s_{gu}$ = 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 45° 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 45°, the effectiveness of the web may be obtained by linear interpolation between 30% for 0° and 100% for 45°.

**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.
S19.4.5 - Allowable stress check

The normal and shear stresses $\sigma$ and $\tau$ are not to exceed the allowable values $\sigma_a$ and $\tau_a$, in N/mm$^2$, given by:

$$\sigma_a = \sigma_F$$
$$\tau_a = 0.5 \cdot \sigma_F$$

$\sigma_F = \text{minimum upper yield stress, in N/mm}^2, \text{of the material.}$

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:

$$C_e = \begin{cases} 1.0 & \text{for } \beta \leq 1.25 \\ \frac{225}{\beta} - \frac{125}{\beta^2} & \text{for } \beta > 1.25 \end{cases}$$

$$\beta = 10^3 \cdot \frac{a}{t_f} \cdot \sqrt[\circ]{\frac{\sigma_F}{E}}$$

$t_f = \text{net flange thickness, in mm}$
$a = \text{width, in m, of the corrugation flange (see Figure 2a)}$
$\sigma_F = \text{minimum upper yield stress, in N/mm}^2, \text{of the material}$
$E = \text{modulus of elasticity, in N/mm}^2, \text{to be assumed equal to } 2.06 \cdot 10^5 \text{ N/mm}^2 \text{ for steel}$

S19.4.6.2 - Shear

The buckling check is to be performed for the web plates at the corrugation ends.

The shear stress $\tau$ is not to exceed the critical value $\tau_c$, in N/mm$^2$ obtained by the following:

$$\tau_c = \tau_E$$
when $\tau_E \leq \frac{\tau_F}{2}$

$$\tau_c = \tau_F \left( 1 - \frac{\tau_E}{4\tau_E} \right)$$
when $\tau_E > \frac{\tau_F}{2}$
where:

\[ \sigma_F = \text{minimum upper yield stress, in N/mm}^2, \text{of the material} \]

\[ \tau_E = 0.9k_tE\left(\frac{t}{1000c}\right)^2 \quad (\text{N/mm}^2) \]

\[ k_t, E, t \text{ and } c \text{ are given by:} \]

\[ k_t = 6.34 \]

\[ E = \text{modulus of elasticity of material as given in S19.4.6.1} \]

\[ t = \text{net thickness, in mm, of corrugation web} \]

\[ c = \text{width, in m, of corrugation web (See Figure 2a)} \]

**S19.4.7 - Local net plate thickness**

The bulkhead local net plate thickness \( t \), in mm, is given by:

\[ t = 14.9s_w\sqrt{\frac{p}{\sigma_F}} \]

where:

\[ s_w = \text{plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is the greater (see Figure 2a)} \]

\[ p = \text{resultant pressure, in kN/m}^2, \text{as defined in S19.2.5, at the bottom of each strake of plating; in all cases, the net thickness of the lowest strake is to be determined using the resultant pressure at the top of the lower stool, or at the inner bottom, if no lower stool is fitted or at the top of shedders, if shedder or gusset/shedder plates are fitted.} \]

\[ \sigma_F = \text{minimum upper yield stress, in N/mm}^2, \text{of the material.} \]

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:

\[ t_n = 14.9s_n\sqrt{\frac{p}{\sigma_F}} \]

\( s_n \) 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 values:

\[ t_w = 14,9 \cdot s_w \cdot \frac{p}{\sigma_F} \]

\[ t_w = \sqrt{\frac{440 \cdot s_w^2 \cdot p}{\sigma_F}} - t_{np}^2 \]

where \( t_{np} \) is actual net thickness of the narrower plating and not to be greater than:

\[ 14,9 \cdot s_w \cdot \frac{p}{\sigma_F} \]

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:

\[ 0,8 \cdot (\sigma_{Ffl} \cdot t_n) \geq \sigma_{Fs} \cdot t_{st} \]
where:

\[ \sigma_{Ff} = \text{minimum upper yield stress, in N/mm}^2, \text{of the material used for the corrugation flanges} \]

\[ \sigma_{Fs} = \text{minimum upper yield stress, in N/mm}^2, \text{of the material used for the lower stool side plating or floors (if no stool is fitted)} \]

\[ t_{fl} = \text{flange thickness, in mm, which is found to be acceptable on the basis of the criteria specified in a) above or, when steel renewal is required, the replenished thickness according to the criteria specified in b) above. The above flange thickness dictated by local pressure requirements (see S19.4.7) need not be considered for this purpose} \]

\[ t_{st} = \text{as built thickness, in mm, of the lower stool side plating or floors (if no stool is fitted)} \]

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).
Figure 1

V = Volume of cargo

P = Calculation point
Figure 2a

Sheeter Plates
Where $\phi < 50^\circ$

$n =$ neutral axis of the corrugations

$s =$ max $[\sin \alpha]$
Note: For the definition of $\ell$, 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
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
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.
Upper end to be suitably tapered

Lower end to be welded to lower shelf by full penetration weld

Flange reinforcement strips to be aligned with strips of same scantlings below shelf plate

Reinforcement strips with shedder plate

Upper end to be suitably tapered

Lower end to be tapered above shelf plate within line of gusset

Gusset plate

Lower shelf plate

Reinforcement strips with shedder and gusset plates

Figure 1
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. Shedders 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

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

- Carriage of cargoes having $\rho_c \geq 1.78 \text{ t/m}^3$: No need for further assessment
  - No
- Check for $\rho_c = 1.78 \text{ t/m}^3$
  - Yes
  - Check satisfactory
    - No
    - Reinforce
      - No
      - Calculate allowable density $\rho_{c_1}$
        - $\rho_{c_1} > 1.78 \text{ t/m}^3$?
          - Yes
            - Cargoes having $\rho_c \leq \rho_{c_1}$ can be carried
          - No
            - Only cargoes having $\rho_c \leq 1.78 \text{ t/m}^3$ can be carried
  - Yes
    - Check for $\rho_c > 1.78 \text{ t/m}^3$
      - Yes
        - All cargoes can be carried
      - No
        - Reinforcements for $\rho_c$
          - (2)
            - Yes
            - Calculate allowable density $\rho_{c_2}$
              - Cargoes having $\rho_c \leq \rho_{c_2}$ can be carried
            - No

NOTES:
(1) $\rho_c$ typical of cargoes to be carried, in any case a value of 3.0 t/m³, 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).
Evaluation of Allowable Hold Loading for Bulk Carriers Considering Hold Flooding

S20.1 - Application and definitions

Revision 4 of this UR is to be complied with in respect of the flooding of any cargo hold of bulk carriers, as defined in UR Z11.2.2, of 150m in length and above, with single deck, topside tanks and hopper tanks, and of single side or double side skin construction, intending to carry solid bulk cargoes having a density 1,0 t/m³, or above, in accordance with Note 2.

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
- $0,9D$ for the other holds

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. Revision 4 of this UR is to be applied by IACS Societies to ships contracted for construction from a date commencing not later than 1 July 2006.
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 \( t_{\text{net}} \), in mm, is given by:

\[
t_{\text{net}} = t - 2.5
\]

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:

\[
S_{f1} = 10^{-3} \cdot A_f \cdot \frac{\tau}{\eta_1}
\]

\[
S_{f2} = 10^{-3} \cdot A_{f,h} \cdot \frac{\tau}{\eta_2}
\]

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)
\( \tau_a \) = allowable shear stress, in N/mm\(^2\), to be taken equal to the lesser of
\[
\tau_a = \frac{162 \cdot \sigma_F^{0.6}}{(s/t_{\text{net}})^{0.8}} \quad \text{and} \quad \frac{\sigma_F}{\sqrt{3}}
\]

For floors adjacent to the stools or transverse bulkheads, as identified in S20.3, \( \tau_a \) may be taken as
\[
\frac{\sigma_F}{\sqrt{3}}
\]

\( \sigma_F \) = minimum upper yield stress, in N/mm\(^2\), of the material
\( s \) = spacing of stiffening members, in mm, of panel under consideration
\( \eta_1 \) = 1.10
\( \eta_2 \) = 1.20
\( \eta_2 \) 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)
\( \tau_a \) = allowable shear stress, in N/mm\(^2\), as given in S20.3.1
\( \eta_1 \) = 1.10
\( \eta_2 \) = 1.15
\( \eta_2 \) may be reduced, to the Society’s discretion, down to 1.10 where appropriate reinforcements are fitted to the Society’s satisfaction
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

\( \rho_c = \) cargo density, in t/m\(^3\); for bulk cargoes see S20.2.1; for steel products, \( \rho_c \) 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 \( perm = 0 \)

\( \rho = \) 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:

\[
Z_1 = \frac{C_h}{A_{DB,h}}
\]

\[
Z_2 = \frac{C_e}{A_{DB,e}}
\]
$C_h = \text{shear capacity of the double bottom, in kN, as defined in S20.3, considering, for each floor, the lesser of the shear strengths } S_{f1} \text{ and } S_{f2} (\text{see S20.3.1}) \text{ and, for each girder, the lesser of the shear strengths } S_{g1} \text{ and } S_{g2} (\text{see S20.3.2})$

$C_e = \text{shear capacity of the double bottom, in kN, as defined in S20.3, considering, for each floor, the shear strength } S_{f1} (\text{see S20.3.1}) \text{ and, for each girder, the lesser of the shear strengths } S_{g1} \text{ and } S_{g2} (\text{see S20.3.2})$

$$A_{DB,e} = \sum_{i=1}^{n} S_i \cdot (B_{DB} - s_1)$$

$n = \text{number of floors between stools (or transverse bulkheads, if no stool is fitted)}$

$S_i = \text{space of ith-floor, in m}$

$B_{DB,i} = B_{DB} - s_1 \text{ for floors whose shear strength is given by } S_{f1} (\text{see S20.3.1})$

$B_{DB,i} = B_{DB,h} \text{ for floors whose shear strength is given by } S_{f2} (\text{see S20.3.1})$

$B_{DB} = \text{breadth of double bottom, in m, between hoppers (see Figure 3)}$

$B_{DB,h} = \text{distance, in m, between the two considered opening (see Figure 3)}$

$s_1 = \text{spacing, in m, of double bottom longitudinals adjacent to hoppers}$
Figure 1

$V = \text{Volume of cargo}$
Figure 3
Evaluation of Scantlings of Hatch Covers and Hatch Coamings of Cargo Holds of Bulk Carriers, Ore Carriers and Combination Carriers (Rev. 4)

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, \( t_{\text{net}} \), 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 \( t_{\text{net}} \).

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

$$p = 34.3 + \frac{p_{FP} - 34.3}{0.25} \cdot \left(0.25 - \frac{x}{L}\right) \geq 34.3,$$  for hatch ways located at the freeboard deck

where:

$p_{FP} = $ pressure at the forward perpendicular

$= 49.1 + (L-100)a$

$a = \begin{cases} 
0.0726 & \text{for type B freeboard ships} \\
0.356 & \text{for ships with reduced freeboard}
\end{cases}$

$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

$$p = 15.8 + \frac{L}{3} \cdot \left(1 - \frac{5}{3} \cdot \frac{x}{L}\right) - 3.6 \cdot \frac{x}{L} \geq 0.195L + 14.9,$$  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 $\sigma$ and $\tau$ in the hatch cover structures are not to exceed the allowable values, $\sigma_a$ and $\tau_a$, in N/mm$^2$, given by:

$$\sigma_a = 0.8 \sigma_F$$

$$\tau_a = 0.46 \sigma_F$$

$\sigma_F$ 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 $\sigma$ and $\tau$, the net scantlings are to be used.
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:

$$A_f = \sum_{nf} (10b_{ef}t)$$

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 $0.165 \ell$
- $b_p = $ half distance, in m, between the considered primary supporting member and the adjacent one
- $\ell = $ 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
  - $= 1.90 \sigma/\sigma_s$, for $\sigma/\sigma_s \geq 0.8$, 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
- $\sigma = $ as defined in S21.3.5
- $\sigma_s = $ 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:
where:

\[ l = \text{secondary stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all secondary stiffener spans, the secondary stiffener span may be reduced by an amount equal to } \frac{2}{3} \text{ of the minimum brackets arm length, but not greater than } 10\% \text{ of the gross span, for each bracket.} \]

\[ s = \text{secondary stiffener spacing, in m} \]

\[ p = \text{pressure, in kN/m}^2, \text{ as defined in S21.2} \]

\[ \sigma_a = \text{as defined in S21.3.1.} \]

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 in both flanges and the shear stress in the web, do not exceed the allowable values \( \sigma_a \) and \( \tau_a \), 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 \( \sigma \) 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 \( \sigma_{C1} \), to be evaluated as defined below:

\[
\sigma_{C1} = \sigma_{E1} \quad \text{when } \sigma_{E1} \leq \frac{\sigma_F}{2} \\
= \sigma_F \left[1 - \frac{\sigma_F}{2} \frac{l}{(4\sigma_{E1})}\right] \quad \text{when } \sigma_{E1} > \frac{\sigma_F}{2}
\]

where:

\[ \sigma_F = \text{minimum upper yield stress, in N/mm}^2, \text{ of the material} \]

\[ \sigma_{E1} = 3.6E \left(\frac{t}{1000s}\right)^2 \]

---

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The mean compressive stress $\sigma$ 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 $\sigma_{c2}$, to be evaluated as defined below:

$$\sigma_{c2} = \sigma_{E2}$$

when $\sigma_{E2} \leq \frac{\sigma_F}{2}$

$$\sigma_{E2} = \sigma_t \left[1 - \frac{1}{4} \frac{\sigma_{F}}{\sigma_{E2}} \right]$$

when $\sigma_{E2} > \frac{\sigma_F}{2}$

where:

$\sigma_F$ = minimum upper yield stress, in N/mm$^2$, of the material

$\sigma_{E2} = 0.9mE \left( \frac{t}{1000s_s} \right)^2$

$m = c \left[1 + \left( \frac{s_s}{l_s} \right)^2 \right]^{2} \frac{2.1}{\psi^2 + 1.1}$

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 $\sigma$ 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 $\sigma_{cs}$, to be evaluated as defined below:
\( \sigma_{CS} = \sigma_{ES} \) when \( \sigma_{ES} \leq \frac{\sigma_F}{2} \)

\[ \sigma_{ES} = \sigma_F \left[ 1 - \sigma_F / (4 \sigma_{ES}) \right] \] when \( \sigma_{ES} > \frac{\sigma_F}{2} \)

where:

- \( \sigma_F \) = minimum upper yield stress, in N/mm\(^2\), of the material
- \( \sigma_{ES} \) = ideal elastic buckling stress, in N/mm\(^2\), of the secondary stiffener,
  = minimum between \( \sigma_{E3} \) and \( \sigma_{E4} \)

\( \sigma_{E3} = \frac{0.001 E I_a}{A L^2} \)

- \( E \) = modulus of elasticity, in N/mm\(^2\)
  = 2.06 \times 10^5 \text{ 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

\( \sigma_{E4} = \frac{\pi^2 E I_w}{10^4 I_p l^2} \left( m^2 + \frac{K}{m^2} \right) + 0.385 E I_p \frac{l}{I_p} \)

\( K = \frac{C l^4}{\pi^4 E I_w} \times 10^6 \)

- \( m \) = number of half waves, given by the following table:

<table>
<thead>
<tr>
<th>( 0 &lt; K &lt; 4 )</th>
<th>( 4 &lt; K &lt; 36 )</th>
<th>( 36 &lt; K &lt; 144 )</th>
<th>( (m-1)^2 m^2 &lt; K \leq m^2(m+1)^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( m )</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

- \( I_w \) = sectorial moment of inertia, in cm\(^6\), of the secondary stiffener about its connection with the plating
  = \( \frac{h^3 t^3}{24} \times 10^{-6} \) for flat bar secondary stiffeners
  = \( \frac{t_f b^3 h_2^2}{6} \times 10^{-6} \) for "Tee" secondary stiffeners
  = \( \frac{b_j h_2^2}{12 b_j + h_2} \left[ t_f \left( b_j^2 + 2 b_j h_2 + 4 h_2^2 \right) + 3 t_w b_j h_2 \right] \times 10^{-6} \) 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
  = \( \frac{h^3 t_w}{3} \times 10^{-4} \) for flat bar secondary stiffeners
It = St Venant’s moment of inertia, in cm^4, of the secondary stiffener without top flange

\[
I_t = \left( \frac{h_w t_w^3}{3} + h_f b_f t_f \right) 10^{-4}
\]

for flanged secondary stiffeners

\[
I_t = \frac{h_w t_w^3}{3} 10^{-4}
\]

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

\[h_w, t_w = \text{height and net thickness, in mm, of the secondary stiffener, respectively}\]

\[b_f, t_f = \text{width and net thickness, in mm, of the secondary stiffener bottom flange, respectively}\]

\[s = \text{spacing, in m, of secondary stiffeners}\]

\[C = \text{spring stiffness exerted by the hatch cover top plating} = \frac{k_p E t_p^3}{3s \left( 1 + \frac{1.33k_F h_w t_w^3}{1000s t_w^3} \right)} 10^{-3}\]

\[k_p = 1 - \eta_p \quad \text{to be taken not less than zero;}
\]

\[\text{for flanged secondary stiffeners, } k_p \text{ need not be taken less than 0.1}\]

\[\eta_p = \frac{\sigma}{\sigma_{E1}}\]

\[\sigma_{E1} = \text{as defined in S21.3.5}\]

\[\sigma = \text{as defined in S21.3.6.1}\]

\[t_p = \text{net thickness, in mm, of the hatch cover plate panel.}\]

For flat bar secondary stiffeners and buckling stiffeners, the ratio h/tW is to be not greater than 15 k0.5, where:

\[h, t_W = \text{height and net thickness of the stiffener, respectively}\]

\[k = 235/\sigma_F\]

\[\sigma_F = \text{minimum upper yield stress, in N/mm}^2, \text{of the material.}\]

**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 \( \tau \) in the hatch cover primary supporting members web panels is not to exceed 0.8 times the critical buckling stress \( \tau_C \), to be evaluated as defined below:

\[
\tau_C = \tau_E \quad \text{when } \tau_E \leq \frac{\tau_F}{2}
\]

\[
= \tau_E \left[ 1 - \tau_F / (4\tau_E) \right] \quad \text{when } \tau_E > \frac{\tau_F}{2}
\]
where:

\[ \sigma_F = \text{minimum upper yield stress, in } N/mm^2, \text{ of the material} \]

\[ \tau_p = \sigma_F / \sqrt{3} \]

\[ \tau_F = 0.9k_E \left( \frac{t_{pr,n}}{1000d} \right) \]

\[ E = \text{modulus of elasticity, in } N/mm^2 \]
\[ = 2.06 \times 10^5 \text{ for steel} \]

\[ t_{pr,n} = \text{net thickness, in mm, of primary supporting member} \]

\[ k_t = 5.35 + 4.0 / (a / d)^2 \]

\[ a = \text{greater dimension, in m, of web panel of primary supporting member} \]

\[ d = \text{smaller dimension, in m, of web panel of primary supporting member}. \]

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 \( \tau_C \). In such a case, the average shear stress \( \tau \) 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/m², on the No. 1 forward transverse hatch coaming is given by:

\[ p_{coam} = 220, \text{ when a forecastle is fitted in accordance with UR S28} \]
\[ = 290 \text{ in the other cases} \]

The pressure \( p_{coam} \), in kN/m², on the other coamings is given by:

\[ p_{coam} = 220 \]
S21.4.2 Local net plate thickness

The local net plate thickness $t$, in mm, of the hatch coaming plating is given by:

$$t = 14.9s \sqrt{\frac{p_{\text{coam}}}{\sigma_{a,\text{coam}}}} \cdot \frac{S_{\text{coam}}}{S_{\text{coam}}}$$

where:

- $s$ = secondary stiffener spacing, in m
- $p_{\text{coam}}$ = pressure, in kN/m$^2$, as defined in S21.4.1
- $S_{\text{coam}}$ = safety factor to be taken equal to 1.15
- $\sigma_{a,\text{coam}} = 0.95 \sigma_F$

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:

$$Z = \frac{1000 S_{\text{coam}}}{m} \cdot \frac{l^2 s}{c_p \sigma_{a,\text{coam}}} \cdot \frac{p_{\text{coam}}}{p_{\text{coam}}}$$

where:

- $m$ = 16 in general
- $m = 12$ for the end spans of stiffeners sniped at the coaming corners
- $S_{\text{coam}}$ = safety factor to be taken equal to 1.15
- $l$ = span, in m, of secondary stiffeners
- $s$ = spacing, in m, of secondary stiffeners
- $p_{\text{coam}}$ = 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
  - $c_p = 1.16$ in the absence of more precise evaluation,
- $\sigma_{a,\text{coam}} = 0.95 \sigma_F$

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
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/m², as defined in S21.4.1

\[ \sigma_{a,coam} = 0.95 \sigma_F \]

\[ \tau_{a,coam} = 0.5 \sigma_F \]

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:
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:

\[
A = 1.4 \frac{a}{f} \text{(cm}^2\text{)}
\]

where:

\[a = \text{spacing in m of securing devices, not being taken less than 2 m}\]
\[f = \left(\frac{\sigma_y}{235}\right)^e\]
\[\sigma_y = \text{specified minimum upper yield stress in N/mm}^2\text{ of the steel used for fabrication, not to be taken greater than 70% of the ultimate tensile strength.}\]
\[e = \begin{cases} 
0.75 & \text{for } \sigma_y > 235 \\
1.0 & \text{for } \sigma_y \leq 235 
\end{cases}\]

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:

\[
I = 6pa^4 \text{(cm}^4\text{)}
\]

\[p = \text{packing line pressure in N/mm, minimum 5 N/mm.}\]
\[a = \text{spacing in m of securing devices.}\]

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
means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m².

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/m².

This pressure may be reduced to 175 kN/m² 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 $\sigma_Y$.

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 double skin 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 double skin hatch covers, steel renewal is required where the gauged thickness is less than $t_{\text{net}} + 0.5$ mm. Where the gauged thickness is within the range $t_{\text{net}} + 0.5$ mm and $t_{\text{net}} + 1.0$ 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 double skin 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 $t_{\text{net}}$.

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 $t_{\text{net}} + 0.5$ mm. Where the gauged thickness is within the range $t_{\text{net}} + 0.5$ mm and $t_{\text{net}} + 1.0$ 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.
Evaluation of Allowable Hold Loading of Cargo Hold No. 1 with Cargo Hold No. 1 Flooded, for Existing Bulk Carriers

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/m³, 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
- $0.95 \cdot D$ 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 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.
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 $t_{\text{net}}$, in mm, is given by:

$$t_{\text{net}} = t - t_c$$

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 $t_c$ 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)

\[ \tau_a = \text{allowable shear stress, in N/mm}^2, \text{to be taken equal to:} \quad \frac{\sigma_F}{\sqrt{3}} \]

\[ \sigma_F = \text{minimum upper yield stress, in N/mm}^2, \text{of the material} \]

\[ \eta_1 = 1.10 \]

\[ \eta_2 = 1.20 \]

\( \eta_2 \) 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)

\( \tau_a \) = allowable shear stress, in N/mm\(^2\), as given in S22.3.1

\[ \eta_1 = 1.10 \]

\[ \eta_2 = 1.15 \]

\( \eta_2 \) 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

\( F = 1.00 \) for steel mill products

\( \rho_c = \text{cargo density, in t/m}^3; \text{for bulk cargoes see S22.2.1; for steel products, } \rho_c \text{ is to be taken as the} \)
density of steel

\( V = \text{volume, in m}^3, \text{occupied by cargo at a level } h_1 \)

\[ h_1 = \frac{X}{\rho_c \cdot g} \]

\( X = \text{for bulk cargoes, the lesser of } X_1 \text{ and } X_2 \) given by

\[ X_1 = \frac{Z + \rho \cdot g \cdot (E - h_f)}{1 + \frac{\rho}{\rho_c} (\text{perm} - 1)} \]

\[ X_2 = Z + \rho \cdot g \cdot (E - h_f \cdot \text{perm}) \]

\( X = \text{for steel products, } X \text{ may be taken as } X_1, \text{ using } \text{perm} = 0 \)

\( \rho = \text{sea water density, in t/m}^3 \)

\( g = 9.81 \text{ m/s}^2, \text{ gravity acceleration} \)

\( E = d_f \cdot 0.1 \cdot D \)

\( d_f, D = \text{as given in S22.2.2} \)

\( h_f = \text{floodling head, in m, as defined in S22.2.2} \)

\( \text{perm} = \text{permeability of cargo, to be taken as } 0.3 \text{ for ore (corresponding bulk cargo density for iron ore may generally be taken as } 3.0 \text{ t/m}^3). \)

\( Z = \text{the lesser of } Z_1 \text{ and } Z_2 \) given by:

\[ Z_1 = \frac{C_h}{A_{DB,h}} \]

\[ Z_2 = \frac{C_e}{A_{DB,e}} \]

\( C_h = \text{shear capacity of the double bottom, in kN, as defined in S22.3, considering, for each floor, the lesser of the shear strengths } S_{f1} \text{ and } S_{f2} \) (see S22.3.1) and, for each girder, the lesser of the shear strengths \( S_{g1} \) and \( S_{g2} \) (see S22.3.2)

\( C_e = \text{shear capacity of the double bottom, in kN, as defined in S22.3, considering, for each floor, the shear strength } S_{f1} \) (see S22.3.1) and, for each girder, the lesser of the shear strengths \( S_{g1} \) and \( S_{g2} \) (see S22.3.2)
\[ A_{DB,h} = \sum_{i=1}^{n} S_i \cdot B_{DB,i} \]

\[ A_{DB,e} = \sum_{i=1}^{n} S_i \cdot B_{DB} - s \]

- \( n \) = number of floors between stools (or transverse bulkheads, if no stool is fitted)
- \( S_i \) = space of \( i \)-th floor, in m
- \( B_{DB,i} = B_{DB} - s \) for floors whose shear strength is given by \( S_f_1 \) (see S22.3.1)
- \( B_{DB,i} = B_{DB,h} \) for floors whose shear strength is given by \( S_f_2 \) (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
Figure 1

$V = \text{Volume of cargo}$
Figure 2

Figure 3
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.

* See Annex for details.
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.
Detection of Water Ingress into Cargo Holds of Bulk Carriers

URS24 superceded by UI SC 179 and SC 180

Deleted on 1 January 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 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, 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/m³ 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/m³ 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/m³.

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.
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/m³)} for notations BC-A and BC-B if the maximum cargo density is less than 3.0 tonnes/m³;
   - {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/m³, 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/m³, 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/m³}.

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/m³, 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/m³, 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/m³}. 

IACS Req. 2002/Rev.2, 2004
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

\[
I = \text{the distance from propeller centerline to the waterline} \\
D = \text{propeller diameter, and}
\]

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.
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.
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.

\( M_{\text{Full}} \): 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. \( M_{\text{Full}} \) 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 \( M_{\text{Full}} \) 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 \( M_{\text{Full}} \) 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 \( M_{\text{Full}} \) 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.
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 seagoing 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.
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.
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 emergency escape need not comply with the requirements 5.1 (i) and (ii), 6.3 and 7 of this UR.

1.4 Securing devices of hatches designed for emergency escape are to be of a quick-acting type (e.g., one action wheel handles are provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover.

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.

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**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.
3. **Implementation * (see footnote)**

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.

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.

* The requirements in 1.4, introduced in Rev. 3 of this UR, are to be uniformly applied by IACS Members and Associates:
(a) to new vessels, contracted for construction on or after 1 July 2007, by the time of delivery;
(b) to vessels contracted for construction prior to 1 July 2007, by the compliance date specified in Section 3 of this UR, or by the due date of the first special survey after 1 July 2007, whichever is later.
Completion prior to 1 July 2007 of a special survey with a due date after 1 July 2007 cannot be used to postpone compliance.
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.

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

<table>
<thead>
<tr>
<th>Nominal size (mm x mm)</th>
<th>Cover plate thickness (mm)</th>
<th>Primary stiffeners</th>
<th>Secondary stiffeners</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flat Bar (mm x mm); number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>630 x 630</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>630 x 830</td>
<td>8</td>
<td>100 x 8 ; 1</td>
<td>-</td>
</tr>
<tr>
<td>830 x 630</td>
<td>8</td>
<td>100 x 8 ; 1</td>
<td>-</td>
</tr>
<tr>
<td>830 x 830</td>
<td>8</td>
<td>100 x 10 ; 1</td>
<td>-</td>
</tr>
<tr>
<td>1030 x 1030</td>
<td>8</td>
<td>120 x 12 ; 1</td>
<td>80 x 8 ; 2</td>
</tr>
<tr>
<td>1330 x 1330</td>
<td>8</td>
<td>150 x 12 ; 2</td>
<td>100 x 10 ; 2</td>
</tr>
</tbody>
</table>
Figure 1. Arrangement of Stiffeners

Nominal size 630 x 630
Nominal size 630 x 830
Nominal size 830 x 830
Nominal size 830 x 630
Nominal size 1030 x 1030
Nominal size 1330 x 1330

- Hinge
- Securing device / metal to metal contact
- Primary stiffener
- Secondary stiffener
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
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 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 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 1 January 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 aftwards, 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.

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. This UR does not apply to the cargo tank venting systems and the inert gas systems of tankers.
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:

- $\rho$ = 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 cylindrical 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:

$$f = 1 + \frac{B}{H}, \text{ but not greater than 2.5}$$

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:

$$R_{xi} = P_x h x_i A_i / I_x$$
$$R_{yi} = P_y h y_i A_i / I_y$$
and

\[ R_i = R_{xi} + R_{yi} - R_{si} \]

where:

- \( P_x, P_y \) = force (kN) acting normal to the shaft axis
- \( h \) = 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 \( i \) (cm²)
- \( I_x, I_y \) = \( \sum A_i x_i^2 \) 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:

\[ F_{x_i} = (P_x - \alpha \cdot g \cdot M) / N \]
\[ F_{y_i} = (P_y - \alpha \cdot g \cdot M) / N \]

and

\[ F_i = (F_{x_i}^2 + F_{y_i}^2)^{0.5} \]

where:

- \( \alpha \) = coefficient of friction (0.5)
- \( M \) = mass of windlass (tonnes)
- \( g \) = gravity acceleration (9.81 m/sec²)
- \( N \) = 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 \( \alpha_y \), where \( \alpha_y \) 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.
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.
Table 1: 760 mm Air Pipe Thickness and Bracket Standards

<table>
<thead>
<tr>
<th>Nominal pipe diameter (mm)</th>
<th>Minimum fitted gross thickness, LL36(c) (mm)</th>
<th>Maximum projected area of head (cm²)</th>
<th>Height (1) of brackets (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40A(3)</td>
<td>6.0</td>
<td>-</td>
<td>520</td>
</tr>
<tr>
<td>50A(3)</td>
<td>6.0</td>
<td>-</td>
<td>520</td>
</tr>
<tr>
<td>65A</td>
<td>6.0</td>
<td>-</td>
<td>480</td>
</tr>
<tr>
<td>80A</td>
<td>6.3</td>
<td>-</td>
<td>460</td>
</tr>
<tr>
<td>100A</td>
<td>7.0</td>
<td>-</td>
<td>380</td>
</tr>
<tr>
<td>125A</td>
<td>7.8</td>
<td>-</td>
<td>300</td>
</tr>
<tr>
<td>150A</td>
<td>8.5</td>
<td>-</td>
<td>300</td>
</tr>
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<td>175A</td>
<td>8.5(2)</td>
<td>1900</td>
<td>300(2)</td>
</tr>
<tr>
<td>200A</td>
<td>8.5(2)</td>
<td>2500</td>
<td>300(2)</td>
</tr>
<tr>
<td>250A</td>
<td>8.5(2)</td>
<td>3200</td>
<td>300(2)</td>
</tr>
<tr>
<td>300A</td>
<td>8.5(2)</td>
<td>3800</td>
<td>300(2)</td>
</tr>
<tr>
<td>350A</td>
<td>8.5(2)</td>
<td>4500</td>
<td>300(2)</td>
</tr>
</tbody>
</table>

(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

<table>
<thead>
<tr>
<th>Nominal pipe diameter (mm)</th>
<th>Minimum fitted gross thickness, LL 36(c) (mm)</th>
<th>Maximum projected area of head (cm²)</th>
<th>Height of brackets (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80A</td>
<td>6.3</td>
<td>-</td>
<td>460</td>
</tr>
<tr>
<td>100A</td>
<td>7.0</td>
<td>-</td>
<td>380</td>
</tr>
<tr>
<td>150A</td>
<td>8.5</td>
<td>-</td>
<td>300</td>
</tr>
<tr>
<td>200A</td>
<td>8.5</td>
<td>550</td>
<td>-</td>
</tr>
<tr>
<td>250A</td>
<td>8.5</td>
<td>880</td>
<td>-</td>
</tr>
<tr>
<td>300A</td>
<td>8.5</td>
<td>1200</td>
<td>-</td>
</tr>
<tr>
<td>350A</td>
<td>8.5</td>
<td>2000</td>
<td>-</td>
</tr>
<tr>
<td>400A</td>
<td>8.5</td>
<td>2700</td>
<td>-</td>
</tr>
<tr>
<td>450A</td>
<td>8.5</td>
<td>3300</td>
<td>-</td>
</tr>
<tr>
<td>500A</td>
<td>8.5</td>
<td>4000</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: For other ventilator heights, the relevant requirements of section 5 are to be applied.
Note:
P_y to be examined from both inboard and outboard directions separately – see 4.2.1. The sign convention for y is reversed when P_y is from the opposite direction as shown.

Figure 1. Direction of Forces and Weight

Coordinates x_i and y_i are shown as either positive (+ve) or negative (-ve).

Figure 2. Sign Convention
Requirements for the Fitting of a Forecastle for Bulk Carriers, Ore Carriers and Combination Carriers

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.

However, if this requirement hinders hatch cover operation, the aft bulkhead of the forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than 7% of ship length abaft the forward perpendicular where the ship length and forward perpendicular are defined in the International Convention on Load Line 1966 and its Protocol 1988.

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

- $H_C + 0.5\text{ m}$, 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 $l_F$:

$$l_F \leq 5\sqrt{H_F - H_C}$$

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 $H_B / \tan 20^\circ$ 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.
Figure 1

Top of the hatch coaming

Forward Bulkhead

$H_C$  $H_B$  $H_F$  $I_F$
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 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.

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:

\[ A = 1.4 \frac{a}{f} \text{ (cm}^2\text{)} \]

where:

\[ a = \text{spacing between securing devices not to be taken less than 2 meters} \]

\[ f = (\sigma_Y / 235)^e \]

\[ \sigma_Y = \text{specified minimum upper yield stress in N/mm}^2\text{ of the steel used for fabrication, not to be taken greater than 70\% of the ultimate tensile strength.} \]

\[ e = \begin{cases} 0.75 \text{ for } \sigma_Y > 235 \\ 1.0 \text{ for } \sigma_Y \leq 235 \end{cases} \]
Rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5 m² 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:

\[ I = 6 \frac{p}{a^4} \text{ (cm}^4) \]

\[ p = \text{packing line pressure in N/mm, minimum 5 N/mm} \]

\[ a = \text{spacing in m of securing devices.} \]

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/m².

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/m².

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/m².

This pressure may be reduced to 175 kN/m² 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 \( \sigma_Y \).

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.
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.

In the case a vessel as defined above does not satisfy above definition in one or more holds, the requirements in UR S31 do not apply to these individual holds.

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 1 January 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.

---

**Note:**

1. 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.
2. The changes introduced in Rev.3 are to be applied by IACS Members and Associates not later than on assessments for compliance commenced on or after 1 July 2006.
3. The changes introduced in Rev.4 are to be applied by IACS Members and Associates not later than on assessments for compliance commenced on or after 1 July 2008.
**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.

1. 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;

2. For OBO carriers which will be 10 years of age or more on 1 July 2005 by the due date of the first special survey after that date;

3. 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.

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 requirements of this UR, except in cases of unusual side structure arrangements or framing to which the requirements of this UR cannot be directly applied. In such cases, the analysis criteria and the strength check criteria are to be in accordance with each Society’s Rules.
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

\[ t_M = \text{thickness as measured, in mm} \]
\[ t_{\text{REN}} = \text{thickness at which renewal is required. See S31.2.1.2} \]
\[ t_{\text{REN,d/t}} = \text{thickness criteria based on d/t ratio. See S31.2.1.2.1} \]
\[ t_{\text{REN,S}} = \text{thickness criteria based on strength. See S31.2.1.2.2} \]
\[ t_{\text{COAT}} = 0.75 \ t_{S12} \]
\[ t_{S12} = \text{thickness in mm as required by UR S12 (Rev.3) in S12.3 for frame webs and in S12.4 for upper and lower bracket webs} \]
\[ t_{AB} = \text{thickness as built, in mm} \]
\[ t_C = \text{See Table 1 below} \]
### Table 1 - \( t_c \) values, in mm

<table>
<thead>
<tr>
<th>Ship’s length ( L ), in m</th>
<th>Holds other than No. 1</th>
<th>Hold No. 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Span and upper brackets</td>
<td>Lower brackets</td>
</tr>
<tr>
<td>≤100</td>
<td>2.0</td>
<td>2.5</td>
</tr>
<tr>
<td>150</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td>≥ 200</td>
<td>2.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

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:

\[
t_{REN} \text{ is the greatest of:}
\]

\[
\begin{align*}
(a) & \quad t_{COAT} - t_c \\
(b) & \quad 0.75 \, t_{AB} \\
(c) & \quad t_{REN,dt} \text{ (applicable to Zone A and B only)} \\
(d) & \quad t_{REN,S} \text{ (where required by S31.2.1.2.2)}
\end{align*}
\]

---

**S31.2.1.2.1 Thickness criteria based on d/t ratio**

Subject to b) and c) below, \( t_{REN,dt} \) is given by the following equation:

\[
t_{REN,dt} = \frac{\text{web depth in mm}}{R}
\]

where:

\[
R = \begin{cases} 
65 \, k^{0.5} & \text{for frames} \\
55 \, k^{0.5} & \text{for symmetrically flanged frames} \\
87 \, k^{0.5} & \text{for asymmetrically flanged frames} \\
73 \, k^{0.5} & \text{for lower brackets (see a) below)} \\
\end{cases}
\]

\[
k = \begin{cases} 
1.0 & \text{for ordinary hull structural steel and according to UR S4 for higher tensile steel.}
\end{cases}
\]
In no instance is \( t_{\text{REN},d/t} \) for lower integral brackets to be taken as less than \( t_{\text{REN},d/t} \) for the frames they support.

a) Lower brackets

Lower brackets are to be flanged or face plate is to be fitted, ref. S31.2.1.3.

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 \( t_{\text{REN},d/t} \) 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 \( t_{\text{REN},d/t} \) may be disregarded in the determination of \( t_{\text{REN}} \) in accordance with S31.2.1.2. The value of \( t_M \) is to be based on zone B according to UR Z10.2, ANNEX V, see Figure 1.

c) Immediately abaft collision bulkhead

For the side frames, including the lower bracket, 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 \( t_{\text{AB}} \) is greater than \( 1.65 \times t_{\text{REN},S} \), the thickness \( t_{\text{REN},d/t} \) may be taken as the value \( t'_{\text{REN},d/t} \) obtained from the following equation:

\[
\frac{t'_{\text{REN},d/t}}{t_{\text{REN},S}} = \sqrt{\frac{1}{t_{\text{REN},d/t}} + \frac{1}{t_{\text{REN},S}}}
\]

where \( t_{\text{REN},S} \) 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 \( t_{\text{COAT}} \), \( t_{\text{REN},S} \) 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 \( t_{\text{AB}} \), \( 1.2t_{\text{COAT}} \) or \( 1.2t_{\text{REN}} \), whichever is the greatest.
S31.2.1.2.4 Criteria for other measures

When $t_{\text{REN}} < t_M \leq t_{\text{COAT}}$, measures are to be taken, consisting of all the following:

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. Tripping brackets not connected to flanges are to have soft toe, and the distance between the bracket toe and the frame flange is not to be greater than about 50 mm, see Figure 4.

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).

When the measured frame webs thickness $t_M$ is such that $t_{\text{REN}} < t_M \leq t_{\text{COAT}}$ and the coating is in GOOD condition, sand blasting and coating as required in a) above may be waived even if not found in “as-new” condition, as defined above, provided that tripping brackets are fitted and the coating damaged in way of the tripping bracket welding is repaired.

S31.2.1.3 Criteria for frames and brackets (Bending check)

When lower end brackets were not fitted with flanges at the design stage, flanges are to be fitted so as to meet the bending strength requirements in S31.3.4. The full width of the bracket flange is to extend up beyond the point at which the frame flange reaches full width. Adequate back-up structure in the hopper is to be ensured, and the bracket is to be aligned with the back-up structure.

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.

The bending check needs not to be carried out in the case the bracket geometry is modified so as to comply with S12(Rev.3) requirements.

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. When renewal is to be carried out, surface preparation and coating are required for the renewed structures as given in UR Z9 for cargo holds of new buildings.

Representative thickness measurements are to be taken for each zone and are to be assessed against the criteria in S31.2.1.

When zone B is made up of different plate thicknesses, the lesser thickness is to be used for the application of the requirements in S31.
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:
   - 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.

When flanges of frames or brackets are to be renewed according to S31, the outstanding breadth to thickness ratio is to comply with the requirements in UR S12.5.

**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.
Where side frames and side shell are made of Higher Strength Steel (HSS), Normal Strength Steel (NSS) tripping brackets may be accepted, provided the electrodes used for welding are those required for the particular HSS grade, and the thickness of the tripping brackets is equal to the frame web thickness, regardless of the frame web material.

**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.

**S31.2.6 Renewal of all frames in one or more cargo holds**

When all frames in one or more holds are required to be renewed according to UR S31, the compliance with the requirements in URS 12 (Rev. 1) may be accepted in lieu of the compliance with the requirements in UR S31, provided that:

- It is applied at least to all the frames of the hold(s)
- The coating requirements for side frames of “new ships” are complied with
- The section modulus of side frames is calculated according to the Classification Society Rules.

**S31.2.7 Renewal of damaged frames**

In case of renewal of a damaged frame already complying with S31, the following requirements apply:

- The conditions accepted in compliance with S31 are to be restored as a minimum.
- For localised damages, the extension of the renewal is to be carried out according to the standard practice of each Classification Society.
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**

The following loading conditions are to be considered:

- Homogeneous heavy cargo (density greater than 1.78 t/m$^3$)
- Homogeneous light cargo (density less than 1.78 t/m$^3$)
- Non homogeneous heavy cargo, if allowed
- Multi port loading/unloading conditions need not be considered.

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) 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

$$= sh \left( \frac{P_{sl,u} + P_{sl,l}}{2} \right)$$

when the upper end of the side frame span $h$ (see Figure 1) is below the load water line

$$= sh' \left( \frac{P_{sl,l}}{2} \right)$$

when the upper end of the side frame span $h$ (see Figure 1) is at or above the load water line
\[ P_1 = \text{wave force, in kN, in head sea} \]
\[ = sh \left( \frac{P_{1,U} + P_{1,L}}{2} \right) \]

\[ P_2 = \text{wave force, in kN, in beam sea} \]
\[ = sh \left( \frac{P_{2,U} + P_{2,L}}{2} \right) \]

\[ h, h_B = \text{side frame span and lower bracket length, in m, defined} \]
\[ \text{in Figures 1 and 2, respectively} \]

\[ h' = \text{distance, in m, between the lower end of side frame span } h \]
\[ \text{(see Figure 1) and the load water line} \]

\[ s = \text{frame spacing, in m} \]

\[ p_{S,U}, p_{S,L} = \text{still water pressure, in kN/m}^2, \text{at the upper and lower end of the} \]
\[ \text{side frame span } h \text{ (see Figure 1), respectively} \]

\[ P_{1,U}, P_{1,L} = \text{wave pressure, in kN/m}^2, \text{as defined in S31.3.1.2.1) below for} \]
\[ \text{the upper and lower end of the side frame span } h, \text{respectively} \]

\[ P_{2,U}, P_{2,L} = \text{wave pressure, in kN/m}^2, \text{as defined in S31.3.1.2.2) below for} \]
\[ \text{the upper and lower end of the side frame span } h, \text{respectively} \]

**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:

\[ p_1 = 1.50 \left[ p_{11} + 135 \frac{B}{2(B + 75)} - 1.2(T - z) \right] \]

\[ p_{11} = 3k_S C + k_f \]

- The wave pressure \( p_1 \), in kN/m\(^2\), above the water line is given by:

\[ p_i = p_{1wl} - 7.50 \left( z - T \right) \]

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:

$$p_2 = p_{2wl} - 5.0 \left( z - T \right)$$

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
  
  $$C = 10.75 \left( \frac{300 - L}{100} \right)^{1.5} \quad \text{for } 90 \leq L \leq 300 \text{ m}$$
  $$C = 10.75 \quad \text{for } 300 \text{ m} < L$$

- $C_r =$
  
  $$C_r = \left( 1.25 - 0.025 \frac{2 k_r}{\sqrt{GM}} \right) k$$

- $k =$
  
  $$k = 1.2 \quad \text{for ships without bilge keel}$$
  $$k = 1.0 \quad \text{for ships with bilge keel}$$

- $k_r =$ 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)
  - 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

- $k_s =$
  
  $$k_s = C_B + \frac{0.83}{\sqrt{C_B}} \quad \text{at aft end of } L$$
  $$k_s = C_B \quad \text{between } 0.2 \text{ L and } 0.6 \text{ L from aft end of } L$$
  $$k_s = C_B + \frac{1.33}{C_B} \quad \text{at forward end of } L$$

Between the above specified points, $k_s$ is to be interpolated linearly.

- $k_l =$ 0.8 $C$
S31.3.2 Allowable stresses

The allowable normal and shear stresses $\sigma_a$ and $\tau_a$, in N/mm$^2$, in the side shell frames and brackets are given by:

\[
\begin{align*}
\sigma_a &= 0.90 \sigma_F \\
\tau_a &= 0.40 \sigma_F
\end{align*}
\]

where $\sigma_F$ 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:

\[
\begin{align*}
k_S &= \text{shear force distribution factor, to be taken equal to 0.6} \\
P_{fr,a}, P_{fr,b} &= \text{pressures forces defined in S31.3.1.1} \\
d_a, d_b &= \text{bracket and frame web depth, in mm, at sections a) and b), respectively (see Figure 2); in case of separate (non integral) brackets, } d_b \text{ is to be taken as the minimum web depth deducing possible scallops} \\
\phi &= \text{angle between frame web and shell plate} \\
\tau_a &= \text{allowable shear stress, in N/mm}^2, \text{ defined in S31.3.2.}
\end{align*}
\]

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)

\[ Z_b = \frac{1000 \ P_{fr,a} \ h}{m_a \ \sigma_a} \]

where:

- \( P_{fr,a} \) = pressures force defined in S31.3.1.1
- \( h \) = side frame span, in m, defined in Figure 1
- \( \sigma_a \) = allowable normal stress, in N/mm², 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 $m_b$

<table>
<thead>
<tr>
<th></th>
<th>$m_a$</th>
<th>$m_b$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$h_B \leq 0.08h$</td>
<td>$h_B = 0.1h$</td>
</tr>
<tr>
<td>Empty holds of ships approved to operate in non homogeneous loading conditions</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Other cases</td>
<td>12</td>
<td>20</td>
</tr>
</tbody>
</table>

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.

Figure 1 – Lower part and zones of side frames
Figure 2 – Sections a) and b)

\[ d_a = \text{lower bracket web depth for determining } t_{\text{brac},s} \]

\[ d_b = \text{frame web depth} \]

\[ h_a = \text{lower bracket length} \]
Figure 3 – Definition of the lower bracket web depth for determining $t_{\text{REN}, \text{dt}}$. 

LOWER BRACKET WEB DEPTH

SOFT TOE

90°
Figure 4 – Tripping brackets

Tripping brackets

Distance from knuckle not greater than 200 mm

Tripping bracket not welded to frame flange

~50 mm
Figure 5 - Pitting intensity diagrams (from 5% to 25% intensity)

5% SCATTERED

20% SCATTERED

10% SCATTERED

25% SCATTERED

15% SCATTERED
[Up-to-date version of S32 for public information. Please note that this draft UR S32 will not be issued since it will be superseded by the IACS Common Structural Rules for Bulk Carrier under finalisation by the IACS’ Joint Bulker Project (JBP)]

[S32] Local Scantlings of Double Side Skin Structure of Bulk Carriers

S32.1 – General

S32.1.1 – Application and definitions

These requirements apply to the double side structures of cargo holds of double side skin bulk carriers, as defined in SOLAS Regulation XII/1, having length as defined in UR S2.1 of 90 m or above and contracted for construction on or after [1st January 2005].

These requirements apply to the following structural members comprising the double side space:

- side shell
- inner side
- transverse bulkheads
- web frames
- stringers

The double side space is the space delimited transversely by the shell and the inner side plating, and vertically by the lower plate of the topside tank and the top plate of the hopper tank. In case no hopper and/or topside tank is fitted, the double side space is delimited vertically by the inner bottom plate and/or the deck.

For the determination of net scantlings and for the assessment of fatigue damage, the double side space is always to be considered as a ballast space, even if it is intended to be a void space, extended up to the deck. This means that the double side space is to be considered as forming a single ballast tank with the topside tank (see Figure 1).

Hull girder stresses are to be calculated using 90% of the hull girder section moduli, calculated according to the requirements specified in UR S5 using the as-built gross scantlings, excluding the Owner’s extra, if any.

The criteria of this UR are to be satisfied at any transverse section within the cargo area.
Figure 1 – Double side space considered as forming a single ballast tank with the topside tank

S32.1.2 – General requirements

For the purpose of this UR, the terms “web frames”, “tank bulkheads” and “non-tight bulkheads” are used to indicate the type of structural elements represented in Figures 2, 3 and 4, respectively.

Figure 2 – Web frame
Figure 3 – Tank bulkhead

Figure 4 – Non-tight bulkhead
The transverse stiffeners of the shell and the inner side are to be continuous or fitted with bracket end connections within the height of the double side. The transverse stiffeners are to be effectively connected to stringers. At their upper and lower ends, opposing shell and inner side transverse stiffeners and supporting stringer plates are to be connected by effective bracket structures.

The longitudinal side shell and inner side stiffeners, where fitted, are to be continuous within the length of the cargo region and are to be fitted with double side brackets in way of transverse bulkheads aligned with cargo hold bulkheads. They are to be effectively connected to transverse web frames of the double side structure.

Option 1: [Transverse bulkheads (tight or non-tight) are to be fitted and aligned with the cargo hold transverse bulkheads].

Option 2: [Transverse deep tank bulkheads are to be fitted and aligned with the cargo hold transverse bulkheads.]

The transverse web frames are to be fitted in line with the web frames of the hopper tank, alternatively with the floors of the double bottom if no hopper tank is arranged. The vertical distance between horizontal primary members of the double side is not to exceed 6 m. Continuity of the inner side structures, including stringers, is to be ensured beyond the cargo area. Scarfing brackets are a possible means.

These requirements are in addition to the requirements of S11.

The net minimum scantlings of the double side structures are to fulfil the strength criteria given in:

- S32.3.1 for side shell plating,
- S32.3.2 for side shell stiffeners,
- S32.3.3 for inner side plating,
- S32.3.4 for inner side stiffeners,
- S32.3.9 - for tank bulkhead and stringer plating,
- S32.3.10 - for tank bulkhead and stringer stiffeners,
- S32.4 for transverse webs, non watertight bulkheads and horizontal stringers.

In addition a fatigue check according to the criteria given in S32.3.5 is to be carried out based on required gross thickness for all the connections of longitudinal and transverse side shell stiffeners in the double side space, within the cargo hold length of ships having length L not less than 150 m, with respect to 25 years operation life in North Atlantic.

Proposal 1: The required gross thicknesses are obtained by adding the corrosion additions, \( t_c \), given in S32.5.1 to \( t_{net} \) and rounding up to the next half millimetre.

Proposal 2: The required gross thicknesses are obtained by adding the corrosion additions, \( t_c \), given in S32.5.1 to \( t_{net} \) and rounding off to the nearest half millimetre.
Actual net thickness of plating and actual net section modulus of stiffeners are to be calculated according to their as-built gross scantlings, by deducting the corrosion addition in S32.5, excluding the Owner’s extra, if any.

The actual net profile properties of the HP and the JIS bulb profiles are to be determined as follows:

- The cross-sectional area of the net profile, $A_n$, in mm$^2$, is given by: $A_n = A - \Delta A t_c$
- The neutral axis position of the net profile, $c_{xn}$, in mm, is given by: $c_{xn} = c_x$
- The moment of inertia of the net profile, $I_{xn}$, in cm$^4$, is given by: $I_{xn} = I_x - \Delta I_x t_c$

where:

$A$, $I_x$, $c_x$ = cross-section parameters for HP and JIS bulb profiles, as given in Table 8a and 8b, respectively, for the selected profile height and web thickness, see also Figure 12.

$\Delta A, \Delta I_x =$ correction factors for net HP and JIS bulb profile parameters, as given in Table 1a and 1b, respectively, for the selected profile height

$t_c =$ corrosion addition, in mm, as given in S32.5.1

### Table 1a. Correction factors for net HP bulb profile parameters

<table>
<thead>
<tr>
<th>Profile height (mm)</th>
<th>$\Delta A$ (mm$^2$ / mm $t_c$)</th>
<th>$\Delta I_x$ (cm$^4$ / mm $t_c$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>253</td>
<td>100</td>
</tr>
<tr>
<td>220</td>
<td>279</td>
<td>133</td>
</tr>
<tr>
<td>240</td>
<td>305</td>
<td>173</td>
</tr>
<tr>
<td>260</td>
<td>330</td>
<td>220</td>
</tr>
<tr>
<td>280</td>
<td>357</td>
<td>276</td>
</tr>
<tr>
<td>300</td>
<td>383</td>
<td>339</td>
</tr>
<tr>
<td>320</td>
<td>409</td>
<td>413</td>
</tr>
<tr>
<td>340</td>
<td>435</td>
<td>496</td>
</tr>
<tr>
<td>370</td>
<td>474</td>
<td>640</td>
</tr>
<tr>
<td>400</td>
<td>513</td>
<td>810</td>
</tr>
<tr>
<td>430</td>
<td>552</td>
<td>1007</td>
</tr>
</tbody>
</table>

### Table 1b. Correction factors for net JIS bulb profile parameters

<table>
<thead>
<tr>
<th>Profile height (mm)</th>
<th>$\Delta A$ (mm$^2$ / mm $t_c$)</th>
<th>$\Delta I_x$ (cm$^4$ / mm $t_c$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>180</td>
<td>202</td>
<td>72</td>
</tr>
<tr>
<td>200</td>
<td>225</td>
<td>100</td>
</tr>
<tr>
<td>230</td>
<td>258</td>
<td>152</td>
</tr>
</tbody>
</table>
S32.1.3 – Symbols used in UR S32

L = ship length as defined in IACS UR S2, in m
B = greatest moulded breadth, in m
D = moulded depth of vessel, in m
T = maximum design draught, in m
TB = minimum ballast draught at midship, in m, in normal ballast condition, as defined in UR S25
TLC = midship draught, in m, in the considered loading condition
Vs = ship’s maximum service speed, in Knots, to be taken not less than 10
CB = block coefficient, as defined in IACS UR S2, but not to be taken less than 0.6
s = stiffener spacing, in m, measured at the middle of the stiffener span along the plating
l = side stiffener span, in m, to be measured as shown in Figures 10a and 10b. The span point is to be taken at the point where the depth of the end bracket, measured from the face of the stiffener is equal to half the depth of the stiffener

σY = 235/k, in N/mm²
k = material coefficient, as defined in UR S4
τa = allowable shear stress, in N/mm²:

τa = 0.4 σF

σF = minimum upper yield stress, in N/mm², of the material.

x = longitudinal distance, in m, from the aft end of L to the point considered
y = transverse distance, in m, from the centre line to the point considered
z = vertical distance, in m, from the baseline to the point considered.

S32.2 – Design loads

S32.2.1 – Load parameters and combination factors

The dynamic loads to be considered for the strength check of the double side structures are given by:
- $p_w$: wave pressure,
- $p_{bl}$: inertial ballast pressure,
- $M_v$: vertical wave bending moment,
- $M_H$: horizontal wave bending moment.

These load parameters are to be combined on the basis of the correlation factors, as defined in Table 2, for each of the following load cases:

1. Maximum external pressure in head sea
2. Maximum internal pressure in head sea
3. Maximum external pressure in beam sea
4. Maximum internal pressure in beam sea
5. Maximum horizontal bending moment in oblique sea.

The formulae of the load parameters are given in:

- S32.2.2, for the wave pressure $p_w$ in head, beam and oblique sea
- S32.2.3.2, for the inertial ballast pressure $p_{bl}$
- UR S11, for the vertical wave bending moment $M_v$
- S32.2.5, for the horizontal wave bending moment $M_H$,

considering the ship in the following loading conditions, separately:

- alternate heavy cargo condition
- homogeneous light cargo condition
- homogeneous heavy cargo condition
- normal ballast condition
- heavy ballast condition.

Heavy ballast conditions are to be considered for calculating pressures induced on inner side by ballast in the ballast holds.
### Table 2 – Load combination factors

<table>
<thead>
<tr>
<th>Load parameter</th>
<th>Load combination factor</th>
<th>Head Sea</th>
<th>Beam Sea</th>
<th>Oblique Sea</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1: Max external pressure</td>
<td>2: Max internal pressure</td>
<td>3: Max external pressure</td>
<td>4: Max internal pressure</td>
</tr>
<tr>
<td>$p_w$</td>
<td>$C_w$</td>
<td>1,0</td>
<td>0,1</td>
<td>1,0</td>
</tr>
<tr>
<td>$a_V$</td>
<td>$C_{AV}$</td>
<td>0,3</td>
<td>1,0</td>
<td>1,0</td>
</tr>
<tr>
<td>$a_H$</td>
<td>$C_{AH}$</td>
<td>0,0</td>
<td>0,0</td>
<td>0,5</td>
</tr>
<tr>
<td>$a_L$</td>
<td>$C_{AL}$</td>
<td>0,5</td>
<td>1,0</td>
<td>0,0</td>
</tr>
<tr>
<td>$M_V$</td>
<td>$C_{vwbm}$</td>
<td>1,0</td>
<td>1,0</td>
<td>0,25</td>
</tr>
<tr>
<td>$M_H$</td>
<td>$C_{whbm}$</td>
<td>0,0</td>
<td>0,0</td>
<td>0,1</td>
</tr>
</tbody>
</table>

### S32.2.2 – Wave pressure load

The wave pressure $p_w$, in kN/m², at any point of the hull is obtained from the following formula:

$$ p_w = p_1, \text{ in head sea} $$

$$ p_w = p_2, \text{ in beam and oblique sea}, $$

where:

- The wave pressure $p_1$, in kN/m², at and below the waterline is given by:
  $$ p_1 = p_{11} + 135 \frac{B}{2(B + 75)} - 1.2(T_{LC} - z) $$
  $$ p_{11} = 3k_s C + k_f $$

- The wave pressure $p_1$, in kN/m², above the water line is given by:
  $$ p_1 = p_{bot} - 5(z - T_{LC}) $$

- The wave pressure $p_2$, in kN/m², at and below the waterline is given by:
  $$ p_2 = 0.5B \frac{50C}{2(B + 75)} + C_B \frac{0.5B + k_f}{14} \left( 0.7 + 2 \frac{z}{T_{LC}} \right) $$

- The wave pressure $p_2$, in kN/m², above the water line is given by:
  $$ p_2 = p_{2w} - 5(z - T_{LC}) $$
where:

\( p_{1wl} = p_1 \) wave sea pressure at the waterline, in kN/m\(^2\)

\( p_{2wl} = p_2 \) wave sea pressure at the waterline, in kN/m\(^2\)

\[ C = \begin{cases} 
10,75 - \left( \frac{300 - L}{100} \right)^{1.5} & \text{for } 90 \leq L \leq 300 \text{ m} \\
10,75 & \text{for } 300 \text{ m} < L 
\end{cases} \]

\[ C_r = (1,25 - 0,025 \frac{2,3k_r}{\sqrt{GM}}) k_b \]

\( k_b = 1,2 \) for ships without bilge keel

\( = 1,0 \) for ships with bilge keel

\( k_r = \) roll radius of gyration, in m, in the considered loading condition:

\( k_r = 0,39 B \) for ships with even distribution of mass in transverse section (e.g. alternate heavy cargo loading or homogeneous light cargo loading)

\( k_r = 0,25 B \) for ships with uneven distribution of mass in transverse section (e.g. homogeneous heavy cargo loading)

\( k_r = 0,45 B \) for ships in normal ballast conditions

\( k_r = 0,35 B \) for ships in heavy ballast conditions

\( GM = \) metacentric height, in m, in the considered loading condition:

\( GM = 0,12 B \) for ships in full load conditions

\( GM = 0,25 B \) for ships in normal ballast conditions

\( GM = 0,18 B \) for ships in heavy ballast conditions

\[ k_s = \begin{cases} 
C_B + \frac{0,83}{\sqrt{C_B}} & \text{at aft end of L} \\
C_B & \text{between 0,2 L and 0,6 L from aft end of L} \\
C_B + \frac{1,33}{C_B} & \text{at forward end of L.}
\end{cases} \]

Between the above specified points, \( k_s \) is to be varied linearly

\( k_f = 0,8 C \)
S32.2.3 – Pressure loads induced by ballast

S32.2.3.1 – Static pressure induced by ballast

The static pressure $p_{bls}$ induced by the ballast is obtained, in kN/m$^2$, from the following formula:

$$p_{bls} = 1.025 \, g \, (Z_{TOP} - z)$$

$Z_{TOP} = \text{vertical distance, in m, of the highest point of the tank from the baseline (see Figures 5 and 6)}$

The static pressure $p_{bls}$ is to be taken not less than 25 kN/m$^2$.

If the ship is intended to perform ballast water exchange operations by means of the flow through method, the stationary pressure $p_{bls}$ is to be not less than:

$$p_{bls} = 1.025 \, g \, (Z_L - z) + 25$$

$Z_L = \text{vertical distance, in m, of the highest point of the overflow pipe from the baseline.}$

S32.2.3.2 – Inertial pressure loads by ballast

The inertial ballast pressure, $p_{bli}$, in kN/m$^2$, is given by the following formula:

$$p_{bli} = \frac{1.025}{2} \left[ C_{AV} \, a_v \, (Z_{TOP} - z) + C_{AH} \, a_t \, d_Y + C_{AL} \, a_l \, d_X \right]$$

where:

$a_v, a_t, a_l = \text{vertical, transverse and longitudinal acceleration, in m/s}^2,$ given by:

$$a_v = \sqrt{a_{\text{heave}}^2 + ((0,3+L/325)a_{\text{pitch}})^2 + (1,2a_{\text{roll}})^2}$$

$$a_t = \sqrt{a_{\text{sway}}^2 + (g \, \sin \theta + a_{\text{roll}})^2}$$

$$a_l = 0,7 \sqrt{a_{\text{surge}}^2 + (L/325(g \, \sin \phi + a_{\text{pitch}})^2}$$

The accelerations $a_v, a_t, a_l$ are to be calculated in way of the centre of gravity of the considered compartment. As an alternative, accelerations may be calculated in way of the centroid of the transverse section of the compartment, at its middle length.

$Z_{TOP} = \text{vertical distance, in m, of the highest point of the tank from the baseline. For ballast holds, } Z_{TOP} \text{ is the vertical distance, in m, of the top of the hatch coaming from the baseline (see Figure 5).}$

d$_X = \text{length, in m, of the compartment}$

d$_Y = \text{maximum transverse distance, in m, from the load calculation point to the two upper transverse extremes of the compartment (see Figure 6)}$
Figure 5 – Definition of $Z_{TOP}$
Figure 6 – Definition of $d_Y$

$$d_y = \max (d_{y_1}, d_{y_2})$$

$a_{\text{heave}}$ = vertical acceleration due to heave, in m/s$^2$, given by:

$$a_{\text{heave}} = f_{\text{heave}} a_0 g$$

$a_{\text{roll} z}$ = vertical acceleration due to roll, in m/s$^2$, given by:

$$a_{\text{roll} z} = f_{\text{roll}} \frac{\theta}{180} \left(\frac{2 \pi}{T_{\text{roll}}}\right)^2 y_G$$

$a_{\text{pitch} z}$ = vertical acceleration due to pitch, in m/s$^2$, given by:

$$a_{\text{pitch} z} = f_{\text{pitch}} \Phi \frac{\pi}{180} \left(\frac{2 \pi}{T_{\text{pitch}}}\right)^2 \|\left(x_G - 0,45L\right)\|,$$

where $\|\left(x_G - 0,45L\right)\|$ is to be taken not less than 0,2 L

$a_{\text{sway}}$ = transverse acceleration due to sway, in m/s$^2$, given by:

$$a_{\text{sway}} = 0,3 g_0 a_0$$

$a_{\text{roll} y}$ = transverse acceleration due to roll, in m/s$^2$, given by:

$$a_{\text{roll} y} = 0 \frac{\pi}{180} \left(\frac{2 \pi}{T_{\text{roll}}}\right)^2 R$$

$a_{\text{surge}}$ = longitudinal acceleration due to surge, in m/s$^2$, given by:

$$a_{\text{surge}} = 0,2 g a_0$$
$a_{\text{pitch}_x} = \text{longitudinal acceleration due to pitch, in m/s}^2, \text{ given by:}$

$$a_{\text{pitch}_x} = \Phi \frac{\pi}{180} \left( \frac{2 \pi}{T_{\text{pitch}}} \right)^2 R$$

$a_0 = \text{acceleration parameter, in m/s}^2, \text{ given by:}$

$$a_0 = (1.58 - 0.47C_B) \left( \frac{2.4}{\sqrt{L}} + 34/L - 600/L^2 \right)$$

$g_0 = \text{acceleration of gravity, in m/s}^2$

$$R = \left| z_G - \min(D/4 + T_{LC}/2, D/2) \right|$$

$T_{\text{roll}} = \text{roll period, in s, given by:}$

$$T_{\text{roll}} = 2.30 \frac{k_r}{\sqrt{GM}}$$

$\theta = \text{maximum single angle roll amplitude, in deg, given by:}$

$$\theta = a_0 \left( \frac{180}{\pi} \right) \sqrt{E}$$

$T_{\text{pitch}} = \text{pitch period, in s, given by:}$

$$T_{\text{pitch}} = \sqrt{\frac{2\pi\lambda}{g}}$$

$\Phi = \text{maximum single pitch amplitude, in deg, given by}$

$$\Phi = 960 \frac{1}{\sqrt{(V_s/C_B)}} \frac{1}{L}$$

$f_{\text{heave}}, f_{\text{roll}}, f_{\text{pitch}} = \text{correlation factors, defined in Table 3}$

$$E = 1.39 \frac{GM}{k_r^2} \cdot B \text{ to be taken not less than 1.0}$$

$k_r = \text{roll radius of gyration, in m, as defined in S32.2.2}$

$GM = \text{metacentric height, in m, as defined in S32.2.2}$

$\lambda = \text{wave length, in m, given by:}$

$$\lambda = 0.6(1+\frac{T_{LC}}{T})L$$

$x_G, y_G, z_G = \text{longitudinal, transverse and vertical distances, in m, of the compartment centre of gravity from the origin of the ship co-ordinate system located in aft perpendicular, centreline and baseline.}$
Table 3 – Correlation factors

<table>
<thead>
<tr>
<th>Correlation factor</th>
<th>Head seas</th>
<th>Beam seas</th>
<th>Oblique seas</th>
<th>Fatigue (see 3.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{heave}$</td>
<td>1,0</td>
<td>1,0</td>
<td>0,7</td>
<td>1,0</td>
</tr>
<tr>
<td>$f_{roll}$</td>
<td>0,0</td>
<td>1,0</td>
<td>0,7</td>
<td>1,0</td>
</tr>
<tr>
<td>$f_{pitch}$</td>
<td>1,0</td>
<td>0,0</td>
<td>0,7</td>
<td>1,0</td>
</tr>
</tbody>
</table>

S32.2.4 – Horizontal wave bending moment

The horizontal wave bending moment, in kN · m, is given by:

$$M_H = (0,3 + \frac{L}{2000}) f_{w,hor} C L^2 T_{LC} C_B$$

$f_{w,hor}$ = distribution factor, to be taken as:

- $f_{w,hor} = 0$ at FP
- $f_{w,hor} = 1$ for $0,4 \leq x \leq 0,65$ L
- $f_{w,hor} = 0$ at AP

Between the above specified points, $f_{w,hor}$ is to be varied linearly

C = coefficient, as defined in S32.2.2

S32.2.5 – Load calculation points

S32.2.5.1 – Plating

Pressures and hull girder stresses are to be calculated at the load calculation points defined in Table 4.
### Table 4 - Load calculation points

<table>
<thead>
<tr>
<th>Longitudinally stiffened plating</th>
<th>Transversely stiffened plating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load calculation point to be the lowest point of each elementary plate panel (EPP)</td>
<td>Load calculation point to be:</td>
</tr>
<tr>
<td></td>
<td>• Lowest point of each elementary plate panel (EPP),</td>
</tr>
<tr>
<td></td>
<td>• Lowest point of each strake.</td>
</tr>
</tbody>
</table>

The elementary plate panel (EPP) is the unstiffened plate between stiffeners.

---

#### S32.2.5.2 – Stiffeners

For longitudinal stiffeners, pressures and hull girder stresses are to be calculated at the stiffener midspan.

For transverse stiffeners, the pressure $p$ is to be calculated as the maximum between the value calculated at midspan and that obtained as:

$$p = \left( \frac{p_u + p_l}{2} \right)$$

when the upper end of the transverse stiffener is below the lowest zero pressure level.
p = \frac{\ell_1}{\ell} \left( \frac{p_L}{2} \right)

when the upper end of the transverse stiffener is at or above the lowest zero pressure level (see Figure 7)

where:

$\ell_1$ = distance, in m, between the lower end of transverse stiffener and the lowest zero pressure level

$p_U, p_L$ = pressures at the upper and lower end of the transverse stiffener span $\ell$, respectively.

Figure 7 – Definition of pressure for transverse stiffeners

S32.3 – Strength criteria for double side structure

S32.3.1 - Required net thickness of the side shell plating

The required net thickness, in mm, of each strake of the side shell plating is given by the largest of the thicknesses given by S32.3.1.1 and S32.3.1.2, calculated for each load calculation point, as defined in S32.2.5.1, representative of the considered strake (see Table 4). The geometry to be considered is that of the elementary plate panel related to the load calculation point.

The required net thickness is the largest of those calculated in the five mutually exclusive load cases, as defined in S32.2.1.
S32.3.1.1 – Local bending check

\[ t = 15.8 s \sqrt{\frac{p}{C_a \sigma_Y}} \]

where:

\( p \) = pressure, in kN/m\(^2\) defined in S32.3.1.1.1 and S32.3.1.1.2 for the full load cargo condition and the normal ballast condition, respectively

\( C_a \) = coefficient defined in S32.3.1.1.3.

S32.3.1.1.1 – Full load cargo conditions

\( p = p_{\text{sea}} \)

\( p_{\text{sea}} = \) sea pressure load, in kN/m\(^2\):

\[ p_{\text{sea}} = p_s + C_w p_w, \text{ to be taken as positive or zero} \]

\( p_s = \) static pressure, in kN/m\(^2\), to be evaluated for the maximum design draft at the calculation point, as defined in S32.2.5.1

\( p_w = \) wave pressure, in kN/m\(^2\), as defined in S32.2.2, to be evaluated for the maximum design draught, at the calculation point, as defined in S32.2.5.1.

S32.3.1.1.2 – Normal ballast conditions

\( p = p_{\text{bl}} - p_{\text{sea}} \)

\( p_{\text{bl}} = \) ballast pressure load of the double side space in kN/m\(^2\):

\[ p_{\text{bl}} = p_{\text{bls}} + p_{\text{bli}} \]

\( p_{\text{bl}} \) is to be taken not less than the value obtained, in kN/m\(^2\), from the following formula:

\[ p_{\text{bl}} = 1.025 g (Z_{\text{TOP}} - z) + 25 \]

\( p_{\text{bli}} = \) inertial ballast pressure, in kN/m\(^2\), as defined in S32.2.3.2, at the calculation point, as defined in S32.2.5.1,

\( p_{\text{bli}} = \) static ballast pressure, in kN/m\(^2\), as defined in S32.2.3.1, at the calculation point, as defined in S32.2.5.1,

\( p_{\text{sea}} = \) sea pressure load, in kN/m\(^2\):

\[ p_{\text{sea}} = p_s - C_w p_w, \text{ to be taken as positive or zero,} \]

\( p_s = \) static pressure, in kN/m\(^2\), to be evaluated for the minimum ballast draft at the calculation point, as defined in S32.2.5.1.
pw = wave pressure, in kN/m², as defined in S32.2.2, to be evaluated for the minimum ballast draft at the calculation point, as defined in S32.2.5.1,

Cw = load combination factor for the wave pressure, as defined in S32.2.1.

The minimum ballast draft is the minimum one at midship section for the normal ballast conditions defined in UR S25.

**S32.3.1.1.3 – Coefficient Ca**

\[ C_a = 0.75 - 0.72 \frac{\sigma_{ax}}{\sigma_y}, \quad \text{max} = 0.55 \]

for transversely stiffened plating within 0.4L amidships. Outside of 0.4L amidships the value of C_a may be increased linearly to the value 0.65 for x/L = 0,0 and 1,0.

\[ C_a = 0.75 - 0.36 \frac{\sigma_{ax}}{\sigma_y}, \quad \text{max} = 0.65 \]

for longitudinally stiffened plating within 0.4L amidships. Outside of 0.4L amidships the value of C_a may be increased linearly to the value 0.65 for x/L = 0,0 and 1,0.

\[ \sigma_{ax} = \sigma_{ax,s} + 0.5 (C_{wvbm}\sigma_{ax,wvbm} + C_{whbm}\sigma_{ax,whbm}) \] to be calculated as the maximum between hogging and sagging conditions,

\[ \sigma_{ax,s} = \text{absolute value of still water hull girder normal stress, in N/mm}^2, \text{ to be calculated from the allowable still water bending moment} \]

\[ \sigma_{ax,wvbm} = \text{absolute value of hull girder normal stress, induced by the vertical wave bending moment, in N/mm}^2, \text{ to be calculated from the vertical wave bending moment defined in UR S11} \]

\[ \sigma_{ax,whbm} = \text{absolute value of hull girder normal stress, induced by the horizontal wave bending moment, in N/mm}^2 \]

C_{wvbm} = load combination factor for the vertical wave bending moment, as defined in S32.2.1

C_{whbm} = load combination factor for the horizontal wave bending moment, as defined in S32.2.1.

**S32.3.1.2 Minimum net plate thickness**

The net plate thickness, in mm, is to be not less than:

\[ t = 0.85 L^{0.5} \]

In addition, from the normal ballast waterline to 0.25 T (minimum 2,2 m) above the maximum design draught, the net plate thickness, in mm, is to be not less than:
\[ t = 28(s + 0.7) \left( \frac{BT}{\sqrt{\sigma_F}} \right)^{0.25} \]

**S32.3.2 - Required net section modulus and net web thickness of side shell stiffeners**

The required net section modulus \( Z \), in cm\(^3\) and web thickness \( t_w \), in mm, of the side shell stiffeners, to be evaluated for each of the five mutually exclusive load cases, as defined in S32.2.1, are given by:

\[
Z = \frac{1000ps\ell^2}{mc\sigma_Y}
\]

\[
t_w = \frac{500ps\ell}{d \sin \phi \tau_a}
\]

- \( p \) = pressure, in kN/m\(^2\) defined in S32.3.2.1 and S32.3.2.2 for the full load cargo condition and the normal ballast condition, respectively
- \( C_S \) = coefficient defined in S32.3.2.3
- \( \phi \) = angle, in deg, between the stiffener web and the shell plate, measured at the middle of the stiffener span; the correction is to be applied when \( \phi \) is less than 75 deg (see Figure 8)
- \( m \) = 12 for longitudinal stiffeners
- 10 for vertical stiffeners
- \( d \) = stiffener web depth, in mm.

The stiffener actual section modulus is to be calculated about an axis parallel to the attached plate (see Figure 8), considering an attached plating breadth equal to 0.1 \( \ell \) on either side of the stiffener. However, the attached plating breadth is not to exceed the stiffener spacing \( s \).
Figure 8 – Definitions for stiffeners

\[ S = 0.5 (s_1 + s_2) : \text{load breadth for stiffener measured at middle of stiffener span.} \]

\[ \phi : \text{angle between stiffener web and attacked plate, measured at middle of stiffener span} \]

\[ \gamma_6 : \text{Axis for calculation of net section modulus of stiffener} \]

\[ p_{\text{sea}} = p_s + C_W \cdot p_w, \text{to be taken as positive or zero} \]

\[ p_s = \text{static pressure, in kN/m}^2, \text{to be evaluated for the maximum design draft at the calculation point, as defined in S32.2.5.2} \]

\[ p_w = \text{wave pressure, in kN/m}^2, \text{as defined in S32.2.2, to be evaluated for the maximum design draft at the calculation point, as defined in S32.2.5.2.} \]

S32.3.2.2 – Normal ballast conditions

\[ p = p_{\text{bl}} - p_{\text{sea}} \]

\[ p_{\text{bl}} = \text{ballast pressure load of the double side space, in kN/m}^2. \]
\[ p_{bls} = p_{bls} + p_{bl} \]

\( p_{bl} \) is to be taken not less than the value obtained, in kN/m², from the following formula:

\[ p_{bl} = 1,025 \cdot g \cdot (Z_{TOP} - z) + 25 \]

\( p_{bls} \) = static ballast pressure of the double side space, in kN/m², as defined in S32.2.3.1, at the calculation point, as defined in S32.2.5.2

\( p_{bl} \) = inertial ballast pressure of the double side space, in kN/m², as defined in S32.2.3.2, at the calculation point, as defined in S32.2.5.2

\( p_{sea} \) = sea pressure load, in kN/m²:

\[ p_{sea} = p_{s} - C_{W} \cdot p_{w}, \text{ to be taken as positive or zero} \]

\( p_{s} \) = static pressure, in kN/m², to be evaluated for the minimum ballast draft at the calculation point, as defined in S32.2.5.2

\( p_{w} \) = wave pressure, in kN/m², as defined in S32.2.2, to be evaluated for the minimum ballast draft at the calculation point, as defined in S32.2.5.2

\( C_{W} \) = load combination factor for the wave pressure, as defined in S32.2.1.

The minimum ballast draft is the minimum one for the normal ballast conditions defined in UR S25, to be determined amidship.

**S32.3.2.3 – Coefficient CS**

\[ C_{S} = 0,95 - 0,9 \cdot \frac{\sigma_{ax}}{\sigma_{Y}}, \text{ max } = 0,7 \]

for longitudinal stiffeners within 0,4L amidships. Outside of 0,4L amidships the value of \( C_{S} \) may be increased linearly to the value 0,7 for \( x/L = 0,0 \) and 1,0.

\[ C_{S} = 0,7 \]

for transverse stiffeners.

\( \sigma_{ax} \) = hull girder stress, in N/mm², as defined in S32.3.1.1.3.

**S32.3.3 - Required net thickness of the inner side plating**

The required net thickness, in mm, of each strake of the inner side plating is given by the largest of the thicknesses given by S32.3.3.1 and S32.3.3.2, calculated for each load calculation point, as defined in S32.2.5.1, representative of the considered strake (see Table 4). The geometry to be considered is that of the elementary plate panel related to the load calculation point.

The required net thickness is the largest of those calculated in the five mutually exclusive load cases, as defined in S32.2.1.
S32.3.3.1 – Local bending check

\[ t = 15.8s \sqrt[3]{\frac{p}{C_a \sigma_Y}} \]

where:

\( p = p_{bl} \)

\( p_{bl} = \) pressure induced by ballast, in kN/m\(^2\), to be calculated for the two following mutually exclusive cases at the calculation point, as defined in S32.2.5.1:

- for the inner side in way of all holds, \( p_{bl} \) is the pressure induced on inner side by ballast in double side spaces in normal ballast conditions
- for the inner side in way of ballast holds, \( p_{bl} \) is the pressure induced on inner side by ballast in the hold in the heavy ballast conditions, with the double side space empty.

\[ p_{bl} = p_{bls} + p_{bli} \]

\( p_{bl} \) is to be taken not less than the value obtained, in kN/m\(^2\), from the following formula:

\[ p_{bl} = 1.025 \ g \ (Z_{TOP} - z) + 25 \]

\( p_{bls} = \) static ballast pressure, in kN/m\(^2\), as defined in S32.2.3.1, at the calculation point, as defined in S32.2.5.1,

\( p_{bli} = \) inertial ballast pressure, in kN/m\(^2\), as defined in S32.2.3.2, at the calculation point, as defined in S32.2.5.1,

\[ C_a = 0.75 - 0.72 \frac{\sigma_{ax}}{\sigma_Y}, \ max = 0.7 \]

for transversely stiffened plating within 0,4L amidships. Outside of 0,4L amidships the value of \( C_a \) may be increased linearly to the value 0,7 for \( x/L = 0,0 \) and 1,0.

\[ C_a = 0.75 - 0.36 \frac{\sigma_{ax}}{\sigma_Y}, \ max = 0.7 \]

for longitudinally stiffened plating within 0,4L amidships. Outside of 0,4L amidships the value of \( C_a \) may be increased linearly to the value 0,7 for \( x/L = 0,0 \) and 1,0.

\( \sigma_{ax} = \) hull girder stress, in N/mm\(^2\), as defined in S32.3.1.1.3.

S32.3.3.2 Minimum net plate thickness

\[ t = 0.60 \ L^{0.5} \]
S32.3.4 – Required net section modulus and net web thickness of inner side stiffeners

The required net section modulus \( Z \), in \( \text{cm}^3 \) and web thickness \( t_w \), in mm, of the inner side stiffeners, to be evaluated for each of the five mutually exclusive load cases as defined in S32.2.1, are given by:

\[
Z = \frac{1000ps\ell^2}{mC_y\sigma_y}
\]

\[
t_w = \frac{500ps\ell}{d\sin \phi \tau_a}
\]

\( p = p_{bl} \)

\( p_{bl} \) = pressure induced by ballast, in kN/m\(^2\), to be calculated for the two following mutually exclusive cases at the calculation point, as defined in S32.2.5.2:

- for the inner side in way of all holds, \( p_{bl} \) is the pressure induced on inner side by ballast in double side spaces in normal ballast conditions
- for the inner side in way of ballast holds, \( p_{bl} \) is the pressure induced on inner side by ballast in the hold in the heavy ballast conditions, with the double side space empty.

\( = p_{bls} + p_{bli} \)

\( p_{bl} \) is to be taken not less than the value obtained, in kN/m\(^2\), from the following formula:

\[
p_{bl} = 1,025 \ g \ (Z_{TOP} - z) + 25
\]

\( p_{bls} \) = static ballast pressure of the double side space, in kN/m\(^2\), as defined in S32.2.3.1, at the calculation point, as defined in S32.2.5.2

\( p_{bli} \) = inertial ballast pressure, in kN/m\(^2\), as defined in S32.2.3.2, at the calculation point, as defined in S32.2.5.2

\( \phi \) = angle, in deg, between the stiffener web and the plate, measured at the middle of the stiffener span; the correction is to be applied when \( \phi \) is less than 75 deg (see Figure 8)

\( m = 12 \) for longitudinal stiffeners

10 for vertical stiffeners

\( d = \) stiffener web depth, in mm

\[
C_s = 0.95 - 0.9 \ \frac{\sigma_{sw}}{\sigma_y}, \ \text{max} = 0.7
\]

for longitudinal stiffeners within 0.4L amidships. Outside of 0.4L amidships the
value of $C_S$ may be increased linearly to the value 0,7 for $x/L = 0,0$ and 1,0.

$$C_S = 0.7$$

for transverse stiffeners.

$\sigma_{ax}$ = hull girder stress, in N/mm$^2$, as defined in S32.3.1.1.3.

The stiffener actual section modulus is to be calculated about an axis parallel to the attached plate (see Figure 8), considering an attached plating breadth equal to 0,1 $\ell$ on either side of the stiffener. However, the attached plating breadth is not to exceed the stiffener spacing s.

**S.32.3.5 - Fatigue check of longitudinal and transverse side shell stiffeners**

**S.32.3.5.1 - General**

Fatigue check is to be carried out for all the connections of longitudinal and transverse side shell stiffeners in the double side space, within the cargo hold length of ships having length L not less than 150 m, with respect to 25 years operation life in North Atlantic.

The allowable end connection details are shown in Table 9. Lapped connections (attachments welded to the web of the stiffener) are not accepted for longitudinal side shell stiffeners and, for ships having length L not less than 190 m, for transverse side shell stiffeners that are required to comply with the fatigue requirements of this UR.

Ships are assumed to operate in normal ballast loading condition during 40% of the time in seagoing conditions. For the remaining time in seagoing conditions, the ship is assumed loaded in the full cargo loading condition (or alternate condition when specified).

**S.32.3.5.2 – Calculation of fatigue damage**

The cumulative fatigue damage $D$, determined for the combined stress response of lateral pressure load and longitudinal hull girder stress, is to comply with the following formula:

$$D = D_C + D_B \leq 1.0$$

where:

$D_C$, $D_B =$ cumulative fatigue damages in full cargo and in normal ballast loading conditions, respectively, to be obtained from the following formulae:

- $D_C = \frac{N_{IC}}{K_2} \frac{S_{RC}^m}{(\ln N_R)^{m/\zeta}} \mu_C \Gamma\left(1+\frac{m}{\zeta}\right)$ for full cargo loading condition

- $D_B = \frac{N_{LB}}{K_2} \frac{S_{RB}^m}{(\ln N_R)^{m/\zeta}} \mu_B \Gamma\left(1+\frac{m}{\zeta}\right)$ for normal ballast loading condition
\( S_{RC}, S_{RB} = \) stress range in full cargo and in normal ballast loading conditions, respectively, to be obtained, in N/mm\(^2\), from the following formulae:

\[
S_{RC} = F_{mc} S_{RC0}
\]
\[
S_{RB} = F_{mB} S_{RB0}
\]

\( F_{mB}, F_{mc} = \) factor for mean stress effect (see also Figure 9), to be taken as

- \( F_{mB} = \max \left[ 0.6; \min \left( 0.8 + \frac{0.4 \sigma_{sB}}{S_{RB0}} ; 1.0 \right) \right] \)
- \( F_{mc} = \max \left[ 0.6; \min \left( 0.8 + \frac{0.4 \sigma_{sC}}{S_{RC0}} ; 1.0 \right) \right] \)

**Figure 9**: Factors \( F_{mb} \) and \( F_{mc} \) for mean stress effect

\[
\mu_c, \mu_b = \text{coefficients taking into account the change in slope of the S-N curve:}
\]

\[
\mu_c = 1 - \frac{\gamma \left( 1 + \frac{m}{\zeta} \theta_c \right) - \nu_c^{-\Delta m/\zeta} \gamma \left( 1 + \frac{m + \Delta m}{\zeta} \theta_c \right)}{\Gamma \left( 1 + \frac{m}{\zeta} \right)}
\]

\[
\nu_c = \left( \frac{S_q}{S_{RC}} \right) ^\zeta \ln N_R
\]
\[ \mu_B = 1 - \frac{\left( \gamma \left( \frac{1}{\zeta} \nu_B \right) - \nu_B^{\Delta m/\zeta} \gamma \left( \frac{1}{\zeta} \nabla B \right) \right)}{\Gamma \left( \frac{1}{\zeta} \right)} \]

\[ \nu_B = \left( \frac{S_q}{S_{RB}} \right) \ln N_R \]

\[ S_q = \text{stress range, in N/mm}^2, \text{at the intersection of the two segments of the S-N curve, as defined in Appendix A, depending on the stiffener end connection type specified in Table 9} \]

\[ N_{LC} = \text{expected number of stress cycles in full cargo loading condition:} \]

\[ N_{LC} = \alpha_C N_L \]

\[ \alpha_C = \text{fraction of time at sea in full cargo loading condition:} \]

\[ \alpha_C = 0,6 \]

\[ N_{LB} = \text{expected number of stress cycles in normal ballast loading condition:} \]

\[ N_{LB} = \alpha_B N_L \]

\[ \alpha_B = \text{fraction of time at sea in normal ballast loading condition:} \]

\[ \alpha_B = 0,4 \]

\[ N_i = \text{expected number of stress cycles for the ship’s life:} \]

\[ N_i = \frac{\alpha_o T_i}{4 \log L} = \frac{1,675 \times 10^8}{Log L} \]

\[ \alpha_o = \text{factor taking into account the time in harbour or sheltered waters needed for loading / unloading operations, repairs, etc.:} \]

\[ \alpha_o = 0,85 \]

\[ T_i = \text{design life, in s, corresponding to 25 years ship’s life:} \]

\[ T_i = 25 \times 365 \times 24 \times 3600 = 7,884 \times 10^8 \]

\[ m, K_2 = \text{S-N curve parameters, as specified in Appendix A, depending on the stiffener end connection type specified in Table 9} \]

\[ N_x = \text{number of cycles corresponding to the probability level of } 10^{-4}, \text{to be taken equal to:} \]

\[ N_x = 10^4 \]
\( \xi = \text{Weibull shape parameter, to be taken as:} \)
\[
\xi = 1.1 - 0.35 \frac{L - 100}{300}
\]

\( \Gamma = \text{Gamma function, as defined in Appendix B} \)

\( \Delta m = \text{slope change from the upper to the lower segments of the S-N curve:} \)
\[
\Delta m = 2.0
\]

\( \gamma(a,x) = \text{incomplete gamma function, Legendre form, as defined in Appendix B} \)

\( S_{RC0}, S_{RB0} = \text{stress ranges, in N/mm}^2, \text{to be taken as:} \)

for longitudinal stiffeners:

- \( S_{RC0} = 2F_{coat} \left( f_1 \sigma_{vc} + f_2 \sigma_{hc} + \frac{1000 f_3 p_{wc} K_n K_d s \ell^2 \left( 1 - \frac{6x_f}{\ell} + \frac{6x_f^2}{\ell^2} \right)}{12w} \right) \)

- \( S_{RB0} = 2F_{coat} \left( f_1 \sigma_{vb} + f_2 \sigma_{hb} + \frac{1000 (f_3 p_{wb} + f_4 p_{i}) K_n K_d s \ell^2 \left( 1 - \frac{6x_f}{\ell} + \frac{6x_f^2}{\ell^2} \right)}{12w} \right) \)

for transverse stiffeners:

- \( S_{RC0} = 2F_{coat} \left( \frac{1000 p_{wc} K_n s \ell^2 \left( 1 - \frac{6x_f}{\ell} + \frac{6x_f^2}{\ell^2} \right)}{mw} \right) \)

- \( S_{RB0} = 2F_{coat} \left( \frac{1000 (f_3 p_{wb} + f_4 p_{i}) K_n s \ell^2 \left( 1 - \frac{6x_f}{\ell} + \frac{6x_f^2}{\ell^2} \right)}{mw} \right) \)

For transverse stiffeners, when external pressure in ballast condition \( (p_{wb}) \) is less than 10% of internal pressure \( (0.1 p_i) \) (for the upper region near the deck inclusive upper part of the stretching area for external pressure), \( S_{RB0} \) is to be calculated considering LCFs \( f_3 \) and \( f_4 \) equal to 0 and 1.0, respectively
\( F_{\text{coat}} = \) nominal stress amplification factor to account for breakdown of coating and corrosion, to be taken as:

\[ F_{\text{coat}} = 1.15 \]

For double skin spaces that are intended to be a void space, \( F_{\text{coat}} \) is to be taken \( = 1.05 \)

\( \sigma_{sC}, \sigma_{sB} = \) still water stresses, in N/mm\(^2\), to be taken as:

for longitudinal stiffeners:

\[
\sigma_{sC} = 10^{-3} \frac{M_{sc}(z - n_0)}{f_c I_v}, \quad \sigma_{sB} = 10^{-3} \frac{M_{sb}(z - n_0)}{f_c I_v},
\]

where:

\[
M_{sc, sB} = \text{still water bending moments, in kNm, in full load condition, to be calculated as:}
\]

- For BC-A ships, the bending moment values in alternate cargo conditions,
- For BC-B and BC-C ships, the bending moment values in homogeneous cargo conditions,

\( M_{sB} = \) still water bending moment, in kNm, in the normal ballast condition

The bending moments \( M_{sc} \) and \( M_{sb} \) are to be calculated at the middle of the hold to which the considered stiffeners belongs. Sagging bending moments are to be given with negative sign.

\( p_{sc}, p_{sb} = \) static pressure, in kN/m\(^2\), to be taken as:

- for full cargo condition:

\[
p_{sc} = \max (10 (T - z), 0) + p_{mC}
\]

where:
\[ p_{mC} = 0.5 \ p_wC \quad \text{for } z \geq T \]
\[ p_{mC} = (1 - C_{NL}) \max |p_1, p_2| \quad \text{for } z < T \]
\[ p_{wC}, C_{NL}, p_1 \text{ and } p_2, \text{ as defined in S.32.3.7.1} \]

- for normal ballast condition:

\[ p_{sB} = -10 (D - z) + p_{mB} \quad \text{for } z \geq T_B \]
\[ p_{sB} = -10 (D - T_B) + p_{mB} \quad \text{for } z < T_B \]

where:

\[ p_{mB} = 0.5 \ p_wB \quad \text{for } z \geq T_B \]
\[ p_{mB} = (1 - C_{NL}) \max |p_1, p_2| \quad \text{for } z < T_B \]

\[ p_{wB}, C_{NL}, p_1 \text{ and } p_2, \text{ as defined in S.32.3.7.1} \]

- lateral wave pressure, in kN/m², on stiffener in normal ballast and full cargo loading conditions, respectively, as defined in S.32.3.7.1
- lateral inertial ballast pressure, in kN/m², on stiffener in normal ballast loading condition, as defined in S.32.3.7.2
- longitudinal stresses, in N/mm², as defined in S.32.3.6.1, due to vertical wave bending moment and acting on stiffener in normal ballast and full cargo loading conditions, respectively,
- longitudinal stresses, in N/mm², as defined in S.32.3.6.2, due to horizontal wave bending moment and acting on stiffener in normal ballast and full cargo loading conditions, respectively,
- stress concentration factor for warping of unsymmetrical profiles, as defined in S.32.3.8
- stress factor for bending stresses in the longitudinal caused by relative deformation between supports, to be taken as:
  - \( K_{d} = 1.0 \) for connection of stiffeners ends with web frames
  - \( K_{d} = 1.15 \) for connection of stiffener ends with double side bulkheads
- distance, in m, to the hot spot from the closest end of \( \ell \), see Figures 10a and 10b
- combination factors, to be taken as:
  \[ f_i = C_L (a \ (z/D) + b) \quad \text{(for } i = 1 \text{ to } 4) \]
C_L = coefficient, to be taken equal to:
- for longitudinal stiffeners: \( C_L = 1,0 \)
- for transverse stiffeners:

\[
C_x = \frac{3}{5L} x + \frac{7}{10} \text{ for } 0 \leq x < \frac{L}{2}
\]

\[
C_x = \frac{x}{L} + \frac{1}{2} \text{ for } \frac{L}{2} \leq x \leq L
\]

a, b = coefficients, as defined in Tables 5 and 6, for longitudinal and transverse stiffeners, respectively

w = actual section modulus, in cm³, of the considered stiffener, to be calculated considering gross as-built thickness of stiffener web, flange and attached plate, but excluding the Owner’s extra, if any

The actual section modulus w is to be calculated considering an effective breadth, in m, of attached plating, \( s_e \) to be obtained, in m, from the following formulae:

\[
s_e = 0.67 s \cdot \sin \left[ \frac{\pi}{6} \left( \frac{\left( 1 - 1/\sqrt{3} \right)}{2s} \right) \right] \quad \text{for } \frac{\ell}{s} \leq \frac{6}{1 - 1/\sqrt{3}}
\]

\[
s_e = 0.67 s \quad \text{for } \frac{\ell}{s} > \frac{6}{1 - 1/\sqrt{3}}
\]

m = 10 for lower end of lowermost span of transverse stiffeners

12 in the other cases

**Table 5. Combination factors for longitudinal stiffeners**

<table>
<thead>
<tr>
<th>Stiffener location</th>
<th>Cargo Condition</th>
<th>Ballast Condition</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>( f_1 )</td>
<td>( f_2 )</td>
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<tr>
<td>Below D/2</td>
<td>a</td>
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<tr>
<td></td>
<td>b</td>
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<td></td>
<td>b</td>
<td>-0.84</td>
</tr>
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**Table 6. Combination factors for transverse stiffeners**

<table>
<thead>
<tr>
<th>Stiffener location</th>
<th>Ballast Condition</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>Below D/2</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>b</td>
</tr>
<tr>
<td>Above D/2</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>b</td>
</tr>
</tbody>
</table>
Figure 10a. Definition of span lengths of longitudinal stiffeners

Supported by free flange transverses (1)

Supported by free flange transverses (2)

Supported by double skin / transverse bulkheads (1)
Supported by double skin / transverse bulkheads (2)
Figure 10b. Definition of span lengths of transverse stiffeners

S.32.3.6 Fatigue check - Longitudinal Stresses Due To Wave Bending Moments

S32.3.6.1 - Longitudinal Stress Due To Vertical Wave Bending Moment

The longitudinal stress $\sigma_C$ and $\sigma_B$ in full cargo loading condition or normal ballast loading condition due to vertical hull girder bending moment, are to be obtained, in N/mm$^2$, from the following formulae:
\[ \sigma_{\text{vC}} = \sigma_{\text{vB}} = \frac{10^{-3} (M_{\text{wC}} + M_{\text{wB}})(z - n_0)}{4I_v} \]

where:

- \( M_{\text{wB}} \) = hogging (positive) wave bending moment, as defined in S11 with respect to the longitudinal position considered
- \( M_{\text{wC}} \) = absolute value of the sagging (negative) wave bending moment, as defined in S11 with respect to the longitudinal position considered
- \( I_v \) = as built moment of inertia of the hull girder, in m\(^4\), in way of the longitudinal position considered, with respect to the transverse axis
- \( n_0 \) = vertical distance, in m, from base line to transverse neutral axis of hull girder, at the longitudinal position considered.

S.32.3.6.2 - Longitudinal stress due to horizontal wave bending moment

The longitudinal stress, \( \sigma_{hB} \) and \( \sigma_{hC} \) due to horizontal hull girder bending moment are to be obtained in N/mm\(^2\), from the following formulae:

\[ \sigma_{hB} = \frac{5 \times 10^{-4} M_{\text{whB}} y}{I_h} \] for normal ballast loading condition
\[ \sigma_{hC} = \frac{5 \times 10^{-4} M_{\text{whC}} y}{I_h} \] for full cargo loading condition

where:

- \( M_{\text{whB}}, M_{\text{whC}} \) = horizontal hull girder bending moments, in KNm, to be calculated as defined in S.32.2.4, at the longitudinal position considered, considering draught \( T_{LC} = T_B \) and \( T \) for normal ballast and full cargo loading conditions, respectively,
- \( I_h \) = as built midship moment of inertia of the hull girder, in m\(^4\), in way of the longitudinal position considered, with respect to the vertical axis.

S.32.3.7 Fatigue check - Wave and inertia load pressure

S.32.3.7.1 - Wave pressures

The wave pressure \( p_{wB} \) and \( p_{wC} \) for the normal ballast and the full cargo loading conditions, are to be obtained, in kN/m\(^2\), from the following formulae:

\[ p_{wB} = p_w \] to be obtained considering \( T_{LC} = T_B \)
\[ p_{wC} = p_w \] to be obtained considering \( T_{LC} = T \),

where:

- \( p_w \) = wave pressure, in kN/m\(^2\), to be calculated for the considered draught \( T_{LC} \), as follows:
\[ p_w = C_{NL} \max |p_1, p_2| \]

\[ C_{NL} = \begin{cases} 
\exp \left( - \left( \frac{z - T_{LC} + \frac{\max|p_1, p_2|}{\rho g}}{\max|p_1, p_2| (\ln 0.5)^{\chi}} \right) \right) & \text{for } z > T_{LC} - \frac{\max|p_1, p_2|}{\rho g} \\
1.0 & \text{for } z \leq T_{LC} - \frac{\max|p_1, p_2|}{\rho g} 
\end{cases} \]

\[ \chi = \begin{cases} 
5.0 & \text{for } z \leq T_{LC} \\
2.5 & \text{for } z > T_{LC} 
\end{cases} \]

\[ p_1 = \text{wave pressure, in kN/m}^2; \text{ For } z \leq T_{LC} \text{ it is to be calculated as defined in S.32.2., for the loading condition considered. For } z > T_{LC}, \text{ the wave pressure } p_1 \text{ is to be taken equal to } p_{1wl}. \]

\[ p_2 = \text{wave pressure, in kN/m}^2; \text{ For } z \leq T_{LC}, \text{ for the loading condition considered, to be calculated as:} \]

\[ p_2 = 11.7 \left[ 0.5B \frac{50c_t}{2(B + 75)} + C_B \frac{T_{LC} 0.5B + k_t}{T 14} \left( 0.7 + 2 \frac{z}{T_{LC}} \right) \right] \]

For \( z > T_{LC} \), the wave pressure \( p_2 \) is to be taken equal to \( p_{2wl} \)

\[ p_{1wl} = p_1 \text{, obtained considering } z = T_{LC} \]

\[ p_{2wl} = p_2 \text{, obtained considering } z = T_{LC} \]

**S.32.3.7.2 – Inertial ballast pressure**

The inertial ballast pressure amplitude \( p_i \) due to the ships acceleration is to be obtained, in kN/m\(^2\), from the following formula:

\[ p_i = 0.5^{1/(\xi - 0.05)} (f_v \ p_{iv} + f_t \ p_{it} + f_l \ p_{il}) \]

where:

\[ p_{iv} = \text{inertial pressure, in kN/m}^2, \text{ due to vertical acceleration:} \]

\[ p_{iv} = \rho \ a \ h_s \]

\[ p_{it} = \text{inertial pressure, in kN/m}^2, \text{ due to transverse acceleration:} \]
\[ p_{il} = 0.5 \rho a_l y_s \]

\( p_{il} \) = inertial pressure, in kN/m\(^2\), due to longitudinal acceleration:

\[ p_{il} = 0.5 \rho a_l x_s \]

\( x_s \) = length, in m, of upper wing tank

\( y_s \) = breadth, in m, of upper wing tank

\( h_s \) = vertical distance, in m, from deck at side to the considered stiffener

\( \rho \) = density, in t/m\(^3\), of ballast water:

\[ \rho = 1.025 \text{ t/m}^3 \]

\( a_v, a_t, a_l \) = vertical, transverse and longitudinal accelerations, in m/s\(^2\), as defined in S32.2.3.2, with respect to the compartment and the loading condition considered.

\( f_v, f_t, f_l \) = combination factors, as defined in Table 7

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f_v )</td>
<td>0.9</td>
</tr>
<tr>
<td>( f_t )</td>
<td>0.6</td>
</tr>
<tr>
<td>( f_l )</td>
<td>0.4</td>
</tr>
</tbody>
</table>

S.32.3.8 - Fatigue check - Stress concentration factor \( K_n \) for stiffeners of unsymmetrical cross-section

The stress concentration factor \( K_n \), which represents the warping response of stiffeners of unsymmetrical cross-section, is to be taken equal to:

- \( K_n = f_s K_{n2} \) for connection details with attachment on top of stiffener
- \( K_n = f_s K_{n1} \) for connection details without attachments on top of stiffener and for lapped connections (when allowed for transverse side shell stiffeners)
- \( K_n = 1.0 \) for connections details with stiffeners of symmetrical cross-section,

where:

\( K_{n1}, K_{n2} \) = stress concentration factors of the flange at support of stiffeners, subject to lateral loading and of unsymmetrical cross-section in panels, as defined in Figure 11, to be obtained from the following formulae:
\[
\begin{align*}
K_{n1} &= \frac{1 + k_w \gamma_f \beta}{1 + k_w \gamma_f \beta^2 \psi} \\
K_{n2} &= \frac{1 + k_w \gamma_f \beta^2}{1 + k_w \gamma_f \beta^2 \psi}
\end{align*}
\]

\[f_s = 1.0, \text{ in general}
\]

1,1, when the stiffener flange is interrupted at the support

\[k_w = \text{coefficient, to be taken equal to:}
\]

\[K_w = \frac{6 A_f \left(b_w + b_g\right)^2}{\lambda^2 I_f \left(1 - \frac{6 x_f}{1 + \frac{6 x_f^2}{1}}\right)}
\]

\[\beta = \text{coefficient, to be taken equal to:}
\]

- \[\beta = 1 - \frac{2 b_g}{b_f} \quad \text{for built up sections}\]
- \[\beta = 1 - \frac{t_w}{b_f} \quad \text{for rolled angles}\]
- \[\beta = 1 - \frac{b_g}{b_w + b_g} \quad \text{for bulb profiles and flanges of irregular shape}\]

\[\gamma_f = \text{coefficient, to be taken equal to:}
\]

\[\gamma_f = \frac{\sinh \lambda l_f - \sin \lambda l_f}{\sinh \lambda l_f + \sin \lambda l_f}
\]

\[\lambda = \text{coefficient, to be taken equal to:}
\]

\[\lambda = \sqrt{\frac{1}{4 I_f h_c^2 \left(\frac{4 h_c}{t_w} + \frac{s}{t_p}\right)}}
\]

\[\psi = \text{ratio of the section modulus of the stiffener web with attached plate flange over the section modulus of the complete stiffener with flange included, to be taken as:}
\]
\[ \psi = \frac{(h-t_f)^2 \left( \frac{1}{12} + 0.40^2 \right) t_w}{1000 \, w \, \left( (0.5 + 0.40)(h-t_f) + t_f \right)} \]

\( w \) = actual section modulus, in cm\(^3\), of the considered stiffener, as defined in 3.5.2

\( \ell_f \) = stiffener span, in mm, between notch points, see also Figures 10a and 10b

\( b_g \) = smallest flange outstand measured from the mid-thickness of the stiffener web, to be taken as (see Figure 11):

\[ b_g = \frac{t_w}{2} \text{ for rolled angle and bulb profiles} \]

\( b_r \) = breadth, in mm, of the rectangular stiffener flange, see also Figure 11.

\( b_w \) = transverse distance, in mm, from mid-thickness of stiffener web to centroid of flange cross-section, see also Figure 11. For HP and JIS bulb profiles, \( b_w \) is given in Table 8a and 8b, respectively

\( t_f \) = flange thickness, in mm, see also Figure 11. For HP and JIS bulb profiles, \( t_f \) is given in Table 8a and 8b, respectively

\( h \) = stiffener height, in mm, see also Figure 11

\( h_{fc} \) = stiffener height, in mm, measured to centroid of flange, see also Figure 11. For HP and JIS bulb profiles, \( h_{fc} \) is given in Table 8a and 8b, respectively

\( t_w \) = web thickness, in mm, see also Figure 11

\( t_p \) = plate thickness, in mm, see also Figure 11

\( A_r \) = area, in mm\(^2\), of the flange section

\( I_r \) = moment of inertia, in mm\(^4\), of the flange with respect to the axis parallel to the stiffener web, passing through the flange centroid. For HP and JIS bulb profiles, \( I_r \) is given in Table 8a and 8b, respectively

For bulb profiles, the stress concentration factor \( K_n \) may be determined based on the equivalent built up cross-section, with rectangular flange having same cross-sectional area, same moment of inertia about the vertical axis and same neutral axis position as the bulb, see Figure 12.

For the HP and JIS bulb profiles, the relevant cross-section parameters are specified in Table 8a and 8b, respectively.
<table>
<thead>
<tr>
<th>h</th>
<th>C</th>
<th>r</th>
<th>( t_1 )</th>
<th>( t_w )</th>
<th>( A_f )</th>
<th>( b_w )</th>
<th>( h_1 )</th>
<th>( I_f )</th>
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Table 8a continued

| 400 | 58  | 18 | 61,9 | 14 | 3481 | 22,9 | 375 | 1188000 | 8214 | 256 | 12933 |

Table 8a. “HP” bulb profiles cross-section parameters
Table 8b. “JIS” bulb profiles cross-section parameters

<table>
<thead>
<tr>
<th>h</th>
<th>C</th>
<th>r</th>
<th>t_w</th>
<th>t_f</th>
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</table>

Figure 11. Stiffener geometry

Figure 12. Geometry of HP bulb profile
Table 9. Fatigue Classification of Stiffener End Connection Details

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<thead>
<tr>
<th>ID</th>
<th>Connection type</th>
<th>Critical Locations</th>
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<td>22</td>
<td><img src="image2" alt="Diagram" /></td>
<td>F</td>
</tr>
<tr>
<td>23</td>
<td><img src="image3" alt="Diagram" /></td>
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</tr>
<tr>
<td>24</td>
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Table 9 continued

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<tbody>
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<td></td>
<td></td>
<td>A</td>
</tr>
</tbody>
</table>
| 25 | AB
    |       | F2     | (see note iii) |
| 26 | F
    |       | F2     | (see note iii) |
| 27 | F2
    |       | F2     | (see note iii) |
| 28 | F2
<pre><code>|       | F2     | (see note iii) |
</code></pre>
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<th>Connection type</th>
<th>Critical Locations</th>
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</tr>
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<td>30</td>
<td><img src="image2.png" alt="Image" /></td>
<td>F</td>
</tr>
<tr>
<td>31</td>
<td><img src="image3.png" alt="Image" /></td>
<td>F (see note iv)</td>
</tr>
</tbody>
</table>

**Notes:**

i) Where the attachment length is less than or equal to 150 mm without deduction of scallop, S-N curve is to be upgraded one class from those specified in the Table for ID. 1-30. For example, if the class shown in the table is F2, upgrade to F. Attachment length is defined as the length of the weld attachment on the longitudinal stiffener face plate.

ii) For lapped connections (when allowed for transverse side shell stiffeners) the detail class is to be scaled down of one grade.

iii) F class may be used if only subjected to axial loading (no lateral pressure).

iv) F class to be used for open and closed slots (with or without collar plate).

v) See examples of soft toes and backing bracket of pillar stiffeners and tripping brackets in Fig. 13 and Fig. 14 respectively.

**Figure 13 : Example of Soft Toes and Backing Bracket of Pillar Stiffeners.**
**Soft toe:**
- Arm length: \( a_1 \approx 0.5 \, d \)
- Radius: \( r_1 \approx l_1 \)

**Backing Bracket:**
- Arm length: \( a_2 \approx 1.5 \, d \)
- Radius: \( r_2 \approx l_2 \)

*Figure 14: Example of Soft Toes and Backing Bracket of tripping brackets.*
S32.3.9 - Required net thickness of tank transverse bulkhead and tank stringer plating

The required net thickness, in mm, of each strake of tank transverse bulkheads and tank stringers is given by the largest of the thicknesses given by S32.3.9.1 and S32.3.9.2, calculated for each load calculation point, as defined in S32.2.5.1, representative of the considered strake (see Table 4). The geometry to be considered is that of the elementary plate panel related to the load calculation point.

The required net thickness is the largest of those calculated in the five mutually exclusive load cases, as defined in S32.2.1.

S32.3.9.1 – Local bending check

\[ t = 15.8 s \sqrt{\frac{p}{C_a \sigma_Y}} \]

where:

- \( p = p_{bl} \)
- \( p_{bl} \) = pressure induced by ballast, in kN/m², in double side spaces in normal ballast conditions, to be calculated at the calculation point, as defined in S32.2.5.1. Pressures are to be calculated considering each double side compartment, adjacent to the considered plate, as individually loaded.

\[ p_{bl} = p_{bls} + p_{bli} \]

\( p_{bl} \) is to be taken not less than the value obtained, in kN/m², from the following formula:

\[ p_{bl} = 1.025 g (Z_{TOP} - z) + 25 \]

- \( p_{bls} \) = static ballast pressure, in kN/m², as defined in S32.2.3.1, at the calculation point, as defined in S32.2.5.1,
- \( p_{bli} \) = inertial ballast pressure, in kN/m², as defined in S32.2.3.2, at the calculation point, as defined in S32.2.5.1,

\[ C_a = 0.75 - 0.72 \frac{\sigma_{ax}}{\sigma_Y}, \quad max = 0.7 \]

for double side stringers transversely stiffened plating within 0.4L amidships. Outside of 0.4L amidships the value of \( C_a \) may be increased linearly to the value 0.7 for \( x/L = 0.0 \) and 1.0.

\[ C_a = 0.75 - 0.36 \frac{\sigma_{ax}}{\sigma_Y}, \quad max = 0.7 \]

for double side stringers longitudinally stiffened plating within 0.4L amidships. Outside of 0.4L amidships the value of \( C_a \)
Ca = 0,7 for double side bulkheads.

\(\sigma_{ax} = \) hull girder stress, in N/mm\(^2\), as defined in S32.3.1.1.3.

### S32.3.9.2 Minimum net plate thickness

\[ t = 0,60 L^{0,5} \]

### S32.3.10 – Required net section modulus and net web thickness of tank bulkhead and stringer stiffeners

The required net section modulus \(Z\), in cm\(^3\) and web thickness \(t_w\), in mm, of double side bulkhead and stringer stiffeners, to be evaluated for each of the five mutually exclusive load cases as defined in S32.2.1, are given by:

\[
Z = \frac{1000 p s l^2}{m C_s \sigma_Y}
\]

\[
t_w = \frac{500 p s l}{d \sin \phi \tau_a}
\]

\(p = p_{bi}\)

\(p_{bi} = \) pressure induced by ballast, in kN/m\(^2\), in double side spaces in normal ballast conditions to be calculated at the calculation point, as defined in S32.2.5.2. Pressures are to be calculated considering each double side compartment adjacent to the considered plate as individually loaded.

\[= p_{bls} + p_{bli}\]

\(p_{bi} = \) to be taken not less than the value obtained, in kN/m\(^2\), from the following formula:

\[p_{bi} = 1,025 g (Z_{TOP} - z) + 25\]

\(p_{bls} = \) static ballast pressure of the double side space, in kN/m\(^2\), as defined in S32.2.3.1, at the calculation point, as defined in S32.2.5.2

\(p_{bli} = \) inertial ballast pressure, in kN/m\(^2\), as defined in S32.2.3.2, at the calculation point, as defined in S32.2.5.2

\(\phi = \) angle, in deg, between the stiffener web and the plate, measured at the middle of the stiffener span; the correction is to be applied when \(\phi\) is less than 75 deg (see Figure 8)

\(m = \) 10 for vertical stiffeners

12 in the other cases.
\( d \) = stiffener web depth, in mm

\[
C_S = 0.95 - 0.9 \frac{\sigma_{ax}}{\sigma_y}, \quad max = 0.7
\]

for longitudinal stiffeners of tank stringers within 0.4L amidships. Outside of 0.4L amidships the value of \( C_S \) may be increased linearly to the value 0.7 for \( x/L = 0,0 \) and 1.0.

\( C_S = 0.7 \)

for transverse stiffeners of tank stringers.

\( C_S = 0.7 \)

for stiffeners of tank bulkheads.

\( \sigma_{ax} = \) hull girder stress, in N/mm\(^2\), as defined in S32.3.1.1.3.

The stiffener actual section modulus is to be calculated about an axis parallel to the attached plate (see Figure 8), considering an attached plating breadth equal to 0.1 \( \ell \) on either side of the stiffener. However, the attached plating breadth is not to exceed the stiffener spacing \( s \).

### S32.4 – Minimum net thickness

#### S32.4.1 – Minimum net thickness of transverse webs, non-tight bulkheads and horizontal stringers

The minimum net thickness, in mm, of transverse webs, non-tight bulkheads and horizontal stringers is given by:

\[
t = 0.60 \ L^{0.5}
\]

#### S32.4.2 – Minimum net thickness of soft toes and backing brackets of stiffeners and tripping brackets

The minimum net thickness, in mm, of soft toes and backing brackets of stiffeners and tripping brackets (see also examples in Fig 13 and Fig 14) is given by:

- \( t = d/18 \) for soft toe of stiffeners
- \( t = d/18 \) for backing bracket of stiffeners
- \( t = a_2 / 27 \) for backing bracket of tripping brackets

where:

\( d \) = stiffener web depth, in mm (see also Fig 13)

\( a_2 \) = bracket length, in mm (see also Fig 14)
S32.5 - Corrosion addition and steel renewal

S32.5.1 - Corrosion addition – Proposal 1

Corrosion addition, $t_c$, for the double side structures is determined by summing the values for each side of the structural member, to be taken not less than the values given in Table 10 or Table 11, as applicable.

Table 10 - Corrosion addition for one side of double side structural member in BC-A and BC-B ships

<table>
<thead>
<tr>
<th>Corrosive environment to which the side of structural member is exposed</th>
<th>Corrosion addition, in mm, to the side of structural member which is exposed to the corrosive environment mentioned in the left column (1) (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cargo hold</td>
<td>Upper part of hold (3)</td>
</tr>
<tr>
<td></td>
<td>Middle or lower part of hold</td>
</tr>
<tr>
<td>Ballast tank</td>
<td>Face plate of primary member</td>
</tr>
<tr>
<td></td>
<td>3 m below the deck</td>
</tr>
<tr>
<td></td>
<td>Locations other than above</td>
</tr>
<tr>
<td></td>
<td>Structural elements other than above</td>
</tr>
<tr>
<td></td>
<td>3 m below the deck</td>
</tr>
<tr>
<td></td>
<td>Locations other than above</td>
</tr>
<tr>
<td>Void space</td>
<td></td>
</tr>
<tr>
<td>Sea water outboard (under full load water line)</td>
<td></td>
</tr>
<tr>
<td>Air outboard (above full load water line)</td>
<td></td>
</tr>
</tbody>
</table>

Note:

(1) Minimum of total corrosion addition for side shell plating is 2.0 mm.

(2) Total thickness of corrosion additions on both sides of structure is to be rounded up to the next half mm.

(3) Upper part of cargo holds corresponds to area above the connection between topside and inner skin. If there are no topside, the upper part corresponds to the upper one third of the cargo hold.
Table 11 - Corrosion additions for one side of double side structural member in BC-C and ships less than 150 m in length

<table>
<thead>
<tr>
<th>Corrosive environment to which the side of structural member is exposed</th>
<th>Corrosion addition, in mm, to the side of structural member which is exposed to the corrosive environment mentioned in the left column (1) (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cargo hold</td>
<td>Upper part of hold (3)</td>
</tr>
<tr>
<td></td>
<td>Middle or lower part of hold</td>
</tr>
<tr>
<td>Ballast tank</td>
<td>Face plate of primary member</td>
</tr>
<tr>
<td></td>
<td>Locations other than above</td>
</tr>
<tr>
<td></td>
<td>Structural elements other than above</td>
</tr>
<tr>
<td></td>
<td>Locations other than above</td>
</tr>
<tr>
<td>Void space</td>
<td></td>
</tr>
<tr>
<td>Sea water outboard (under full load water line)</td>
<td></td>
</tr>
<tr>
<td>Air outboard (above full load water line)</td>
<td></td>
</tr>
</tbody>
</table>

Note :
(1) Minimum of total corrosion addition for side shell plating is 2.0 mm.
(2) Total thickness of corrosion additions on both sides of structure is to be rounded up to the next half mm.
(3) Upper part of cargo holds corresponds to area above the connection between topside and inner skin. If there are no topside, the upper part corresponds to the upper one third of the cargo hold.

S32.5.1 – Total corrosion additions – Proposal 2

Total corrosion addition, $t_C$, for the double side structures is to be taken not less than the values given in Table 10 or Table 11, as applicable.

Table 10 – Total corrosion additions of double side structural members in BC-A and BC-B ships

<table>
<thead>
<tr>
<th>Structural Element: (See note 1)</th>
<th>Total corrosion addition, in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck and Side plating within 3,0 m below weather deck (see note 2)</td>
<td>4,0</td>
</tr>
<tr>
<td>Side plating outside 3,0 m below weather deck (see note 2)</td>
<td>3,0</td>
</tr>
<tr>
<td>Inner skin and top side plating</td>
<td>3,5</td>
</tr>
<tr>
<td>Internal structure in water ballast</td>
<td>Within 3,0 m below weather deck</td>
</tr>
<tr>
<td></td>
<td>Outside 3,0 m below weather</td>
</tr>
</tbody>
</table>
Notes:
1. Corrosion addition for structural elements within and on the boundaries of double side skin void spaces is equal to 0.5 mm less than above, for each side.
2. 3.0 m below weather deck is defined by a horizontal line 3.0 m below the elevation of the deck at side.

### Table 11 – Total corrosion additions of double side structural member in BC-C and ships less than 150 m in length

<table>
<thead>
<tr>
<th>Structural Element: (See note 1)</th>
<th>Total corrosion addition, in mm</th>
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</thead>
<tbody>
<tr>
<td>Deck and Side plating within 3.0 m below weather deck (see note 2)</td>
<td>4.0</td>
</tr>
<tr>
<td>Side plating outside 3.0 m below weather deck (see note 2)</td>
<td>3.0</td>
</tr>
<tr>
<td>Inner skin and top side plating</td>
<td>3.0</td>
</tr>
<tr>
<td>Internal structure in water ballast tank</td>
<td></td>
</tr>
<tr>
<td>Within 3.0 m below weather deck</td>
<td>3.5</td>
</tr>
<tr>
<td>Outside 3.0 m below weather deck</td>
<td></td>
</tr>
<tr>
<td>Face plate of main supporting structure</td>
<td>3.5</td>
</tr>
<tr>
<td>Structural elements other than above</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Notes:
1. Corrosion addition for structural elements within and on the boundaries of double side skin void spaces is equal to 0.5 mm less than above, for each side.
2. 3.0 m below weather deck is defined by a horizontal line 3.0 m below the elevation of the deck at side.

### S32.5.2 – Steel renewal

For the purpose of the application of the requirements in 5.2, the net scantlings $t_{\text{net}}$ of the double side structures to be considered are the maximum among those obtained according to the strength criteria in this UR and those obtained according to the strength criteria specified in other URs and in each Society Rules, as applicable.

#### Proposal 1:
With respect to general corrosion diminution, where the gauged thickness of the structural member is within the range $t_{\text{net}} + 0.2\ t_c$ mm and $t_{\text{net}} + 0.4\ t_c$ mm:

- steel renewal, or
- coating (applied in accordance with the coating manufacturer’s requirements), or
- annual gauging

is to be adopted.

Steel renewal of the structural member is required when the gauged thickness is less than $t_{\text{net}} + 0.2\ t_c$ mm.
Proposal 2: With respect to general corrosion diminution, steel renewal of a structural member is required when the gauged thickness is less than $t_{AB} - t_{Owner} - (t_C - 0.5)$, where $t_{AB}$ is the gross as-built thickness, $t_{Owner}$ is any Owner's extra thickness and $t_C$ is the corrosion addition, as given in Tables 9 and 10.

In addition, steel renewal for pitting and grooving is to comply with the requirements in S32.5.1

S32.5.3 Pitting and grooving

If pitting intensity is higher than 15% in area (see Figure 15), thickness measurement is to be taken to check pitting corrosion.

The minimum acceptable remaining thickness in pits or grooves is equal to 70% of the as built thickness.

Figure 15 - Pitting intensity diagrams (from 5% to 25% intensity)
APPENDIX A. DESIGN S-N CURVES
The following describes the DEn basic design S-N curves upon which the assessment of the fatigue strength of hull structural details is to be based.

The capacity of welded steel joints with respect to the fatigue strength is characterised by S-N curves which give the relationship between the stress ranges applied to a given detail and the number of constant amplitude load cycles to failure.

For ship structural details, S-N curves are represented by the following formula:

$$S^m N = K$$

where:

- $S$ = stress range, defined as $S_{RB}$ and $S_{RC}$ in S.32.3.5.2
- $N$ = number of cycles to failure
- $m, K$ = constants depending on: material and weld type, type of loading, geometrical configuration, environmental conditions (air or sea water).

Experimental S-N curves are defined by their mean fatigue life and standard deviation. The mean S-N curve gives the stress level $S$ at which the structural detail will fail with a probability level of 50 per cent after $N$ loading cycles. S-N curves considered in the present Guide are based upon a statistical analysis of appropriate experimental data and represent two standard deviations below the mean lines, which correspond to a survival probability of 97.5%.

As shown in Figure A1, the basic design curves consist of linear relationships between log($S$) and log ($N$), which can be expressed as:

$$\log(N) = \log(K_2) - m \log(S)$$

where:

- $\log(K_2) = \log(K_1) - 2\delta$
- $N$ = predicted number of cycles to failure under stress range $S$
- $K_1$ = constant relating to the mean S-N curve
- $\delta$ = standard deviation of log($N$)
- $m$ = inverse slope of the S-N curve

The relevant values of these terms are show in the table A1 below.

The S-N curves have a change of inverse slope from $m$ to $m + 2$ at $N = 10^7$ cycles (which corresponds to stress range $S_q$).
Effect of plate thickness

For the purpose of UR S32 the basic design S-N curves are generally applicable to end connection structures of rolled profiles. For end connection details welded to stiffeners of built up type with flange thickness, $t$, greater than 22 mm, the following equation of the S-N curve is to be used:

$$\log(N) = \log(K_2) - m \log\left(\frac{S}{(22/t)^{0.25}}\right)$$

Table A1: S-N curve data

<table>
<thead>
<tr>
<th>Class</th>
<th>$K_1$</th>
<th>$K_1$</th>
<th>$m$</th>
<th>Standard Deviation</th>
<th>$K_2$</th>
<th>$S_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\log_{10}$</td>
<td>$\log_e$</td>
<td></td>
<td>$\log_{10}$</td>
<td>$\log_e$</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>2.343E15</td>
<td>15.3697</td>
<td>35.3900</td>
<td>4.0</td>
<td>0.1821</td>
<td>0.4194</td>
</tr>
<tr>
<td>C</td>
<td>1.082E14</td>
<td>14.0342</td>
<td>32.3153</td>
<td>3.5</td>
<td>0.2041</td>
<td>0.4700</td>
</tr>
<tr>
<td>D</td>
<td>3.988E12</td>
<td>12.6007</td>
<td>29.0144</td>
<td>3.0</td>
<td>0.2095</td>
<td>0.4824</td>
</tr>
<tr>
<td>E</td>
<td>3.289E12</td>
<td>12.5169</td>
<td>28.8216</td>
<td>3.0</td>
<td>0.2509</td>
<td>0.5777</td>
</tr>
<tr>
<td>F</td>
<td>1.726E12</td>
<td>12.2370</td>
<td>28.1770</td>
<td>3.0</td>
<td>0.2183</td>
<td>0.5027</td>
</tr>
<tr>
<td>F2</td>
<td>1.231E12</td>
<td>12.0900</td>
<td>27.8387</td>
<td>3.0</td>
<td>0.2279</td>
<td>0.5248</td>
</tr>
<tr>
<td>G</td>
<td>0.566E12</td>
<td>11.7525</td>
<td>27.0614</td>
<td>3.0</td>
<td>0.1793</td>
<td>0.4129</td>
</tr>
<tr>
<td>W</td>
<td>0.368E12</td>
<td>11.5662</td>
<td>26.6324</td>
<td>3.0</td>
<td>0.1846</td>
<td>0.4251</td>
</tr>
</tbody>
</table>

Figure A1: DEn basic design S-N curves
APPENDIX B. Gamma Function

Table B1 - Gamma function

<table>
<thead>
<tr>
<th>x</th>
<th>Γ(x+1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.</td>
<td>1.</td>
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IACS WP/S – UR S32 agreed at the WP/S Meeting of 30 September – 2 October 2003
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5.4

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γ(x+1,2)
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0.65451
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0.623011
0.634086
0.646647
0.660689
0.676214
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0.753563
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0.954746
0.991449
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1.07179
1.11566
1.16217
1.21146
1.26367
1.31898
1.37754
1.43953
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1.57463
1.64815
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1.98763
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2.18848
2.29777
2.41344

γ(x+1,3)
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0.852747
0.822422
0.801128
0.787315
0.779871
0.777997
0.781117
0.788827
0.800852
0.817017
0.837233
0.861479
0.889794
0.922271
0.959051
1.00032
1.04632
1.09731
1.15362
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1.28372
1.35839
1.44015
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2.43333
2.61366
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3.0252
3.25962
3.51555
3.79501
4.10024
4.43368
4.79804
5.19627
5.63163
6.10772
6.62847
7.19821
7.82174
8.50428
9.25163
10.0702
10.9668
11.9494
13.0264
14.2071

γ(x+1,4)
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0.867894
0.852542
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13.4969
15.0065
16.698
18.5942
20.7207
23.1066
25.7844
28.791
32.1682
35.9631
40.2287

Page 60 of 61

γ(x+1,5)
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0.885966
0.873507
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0.885083
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21.7361
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27.8243
31.5246
35.7484
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γ(x+1,6)
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13.2827
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17.1586
19.543
22.2882
25.4514
29.0991
33.3087
38.1703
43.7891
50.2875
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76.6123
88.3172
101.899
117.667

γ(x+1,7)
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13.2494
15.1347
17.3177
19.8482
22.7843
26.1946
30.1593
34.7731
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19/02/2004


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