Rules for Classification and Construction

I Ship Technology

1 Seagoing Ships

1 Hull Structures

Edition 2013

The following Rules come into force on 1 May 2013.

Alterations to the preceding Edition are marked by beams at the text margin.

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Section 1 General, Definitions

A General

A.1 Application

A.1.1 Unless specially mentioned in specific Sections, the requirements of the Sections of this Chapter apply to all seagoing steel ships classed **100A5** whose breadth to depth ratio is within the range common for seagoing ships and the depth **H** of which is not less than:

- $\mathbf{L} / 16$ for unlimited range of service and **RSA (200)** (**R**estricted **S**ervice **A**rea)
- $\mathbf{L} / 18$ for **RSA (50)**, **RSA (20)**
- $\mathbf{L} / 19$ for **RSA (SW)**

Smaller depths may be accepted if proof is submitted of equal strength, rigidity and safety of the ship.

A.1.2 Ships deviating from the Construction Rules in their types, equipment or in some of their parts may be classed, provided that their structures or equipment is found to be equivalent to the Society's requirements for the respective class.

A.1.3 Passages of this chapter printed in italics contain recommendations and notes which are not part of the Classification Rules.

A.2 References

A.2.1 Application, characters of classification and class notations

For application, characters of classification and class notations see the GL Rules for Classification and Surveys (I-0), Section 2.

A.2.2 International Conventions and Codes

A.2.2.1 Paragraphs of this section are based on the following international convention(s) and / or code(s):

IACS UR S2 Rev.1

IACS UR S21A

ICLL containing all amendments up to 1st July 2010

MARPOL 73/78 containing all amendments up to 1st February 2012

IBC Code containing all amendments up to 1st January 2009

IGC Code containing all amendments up to 1st July 2008

At the end of each relevant paragraph of this section, the corresponding paragraphs of the international convention(s) and / or code(s) are given in brackets.

A.2.2.2 Where reference is made of international Conventions and Codes these are defined as follows:

ICLL

International Convention on Load Lines, 1966, as amended.

MARPOL

International Convention for the Prevention of Pollution from Ships, 1973 including the 1978 Protocol as amended.

SOLAS

International Convention for the Safety of Life at Sea, 1974, as amended.

IBC Code

International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk as amended.

IGC Code

International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk as amended.

IMSBC Code

International Maritime Solid Bulk Cargoes Code.

A.3 Definitions

A.3.1 Parameters

Considering the range of application, definitions of parameter are made at different locations of this chapter as follows:

- parameters only used in one paragraph are defined in the specific paragraph
- parameters used in more than one paragraph of the same section are defined at the beginning of the specific section
- parameters used in more than one section are defined in the following paragraphs

A.3.1.1 Principal dimensions

Length $\mathbf{L}$

The length $\mathbf{L}$ [m] is the distance in metres on the summer load waterline from the fore side of the stem to the centre of the rudder stock. $\mathbf{L}$ is not to be less than 96 % and need not be greater than 97 % of the extreme length of the summer load waterline. In ships with unusual stern and bow arrangement, the length $\mathbf{L}$ will be specially considered.

(IACS UR S2.1)

Length $\mathbf{L_c}$

The length $\mathbf{L_c}$ [m] is to be taken as 96 % of the total length on a waterline at 85 % of the least moulded depth H_c measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that be greater.

For ships without a rudder stock, the length $\mathbf{L_c}$ is to be taken as 96 % of the waterline at 85 % of the least moulded depth.

In ships designed with a rake of keel the waterline on which this length is measured is to be parallel to the designed waterline.

Where the stem contour is concave above the waterline at 85 % of the least moulded depth, both the forward terminal of the total length and the fore side of the stem respectively shall be taken at the vertical projection to the waterline of the aftermost point of the stem contour (above that waterline) (see Fig. 1.1).

(ICLL Annex I, I, 3(1); MARPOL 73/78 Annex 1, 1.19; IBC Code 1.3.19 and IGC Code 1.2.23)

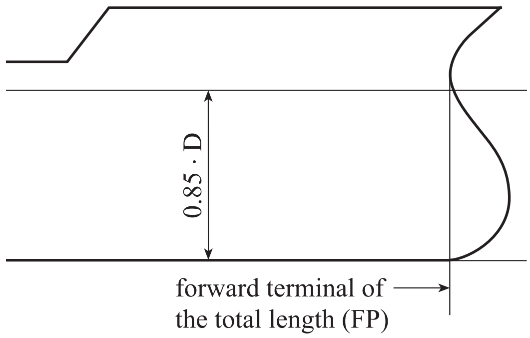


Fig. 1.1 Length $\mathbf{L_c}$ in case of concave stern contour

Forward perpendicular F.P.

The forward perpendicular coincides with the foreside of the stem on the waterline on which the respective length $\mathbf{L}$ or $\mathbf{L_c}$ is measured.

Breadth B

The breadth $\mathbf{B}$ [m] is the greatest moulded breadth of the ship.

Depth H

The depth $\mathbf{H}$ [m] is the vertical distance, at the middle of the length $\mathbf{L}$, from the base line to top of the deck beam at side on the uppermost continuous deck.

In way of effective superstructures the depth is to be measured up to the superstructure deck for determining the ship's scantlings.

Depth $\mathbf{H_c}$

The moulded depth $\mathbf{H_c}$ [m] is the vertical distance measured from the top of the keel to the top of the freeboard deck beam at side. In wood and composite ships the distance is measured from the lower edge of the keel rabbet. Where the form at the lower part of the midship section is of a hollow character, or where thick garboards are fitted, the distance is measured from the point where the line of the flat of the bottom continued inwards cuts the side of the keel.

In ships having rounded gunwales, the moulded depth is to be measured to the point of intersection of the moulded lines of deck and sides, the lines extending as though the gunwale were of angular design.

Where the freeboard deck is stepped and the raised part of the deck extends over the point at which the moulded depth is to be determined, the moulded depth is to be measured to a line of reference extending from the lower part of the deck along a line parallel with the raised part.

(ICLL Annex I, I, 3(5))

Draught T

The draught $\mathbf{T}$ [m] is the vertical distance at the middle of the length $\mathbf{L}$ from base line to freeboard marking for summer load waterline. For ships with timber load line the draught $\mathbf{T}$ is to be measured up to the freeboard mark for timber load waterline.

Frame spacing a

The frame spacing $\mathbf{a}$ [m] will be measured from moulding edge to moulding edge of frame.

Block coefficient $\mathbf{C_B}$

Moulded block coefficient at load draught $\mathbf{T}$, based on length $\mathbf{L}$.

$$C_B = \frac{\text{moulded volume of displacement } [m^3] \text{ at } \mathbf{T}}{\mathbf{L} \cdot \mathbf{B} \cdot \mathbf{T}}$$

(IACS UR S2.2)

Ship's speed v_0

Maximum service speed [kn], which the ship is designed to maintain at the summer load line draught and at the propeller RPM corresponding to MCR (Maximum Continuous Rating).

In case of controllable pitch propellers the speed v_0 is to be determined on the basis of maximum pitch.

A.3.1.2 Material properties

Yield strength R_{eH}

The yield strength R_{eH} $[N/mm^2]$ of the material is defined as the nominal upper yield point. In case of materials without a marked yield point, the proof stress R_p is to be used instead. See also Section 2, D, Section 2, E and Principles and Test Procedures (II-1-1), Section 2, D.

Tensile strength R_m

R_m $[N/mm^2]$ is the minimum tensile strength of the material. See also Principles and Test Procedures (II-1-1), Section 2, D.

Proof stress R_p

The proof stress R_p $[N/mm^2]$ is the stress that will cause a specified permanent extension of a specimen of a tensile test. The specified permanent extension is denoted in the index.

- $R_{p0.2}$ = 0.2 % proof stress
- $R_{p1.0}$ = 1.0 % proof stress

See also Principles and Test Procedures (II-1-1), Section 2, D.

Young's modulus E

E : Young's modulus $[N/mm^2]$, defined as:

$E = 2.06 \cdot 10^5 \quad N/mm^2$ for mild and higher strength structural steels

$E = 0.69 \cdot 10^5 \quad N/mm^2$ for aluminium alloys

A.3.2 Decks

Bulkhead deck

Bulkhead deck is the deck up to which the watertight bulkheads are carried.

Freeboard deck

1. The freeboard deck is normally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part thereof, and below which all openings in the side of the ship are fitted with permanent means of watertight closing.
2. Lower deck as a freeboard deck

   At the option of the owner and subject to the approval of the Administration, a lower deck may be designated as the freeboard deck provided it is a complete and permanent deck continuous in a fore and aft direction at least between the machinery space and peak bulkheads and continuous athwartships.

For details of the definition, see **ICLL**.

(ICLL Annex I, I, 3(9))

Strength deck

The strength deck is:

- the uppermost continuous deck which is forming the upper flange of the hull structure
- a superstructure deck which extends into 0.4 **L** amidships and the length of which exceeds 0.15 **L**
- a quarter deck which extends into 0.4 **L** amidships

Weather deck

All free decks and parts of decks exposed to the sea are defined as weather deck.

Lower decks

Starting from the first deck below the uppermost continuous deck, the decks are defined as 2nd, 3rd deck, etc.

Superstructure decks

The superstructure decks situated immediately above the uppermost continuous deck are termed forecastle deck, bridge deck and poop deck. Superstructure decks above the bridge deck are termed 2nd, 3rd superstructure deck, etc.

A.3.3 Position of hatchways, doorways and ventilators

For the arrangement of hatches, doors and ventilators the following areas are defined:

- Position 1
  - on exposed freeboard decks
  - on raised quarter decks
  - on the first exposed superstructure deck above the freeboard deck within the forward quarter of $\mathbf{L_c}$
- Position 2
  - on exposed superstructure decks aft of the forward quarter of $\mathbf{L_c}$ located at least one standard height of superstructure above the freeboard deck
  - on exposed superstructure decks within the forward quarter of $\mathbf{L_c}$ located at least two standard heights of superstructure above the freeboard deck

(IACS UR S21A 1.2.2)

B *Note for Vibrations and Noise*

B.1 *Mechanical vibrations*

Operating conditions which are encountered most frequently should be kept free as far as possible from resonance vibrations of the ship hull and individual structural components. Therefore, the exciting forces coming from the propulsion plant and pressure fluctuations should be limited as far as possible. Beside the selection of the propulsion units particular attention is to be given to the ship's lines including the stern post, as well as to the minimisation of possible cavitation. In the shaping of the bow it should be kept in mind that a large flare above the waterline will not only cause very high local slamming pressures, but will also excite increasingly whipping vibrations of the ship's hull. If critical excitation loads cannot be eliminated, appropriate measures are to be taken on the basis of theoretical investigations at an early design stage.

For example, the risk of large global and local structural vibrations can be minimized by a global or local vibration analysis, respectively, to be conducted during the steel structures design phase.

Limit values for vibrations aboard ships may be assessed under several aspects. If the application of other national or international rules or standards is not mandatory, the following guidelines and regulations are recommended:

Vibration load to the crew:

- *measurement and analysis techniques according to ISO 6954, ed. 2000*
- *limit values according to ISO 6954, depending on ship type and location within the ship. (the GL Service Group Vibration is ready to provide support to this activity)*
- *ships flying the German Flag according to the Guidelines of the Accident Prevention Regulations of BG Verkehr Dienststelle Schiffssicherheit (BG Verkehr Ship Safety Division)*

- *inconvenience to passengers due to ship vibrations for the GL Class Notation Harmony Class according to the Harmony Class – Rules on Rating Noise and Vibration for Comfort, Cruise Ships ($v \leq$ 25 kn) (I-1-16)*
- *vibrations of machinery, installations and other equipment according to Machinery Installations (I-1-2), Section 1*

B.2 *Noise*

Suitable precautions are to be taken to keep noises as low as possible particularly in the crew's quarters, working spaces, passengers' accommodation, etc.

Attention is drawn to regulations concerning noise level limitations, if any, of the flag administration.

C Rounding-Off Tolerances

Where in determining plate thicknesses in accordance with the provisions of the following Sections the figures differ from full or half mm, they may be rounded off to full or half millimetres up to 0.2 or 0.7; above 0.2 or 0.7 mm they are to be rounded up.

If plate thicknesses are not rounded the calculated required thicknesses is to be shown in the drawings.

The section moduli of profiles usual in the trade and including the effective width according to Section 3, C and Section 3, D may be 3 % less than the required values according to the rules for dimensioning of this chapter.

D Regulations of National Administrations

For the convenience of the user of these Rules several Sections contain for guidance references to such regulations of national administrations, which deviate from the respective rule requirements of this Society but which may have effect on scantlings and construction. These references have been specially marked.

Compliance with these regulations of national administrations is not conditional for class assignment.

E Direct Calculations

E.1 In order to increase the flexibility in the structural design of ships GL also accepts direct calculations with computer programs. The aim of such analyses should be the proof of equivalence of a design with the rule requirements.

E.2 For such calculation the computer model, the boundary condition and load cases are to be agreed upon with GL. The calculation documents are to be submitted including input and output. During the examination it may prove necessary that GL perform independent comparative calculations.

E.3 The choice of computer programs according to "State of the Art" is free. The programs may be checked by GL through comparative calculations with predefined test examples. A generally valid approval for a computer program is, however, not given by GL.

E.4 GL is prepared to carry out the following calculations of this kind within the marine advisory services:

E.4.1 Strength

Linear and/or non-linear strength calculations with the FE-method:

For an automated performance of these calculations, a number of effective pre- and post processing programmes is at disposal:

- calculation of seaway loads as per modified strip method or by 3D-panel method
- calculation of resultant accelerations to ensure quasi-static equilibrium
- calculation of composite structures
- evaluation of deformations, stresses, buckling behaviour, ultimate strength and local stresses, assessment of fatigue strength

E.4.2 Vibrations

Calculation of free vibrations with the FE-method as well as forced vibrations due to harmonic or shock excitation:

- global vibrations of hull, aft ship, deckhouse, etc.
- vibrations of major local components, such as rudders, radar masts, etc.
- local vibrations of plate fields, stiffeners and panels
- vibrations of simply or double-elastically mounted aggregates

  A number of pre- and post processing programs is available here as well for effective analyses:
  - calculation of engine excitation (forces and moments)
  - calculation of propeller excitation (pressure fluctuations and shaft bearing reactions)
  - calculation of hydrodynamic masses
  - graphic evaluation of amplitude level as per ISO 6954 recommendations or as per any other standard
  - noise predictions

E.4.3 Collision resistance

Calculation of the structure's resistance against collision for granting the additional class notation **COLL** according to Section 33.

F Specific Programs related to Rules

F.1 General

GL has developed the computer program "POSEIDON" as an aid to fast and reliable dimensioning a hull's structural members according to GL Rules, and for direct strength calculations.

F.2 POSEIDON

POSEIDON includes both the traditional dimensioning as well as the automatic optimisation of scantlings by means of direct calculations according to the FE-method.

POSEIDON is supported on PCs by Microsoft Windows ®, and a hotline has been set up to assist users. Further information is available via the GL-homepage, at inspection offices world-wide and at GL Head Office.

F.3 GL RULES and Programs

GLRP is available on CD-ROM. It includes the wording of GL-Rules and an elementary program for dimensioning the structural members of the hull.

GLRP can be used together with POSEIDON.

Section 2 Materials

A General

A.1 References

International conventions and codes

Paragraphs of this section are based on the following international convention(s) and / or code(s):

IACS UR S4 Rev.3

IACS UR S6 Rev.6

At the end of each relevant paragraph of this section, the corresponding paragraphs of the international convention(s) and / or code(s) are given in brackets.

A.2 Definitions

Normal strength hull structural steel

Normal strength hull structural steel is a hull structural steel with yield strength R_{eH} of 235 N / mm^2 and a tensile strength R_m of 400 – 520 N / mm^2.

Depending of their toughness properties, normal strength hull structural steel is grouped into the following grades:

- GL–A
- GL–B
- GL–D
- GL–E

Higher strength hull structural steels

Higher strength hull structural steel is a hull structural steel, the yield and tensile properties of which exceed those of normal strength hull structural steel. According to the GL Rules for Metallic Materials (II-1), for three groups of higher strength hull structural steels the yield strength R_{eH} has been fixed at 315, 355 and 390 N / mm^2 respectively.

Depending of their toughness properties, higher strength hull structural steel is grouped into the following grades:

- GL–A 32 / 36 / 40
- GL–D 32 / 36 / 40
- GL–E 32 / 36 / 40
- GL–F 32 / 36 / 40

In Table 2.1 – Table 2.7 the grades of the higher strength hull structural steels are marked by the letter "H".

Material Factor k

The material factor k is to be determined by the following formulae:

$k = 1$ for $R_{eH} = 235\ N/mm^2$

$k = 0.78$ for $R_{eH} = 315\ N/mm^2$

$k = 0.72$ for $R_{eH} = 355\ N/mm^2$

$k = 0.66$ for $R_{eH} = 390\ N/mm^2$

$k = \frac{295}{R_{eH} + 60}$ for $235 < R_{eH} < 390\ N/mm^2$ and $R_{eH} \neq 315$ or $355\ N/mm^2$

(IACS UR S4)

B Hull Structural Steel for Plates and Sections

B.1 General

B.1.1 All materials to be used for the structural members indicated in the Construction Rules are to be in accordance with the GL Rules for Metallic Materials (II-1).

Materials the properties of which deviate from these Rule requirements may only be used upon special approval.

B.1.2 In general ships are to be made out of normal and higher strength hull structural steels.

According to B.1.1 higher strength hull structural steel with yield strength in the range of $235 < R_{eH} < 390\ N/mm^2$ and $R_{eH} \neq 315$ or $355\ N/mm^2$ may be accepted upon special approval.

B.1.3 Where structural members are completely or partly made from higher strength hull structural steel, a suitable Notation will be entered into the ship's certificate.

B.1.4 In the drawings submitted for approval it is to be shown which structural members are made of higher strength hull structural steel. These drawings are to be placed on board in case any repairs are to be carried out.

B.2 Material selection for the hull

B.2.1 Material classes and grades

For the material selection for hull structural members material classes and grades as given in Table 2.1 are defined.

For structural members not specifically mentioned in Table 2.1, grade A / AH material may generally be used. However, GL may require also higher grades depending on the stress level.

The steel grade is to correspond to the as-built plate thickness when this is greater than the rule requirement.

(IACS UR S6.1)

Table 2.1 Material classes and grades for ships in general

Structural member category		Material class / grade
Secondary:		
A1. A2. A3.	Longitudinal bulkhead strakes, other than that belonging to the Primary category Deck plating exposed to weather, other than that belonging to the Primary or Special category Side plating	• Class I within 0.4 **L** amidships • Grade A / AH outside 0.4 **L** amidships
Primary:		
B1. B2. B3. B4. B5.	Bottom plating, including keel plate Strength deck plating, excluding that belonging to the Special category Continuous longitudinal members above strength deck, excluding hatch coamings Uppermost strake in longitudinal bulkhead Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	• Class II within 0.4 **L** amidships • Grade A / AH outside 0.4 **L** amidships
Special:		
C1. C2. C3.	Sheer strake at strength deck [1] Stringer plate in strength deck [1] Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships [1]	• Class III within 0.4 **L** amidships • Class II outside 0.4 **L** amidships • Class I outside 0.6 **L** amidships
C4.	Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch opening configurations	• Class III within 0.4 **L** amidships • Class II outside 0.4 **L** amidships • Class I outside 0.6 **L** amidships • Min. Class III within cargo region
C5.	Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch opening configurations	• Class III within 0.6 **L** amidships • Class II within rest of cargo region
C6.	Bilge strake in ships with double bottom over the full breadth and length less than 150 m [1]	• Class II within 0.6 **L** amidships • Class I outside 0.6 **L** amidships
C7.	Bilge strake in other ships [1]	• Class III within 0.4 **L** amidships • Class II outside 0.4 **L** amidships • Class I outside 0.6 **L** amidships
C8. C9.	Longitudinal hatch coamings of length greater than 0.15 **L** End brackets and deck house transition of longitudinal cargo hatch coamings	• Class III within 0.4 **L** amidships • Class II outside 0.4 **L** amidships • Class I outside 0.6 **L** amidships • Not to be less than grade D / DH

[1] Single strakes required to be of Class III within 0.4 **L** amidships are to have breadths not less than $800 + 5 \cdot \mathbf{L}$ [mm] need not be greater than 1 800 mm, unless limited by the geometry of the ship's design.

(IACS UR S6 Table 1)

B.2.2 Material selection for longitudinal structural members

Materials in the various strength members are not to be of lower grade than those corresponding to the material classes and grades specified in Table 2.1 – Table 2.7. General requirements are given in Table 2.1, while additional minimum requirements for ships with length exceeding 150 m and 250 m, bulk carriers subject to the requirements of **SOLAS** regulation XII/ 6.5.3, and ships with ice strengthening are given in Table 2.2 – Table 2.5. The material grade requirements for hull members of each class depending on the thickness are defined in Table 2.7.

(IACS UR S6.1)

Table 2.2 Minimum material grades for ships with length exceeding 150 m and single strength deck

Structural member category	Material grade
Longitudinal strength members of strength deck plating	Grade B / AH within 0.4 **L** amidships
Continuous longitudinal strength members above strength deck	Grade B / AH within 0.4 **L** amidships
Single side strakes for ships without inner continuous longitudinal bulkhead(s) between bottom and the strength deck	Grade B / AH within cargo region

(IACS UR S6 Table 2)

Table 2.3 Minimum material grades for ships with length exceeding 250 m

Structural member category	Material grade
Shear strake at strength deck [1]	Grade E / EH within 0.4 **L** amidships
Stringer plate in strength deck [1]	Grade E / EH within 0.4 **L** amidships
Bilge strake [1]	Grade D / DH within 0.4 **L** amidships
[1] Single strakes required to be of Grade E / EH and within 0.4 **L** amidships are to have breadths not less than $800+5 \cdot \mathbf{L}$ [mm], need not be greater than 1 800 mm, unless limited by the geometry of the ship's design.	

(IACS UR S6 Table 3)

Table 2.4 Minimum material grades for single-side skin bulk carriers subjected to SOLAS regulation XII/6.5.3

Structural member category	Material grade
Lower bracket of ordinary side frame [1, 2]	Grade D / DH
Side shell strakes included totally or partially between the two points located to $0.125 \cdot \ell$ above and below the intersection of side shell and bilge hopper sloping plate or inner bottom plate [2]	Grade D / DH
[1] The term "lower bracket" means webs of lower brackets and webs of the lower part of side fram es up to the point of $0.125 \cdot \ell$ above the intersection of side shell and bilge hopper sloping plate or inner bottom plate. [2] The span of the side frame ℓ is defined as the distance between the supporting structures.	

(IACS UR S6 Table 4)

Table 2.5 Minimum material grades for ships with ice strengthening

Structural member category	Material grade
Shell strakes in way of ice strengthening area for plates	Grade B / AH

(IACS UR S6 Table 5)

Table 2.6 Minimum material grades in the area of crane columns and foundations

Thickness t [mm]		> 12.5	> 25	> 70
	≤ 12.5	≤ 25	≤ 70	
Minimum material grade	A / AH	B / AH	D / DH	E / EH

The requirements for material grades are valid for design temperatures up to 0 °C. For lower design temperatures the requirements for material grades defined in GL Rules for Loading Gear on Seagoing Ships and Offshore Installations (VI-2-2) are to be considered.

Table 2.7 Steel grades to be used, depending on plate thickness and material class

Thickness t [mm] [1]		> 15	> 20	> 25	> 30	> 35	> 40	> 50
Material class	≤ 15	≤ 20	≤ 25	≤ 30	≤ 35	≤ 40	≤ 50	≤ 100 [3]
I	A / AH	A / AH	A / AH	A / AH	B / AH	B / AH	D/DH	D / DH [2]
II	A / AH	A / AH	B / AH	D / DH	D / DH [4]	D / DH [4]	E/EH	E / EH
III	A / AH	B / AH	D / DH	D / DH [4]	E / EH	E / EH	E/EH	E / EH

1 Actual thickness of the structural member.

2 For thicknesses $t > 60$ mm E / EH.

3 For thicknesses $t > 100$ mm the steel grade is to be agreed with GL.

4 For nominal yield stresses $R_{eH} \geq 390$ N/mm^2 EH.

(IACS UR S6 Table 6)

Table 2.8 Material selection for local structural members

Structural member	Material class
hawse pipe, stern tube, pipe stanchion [3]	I
hatch covers	I
face plates and webs of girder systems	II [1]
rudder body [2], rudder horn, sole piece, stern frame, propeller bracket, trunk pipe	II

1 Class I material sufficient, where rolled sections are used or the parts are machine cut from plates with condition on delivery of either "normalised", "rolled normalised" or "rolled thermo-mechanical".

2 Rudder body plates, which are subjected to stress concentrations (e.g. in way of lower support of semi-spade rudders), are to be of class III material.

3 For pipe stanchions for cargo reefer holds Table 2.10 is applicable.

(IACS UR S6.1)

B.2.3 Material selection for local structural members

B.2.3.1 The material selection for local structural members, which are not part of the longitudinal hull structure, may in general be effected according to Table 2.8. For parts made of forged steel or cast steel C is to be applied.

B.2.3.2 For topplates of machinery foundations located outside $0.6\ \mathbf{L}$ amidships, grade A ordinary hull structural steel may also be used for thicknesses above 40 mm.

B.2.4 Material selection for structural members which are exposed to low temperatures

B.2.4.1 The material selection for structural members, which are continuously exposed to temperatures below 0 °C, e.g. in or adjacent to refrigerated cargo holds, is governed by the design temperature of the structural members. The design temperature is the temperature determined by means of a temperature distribution calculation taking into account the design environmental temperatures. The design environmental temperatures for unrestricted service are:

- air: + 5 °C
- sea water: 0 °C

B.2.4.2 For ships intended to operate permanently in areas with low air temperatures (below and including –20 °C), e.g. regular service during winter seasons to Arctic or Antarctic waters, the materials in exposed structures are to be selected based on the design temperature t_D, to be taken as defined in B.2.4.5.

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 2.9, depending on the categories of structural members (Secondary, Primary and Special). For non-exposed structures and structures below the lowest ballast water line, see B.2.2 and B.2.3.

(IACS UR S6.2)

B.2.4.3 The material grade requirements for hull members of each material class depending on thickness and design temperature are defined in Table 2.10. For design temperatures $t_D < -55$ °C, materials are to be specially considered.

(IACS UR S6.2)

B.2.4.4 Single strakes required to be of class III or of grade E / EH or FH are to have breadths not less than $800 + 5 \cdot \mathbf{L}$ [mm], maximum 1 800 mm.

Plating materials for stern frames, rudder horns, rudders and shaft brackets are not to be of lower grades than those corresponding to the material classes given in B.2.3.

(IACS UR S6.2)

B.2.4.5 The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation, see Fig. 2.1 The following definitions apply:

- Mean: statistical mean over an observation period of at least 20 years
- Average: average during one day and night
- Lowest: lowest during year

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

(IACS UR S6.3)

B.3 Structural members which are stressed in direction of their thickness

In case of high local stresses in the thickness direction, e.g. due to shrinkage stresses in single bevel or double bevel T-joints with a large volume of weld metal, steels with guaranteed material properties in the thickness direction according to the GL Rules for Steel and Iron Materials (II-1-2), Section 1, I. are to be used.

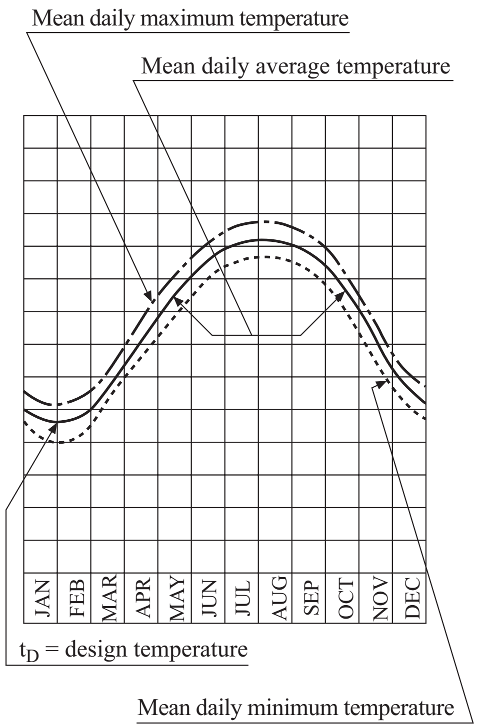


Fig. 2.1 Commonly used definitions of temperatures

C Forged Steel and Cast Steel

Forged steel and cast steel for stem, stern frame, rudder post as well as other structural components, which are subject of this Rule, are to comply with the GL Rules for Metallic Materials (II-1). The tensile strength of forged steel and of cast steel is not to be less than $400\ N/mm^2$. While selecting forged steel and cast steel toughness requirements and weldability are to be considered beside the strength properties.

D Aluminium Alloys

D.1 Where aluminium alloys, suitable for seawater, as specified in the GL Rules for Materials and Welding (II), are used for the construction of superstructures, deckhouses, hatchway covers and similar parts, the conversion from steel to aluminium scantlings is to be carried out by using the material factor:

$$k_{A\ell} = \frac{635}{R_{p0,2} + R_m}$$

For welded connections the respective values in welded condition are to be taken. Where these figures are not available, the respective values for the soft-annealed condition are to be used.

Method of conversion:

$$W_{A\ell} = W_{St} \cdot k_{A\ell}$$ for the section modulus

$$t_{A\ell} = t_{ST} \cdot \sqrt{k_{A\ell}}$$ for the plate thickness

D.2 The smaller Young's modulus E is to be taken into account when determining the buckling strength of structural elements subjected to compression. This is to be applied accordingly to structural elements for which maximum allowable deflections have to be adhered to.

D.3 The conversion of the scantlings of the main hull structural elements from steel into aluminium alloy is to be specially considered taking into account the smaller Young's modulus E, as compared with steel, and the fatigue strength aspects, specifically those of the welded connections.

E Austenitic Steels

Where austenitic steels are applied having a ratio $R_{p0.2} / R_m \leq 0.5$, after special approval the 1 % proof stress $R_{p1.0}$ may be used for scantling purposes instead of the 0.2 % proof stress $R_{p0.2}$.

Table 2.9 Material classes and grades for structures exposed to low temperatures

Structural member category	Material class	
	Within 0.4 L amidships	**Outside 0.4 L amidships**
Secondary: Deck plating exposed to weather, in general Side plating above BWL [5] Transverse bulkheads above BWL [5]	I	I
Primary: Strength deck plating [1] Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings Longitudinal bulkhead above BWL [5] Top wing tank plating above BWL [5]	II	I
Special: Sheer strake at strength deck [2] Stringer plate in strength deck [2] Deck strake at longitudinal bulkhead [3] Continuous longitudinal hatch coamings [4]	III	II

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 m.

3 In ships with breadth exceeding 70 m at least three deck strakes to be of class III.

4 Not to be less than grade D / DH

5 BWL = ballast water line.

(IACS UR S6 Table 7)

Table 2.10 Material grade requirements for classes I, II and III at low temperature

Class I								
Plate thickness [mm]	t_D		t_D		t_D		t_D	
	– 20 C to – 25 °C		**– 26 °C to – 35 °C**		**– 36 °C to – 45 °C**		**– 46 °C to – 55 °C**	
	normal strength	**higher strength**	**normal strength**	**higher strength**	**normal strength**	**higher strength**	**normal strength**	**higher strength**
$t \leq 10$	A	AH	B	AH	D	DH	D	DH
$10 < t \leq 15$	B	AH	D	DH	D	DH	D	DH
$15 < t \leq 20$	B	AH	D	DH	D	DH	E	EH
$20 < t \leq 25$	D	DH	D	DH	D	DH	E	EH
$25 < t \leq 30$	D	DH	D	DH	E	EH	E	EH
$30 < t \leq 35$	D	DH	D	DH	E	EH	E	EH
$35 < t \leq 45$	D	DH	E	EH	E	EH		FH
$45 < t \leq 50$	E	EH	E	EH		FH		FH

Class II								
Plate thickness [mm]	t_D		t_D		t_D		t_D	
	– 20 C to – 25 °C		**– 26 °C to – 35 °C**		**– 36 °C to – 45 °C**		**– 46 °C to – 55 °C**	
	normal strength	**higher strength**	**normal strength**	**higher strength**	**normal strength**	**higher strength**	**normal strength**	**higher strength**
$t \leq 10$	B	AH	D	DH	D	DH	E	EH
$10 < t \leq 20$	D	DH	D	DH	E	EH	E	EH
$20 < t \leq 30$	D	DH	E	EH	E	EH		FH
$30 < t \leq 40$	E	EH	E	EH		FH		FH
$40 < t \leq 45$	E	EH		FH		FH		
$45 < t \leq 50$	E	EH		FH		FH		

Class III								
Plate thickness [mm]	t_D		t_D		t_D		t_D	
	– 20 C to – 25 °C		**– 26 °C to – 35 °C**		**– 36 °C to – 45 °C**		**– 46 °C to – 55 °C**	
	normal strength	**higher strength**	**normal strength**	**higher strength**	**normal strength**	**higher strength**	**normal strength**	**higher strength**
$t \leq 10$	D	DH	D	DH	E	EH	E	EH
$10 < t \leq 20$	D	DH	E	EH	E	EH		FH
$20 < t \leq 25$	E	EH	E	EH		FH		FH
$25 < t \leq 30$	E	EH	E	EH		FH		FH
$30 < t \leq 35$	E	EH		FH		FH		
$35 < t \leq 40$	E	EH		FH		FH		
$40 < t \leq 50$		FH		FH				

(IACS UR S6 Table 8)

Section 3 Design Principles

A General

A.1 Application

This Section contains definitions and general design criteria for hull structural elements as well as indications concerning structural details.

A.2 References

International conventions and codes

Paragraphs of this section are based on the following international convention(s) and / or code(s):

IACS UR S11 Rev.7

At the end of each relevant paragraph, the corresponding paragraphs of the international convention(s) and / or code(s) are given in brackets.

A.3 Definitions

Unsupported span ℓ

In general the unsupported span ℓ is the true length of stiffenings between their two supporting structural members or else their length including end attachments (brackets).

In case of corrugated bulkhead elements the unsupported span ℓ is their length between bottom or deck and their length between vertical or horizontal girders. Where corrugated bulkhead elements are connected to box type elements of comparatively low rigidity, their depth is to be included into the span ℓ unless otherwise proved by calculations.

Frame spacings and spans

The frame spacings and spans are normally assumed to be measured in a vertical plane parallel to the centreline of the ship. However, if the ship's side deviates more than $10°$ from this plane, the frame distances and spans are to be measured along the side of the ship.

Instead of the true length of curved frames the length of the chord between the supporting points can be selected.

Symbols

k : material factor according Section 2, A.2

W : section modulus $[cm^3]$ of smaller section

t : plate thickness $[mm]$

t_a : "as built" plate thickness $[mm]$

t_K : corrosion addition $[mm]$ according to G

t_n : nominal plate thickness [mm]

$$t_n = t_a - t_K$$

A.4 Fatigue strength

Where a fatigue strength analysis is required or will be carried out for structures or structural details this is to be in accordance with the requirements of Section 20.

A.5 Permissible stresses and required sectional properties

In the following Sections permissible stresses have been stated in addition to the formulae for calculating the section moduli and cross sectional areas of webs of frames, beams, girders, stiffeners etc. and may be used when determining the scantlings of those elements by means of direct strength calculations.

B Structural Members

B.1 Upper and lower hull flange

B.1.1 All continuous longitudinal structural members up to z_o below the strength deck at side and up to z_u above base line are considered to be the upper and lower hull flange respectively.

B.1.2 Where the upper and/or the lower hull flange are made from normal strength hull structural steel their vertical extent $z_o = z_u$ equals $0.1 \cdot \mathbf{H}$.

On ships with continuous longitudinal structural members above the strength deck a fictitious depth $H' = e_B + e'_D$ is to be applied.

e_B : distance [m] between neutral axis of the midship section and base line

e'_D : distance [m] from neutral axis of hull section to fictitious top of deck section according to Section 5, E.1.1.1

B.1.3 The vertical extent z of the upper and lower hull flange respectively made from higher tensile steel of one quality is not to be less than determined by the following formula:

$$z = e \cdot (1 - n \cdot k)$$

e : distance of deck at side or of the base line from the neutral axis of the midship section. For ships with continuous longitudinal structural members above the strength deck, see Section 5, E.1.1.1

n : ratio of section moduli, defined as:

$$n = \frac{W_{(a)}}{W}$$

$W_{(a)}$: actual deck or bottom section modulus

W : rule deck or bottom section modulus

Where two different steel grades are used it has to be observed that at no point the stresses are higher than the permissible stresses according to Section 5, E.1.2.1.

B.2 Plating

B.2.1 Tapering

In general in case of different thicknesses of adjacent plates the plate thicknesses are to be tapered gradually.

B.2.2 Plates subjected to lateral pressure

The formulae for plate panels subjected to lateral pressure as given in the following Sections are based on the assumption of an uncurved plate panel having an aspect ratio $b / a \geq 2.24$.

For curved plate panels and/or plate panels having aspect ratios smaller than $b / a \approx 2.24$, the thickness may be reduced as follows:

$$t = C \cdot a \cdot \sqrt{p \cdot k} \cdot f_1 \cdot f_2 + t_K \quad [mm]$$

C : constant, e.g. $C = 1.1$ for tank plating

p : applicable design load

f_1 : curvature factor, defined as:

$$f_1 = 1 - \frac{a}{2 \cdot r} \qquad \text{with } f_1 \geq 0.75$$

f_2 : aspect ratio factor, defined as:

$$f_2 = \sqrt{1.1 - 0.5 \cdot \left(\frac{a}{b}\right)^2} \qquad \text{with } f_2 \leq 1.0$$

a : smaller breadth of plate panel

b : larger breadth of plate panel

r : radius of curvature

The above does not apply to plate panels subjected to ice pressure according to Section 15 and to longitudinally framed shell plating according to Section 6.

B.2.3 Plates at sniped ends of stiffeners

If a stiffener with a sniped end is attached to plate, the minimum thickness t of the plate is to be determined by the following formula:

$$t = c \cdot \sqrt{\frac{p \cdot a \cdot (\ell - 0.5 \cdot a)}{R_{eH}}} \quad [mm]$$

c : coefficient , defined as:

$c = 15.8$	for watertight bulkheads and for tank bulkheads when loaded by p_{T2} as defined in Section 4, D.1.2
$c = 19.6$	otherwise

p : design load $[kN / m^2]$

a : spacing of stiffeners $[m]$

ℓ : unsupported span of stiffener $[m]$

B.3 Stiffener and primary supporting members

B.3.1 Required sectional properties

B.3.1.1 The required section moduli and web areas are related on principle to an axis which is parallel to the connected plating.

B.3.1.2 For profiles usual in the trade and connected vertically to the plating in general the appertaining sectional properties are given in tables.

B.3.1.3 Where webs of stiffeners and girders are not fitted vertically to the plating (e.g. frames on the shell in the flaring fore body) the sectional properties (moment of inertia, section modulus and shear area) have to be determined for an axis which is parallel to the plating.

B.3.1.4 For bulb profiles and flat bars the section modulus of the inclined profile including plating can be calculated simply by multiplying the corresponding value for the vertically arranged profile by $\sin\alpha$ where α is the smaller angle between web and attached plating.

Note

For bulb profiles and flat bars α in general needs only be taken into account where α is less than 75 °.

B.3.1.5 Furthermore, with asymmetric profiles where additional stresses occur according to B.3.7 the required section modulus is to be increased by the factor k_{sp} depending on the type of profile, see B.3.7.

B.3.2 Stiffeners loaded by lateral pressure

If stiffened plate panels are loaded by lateral pressure, the load is transmitted partly direct and partly by the stiffeners to the girders. The factor m_a takes into account the corresponding load distribution on stiffeners and is to be determined by the following formula:

$$m_a = 0.204 \cdot \frac{\mathbf{a}}{\ell} \cdot \left[4 - \left(\frac{\mathbf{a}}{\ell}\right)^2\right] \qquad \text{with } \frac{\mathbf{a}}{\ell} \le 1$$

B.3.3 Unsupported span ℓ

B.3.3.1 Stiffeners and frames

The factor m_{k1} takes into account shortening of the unsupported span ℓ due to brackets and heel stiffeners and is to be determined by the following formula:

$$m_{k1} = 1 - \frac{\ell_{KI} + \ell_{KJ}}{10^3 \cdot \ell}$$

ℓ_{KI}, ℓ_{KJ} : effective supporting length [mm] due to heel stiffeners and brackets at frame I and J (see Fig. 3.1)

$$\ell_{KI}, \ell_{KJ} = \min\left[h_s + 0.3 \cdot h_b + \frac{1}{c_1} \; ; \; \ell_b + h_s\right]$$

c_1 : coefficient [1 / mm], defined as:

$$\frac{1}{c_1} = \frac{1}{\dfrac{1}{\ell_b - 0.3 \cdot h_b} + \dfrac{c_2(\ell_b - 0.3 \cdot h_b)}{h_e^2}} \qquad \text{for } \ell_b > 0.3 \cdot h_b$$

$$\frac{1}{c_1} = 0 \qquad \text{for } \ell_b \le 0.3 \cdot h_b$$

h_s : height of the heel stiffener [mm] (see also Fig. 3.1)

ℓ_b, h_b : dimensions of the brackets [mm] (see also Fig. 3.1)

h_e : height of bracket [mm] in the distance of $h_s + 0.3 \cdot h_b$ of frame I or J respectively (see also Fig. 3.1)

c_1 : coefficient, defined as:

$c_2 = 3$ general

$c_2 = 1$ for flanged brackets (see Fig. 3.1)

If no heel stiffeners or brackets are arranged the respective values are to be taken as $(h_s, h_b, 1 / c_1) = 0$ (see Fig. 3.1).

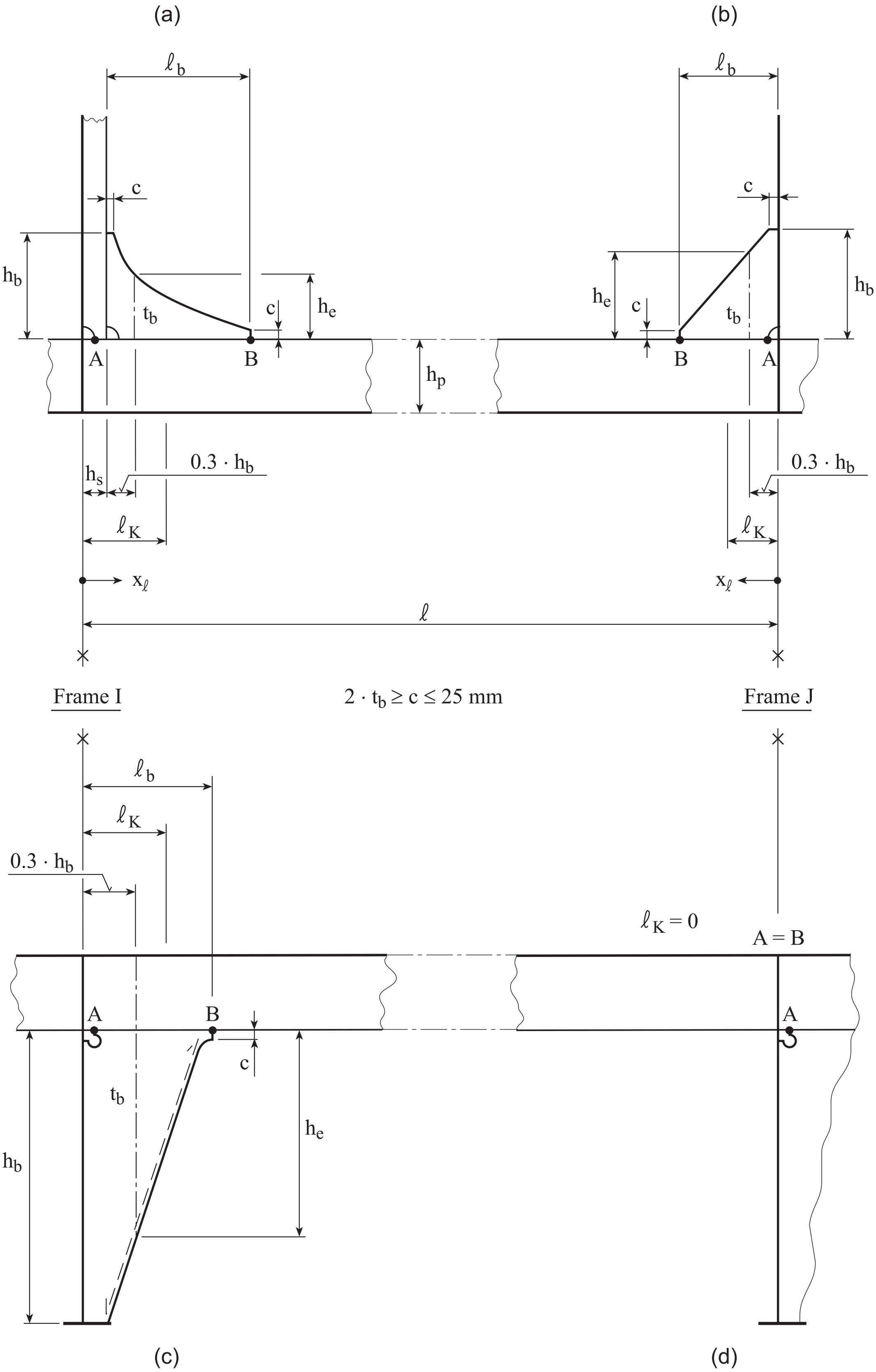


Fig. 3.1 End attachment of stiffeners and frames

B.3.3.2 Transverses and girders

The factor m_{k2} takes into account shortening of the unsupported span ℓ of transverses and girders due to end attachments and is to be determined by the following formula:

$$m_{k2} = \frac{a + b}{4}$$

a, b : length's according to Fig. 3.2, depending on the type of end attachment

In special cases, the rigidity of the adjoining girders is to be taken into account when determining the span of girder.

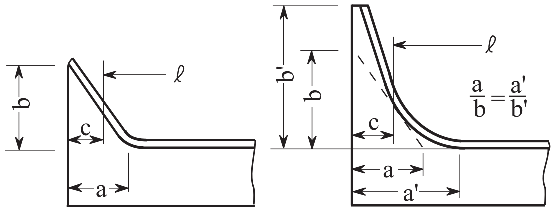


Fig. 3.2 End attachment of transverses and girders

B.3.3.3 Main frames

The factor m_{k3} takes into account shortening of the unsupported length ℓ of main frames due to end attachments and is to be determined by the following formula:

$$m_{k3} = 1.0 - \left(\frac{\ell_{Ku}}{\ell} + 0.4 \cdot \frac{\ell_{Ko}}{\ell} \right) \qquad \text{with } m_{k3} \geq 0.6$$

ℓ_{Ku}, ℓ_{Ko} : length of lower/upper bracket connection of main frames within the length ℓ [m], see Fig. 3.3

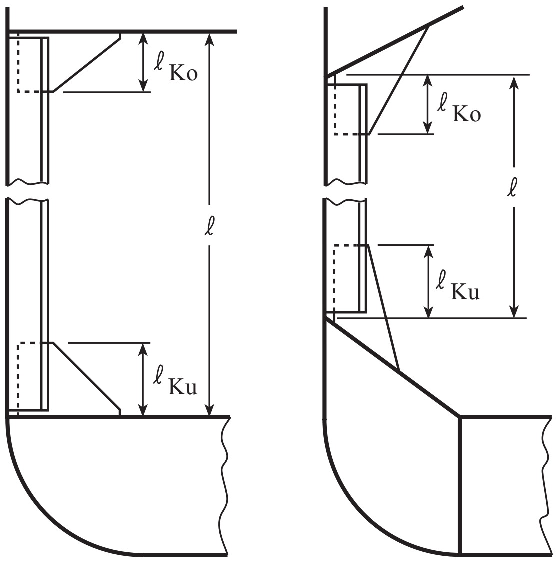


Fig. 3.3 End attachment of main frames

B.3.4 Curved frames

The capacity of a frame subjected to lateral pressure depends among others parameters on its curvature, if excisting.

The factor m_c to takes into account the influnece of a curvature and is to be determined by the following formula:

$$m_c = 1.0 - 2 \cdot \frac{s}{\ell} \qquad \text{with } c_r \geq 0.75$$

s : maximum height of curve [m]

B.3.5 End attachments

B.3.5.1 Definitions

For determining scantlings of beams, stiffeners and girders the terms "constraint" and "simple support" will be used.

"Constraint" will be assumed where the stiffeners are rigidly connected to other members by means of brackets or are running throughout over supporting girders.

"Simple support" will be assumed where the stiffener ends are sniped or the stiffeners are connected to plating only, see also B.2.3.

B.3.5.2 Brackets

B.3.5.2.1 For the scantlings of brackets the required section modulus of the section is decisive. Where sections of different section moduli are connected to each other, the scantlings of the brackets are generally governed by the smaller section.

B.3.5.2.2 The thickness t of brackets is to be determined by the following formula:

$$t = c \cdot \sqrt[3]{\frac{W}{k_1}} + t_K \quad [\text{mm}]$$

with $5.0 + t_k \leq t \leq$ web thickness of smaller section

c : coefficient $[1/\text{mm}]$, defined as:

$c = 1.20$ for non-flanged brackets

$c = 0.95$ for flanged brackets

k_1 : material factor k for the section, according to Section 2, A.2

For minimum thicknesses in tanks and in cargo holds of bulk carriers see Section 12, B.1.3, Section 23, C.4.3 and Section 24, G.1.

B.3.5.2.3 The arm length ℓ_b of brackets is to be determined by the following formula:

$$\ell_b = 46.2 \cdot \sqrt[3]{\frac{W}{k_1}} \cdot \sqrt{k_2} \cdot c_t \quad [\text{mm}]$$

with $\ell_b \geq \ell_{b,min}$

$\ell_{b,min}$: minimum arm length [mm], defined as:

$\ell_{b,min} = 100 \text{ mm}$

k_1 : material factor k for the section, according to Section 2, A.2

k_2 : material factor k for the bracket, according to Section 2, A.2

c_t : coefficient, defined as:

$$c_t = \sqrt{\frac{t}{t_a}}$$

t_a : "as built" thickness of bracket $[\text{mm}]$, with:

$t_a \geq t$ according to B.3.5.2.2

The arm length ℓ_b is the length of the welded connection.

Note

For deviating arm length the thickness of brackets is to be estimated by direct calculations considering sufficient safety against buckling.

B.3.5.2.4 The throat thickness a of the welded connection is to be determined according to Section 19, C.2.7.

B.3.5.2.5 Where flanged brackets are used the width of flange is to be determined by the following formula:

$$b = 40 + \frac{W}{30} \quad [\text{mm}] \qquad \text{with } 50 \text{ mm} \le b \le 90 \text{ mm}$$

B.3.6 Longitudinals and longitudinal beams in way of curved plates

In way of curved plates (e.g. in the bilge area) the requirements regarding scantlings of longitudinals and longitudinal beams may be reduced by the following factor c_R:

$$c_R = \frac{1}{1 + \dfrac{\mathbf{a} \cdot \ell^4 \cdot t}{0.006 \cdot I_a \cdot R^2}}$$

t : thickness [mm] of shell plating

I_a : moment of inertia [cm^4] of the longitudinal frame, including effective breadth

R : bending radius [m] of the plate

In way of straight plates the factor c_R is to be set to zero.

B.3.7 Asymmetric sections / profiles

B.3.7.1 Additional stresses for fatigue strength analysis

The additional stress σ_h occurring in asymmetric sections may be determined by the following formula:

$$\sigma_h = \frac{Q \cdot \ell_f \cdot t_f}{c \cdot W_y \cdot W_z} \cdot \left(b_1^2 - b_2^2\right) \quad [\text{N/mm}^2]$$

Q : load [kN] on section parallel to its web within the unsupported span ℓ_f, defined as:

$Q = p \cdot \mathbf{a} \cdot \ell_f$ [kN] in case of uniformly distributed load p [kN/m^2]

ℓ_f : unsupported span [m] of flange

t_f, b_1, b_2 : flange dimensions [mm] as shown in Fig. 3.4, with:

$b_1 \ge b_2$

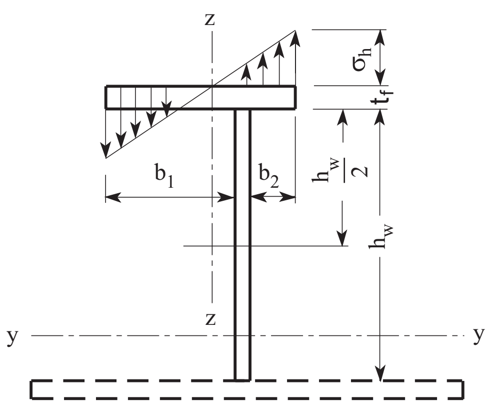


Fig. 3.4 Asymmetric profiles

c : factor depending on kind of load, stiffness of the section's web and length and kind of support of the profile.

For profiles clamped at both ends and constant area load $c = 80$ can be taken for approximation. A precise calculation may be required, e.g. for longitudinal frames.

W_y : section modulus $[cm^3]$ of section related to the y-y axis including the effective breadth of plating

W_z : section modulus $[cm^3]$ of the partial section consisting of flange and half of web area related to the z-z axis, (bulb sections may be converted into a similar L-section)

This additional stress σ_h is to be added directly to other stresses such as those resulting from local and hull girder bending.

B.3.7.2 Correction of section modulus

In case of asymmetric sections the required section modulus is to be multiplied with the factor k_{sp} according to Table 3.1.

Table 3.1 Increase factor k_{sp}

Type of Profile	k_{sp}
Flat bars and symmetric T-profiles	1.00
Bulb profiles	1.03
Asymmetric T-profiles with $\frac{b_2}{b_1} \approx 0.5$	1.05
Rolled angles (L-profiles)	1.15

B.3.8 Additional stresses due to local bending of stiffeners

B.3.8.1 Additional stresses for fatigue strength analysis

For fatigue strength calculations according to Section 20, Table 20.1 bending stresses due to local stiffener bending and longitudinal normal stresses due to global hull girder bending are to be combined. Bending stresses at the points A and B (see Fig. 3.1) from local stiffener bending due to lateral loads p can be determined by the following formulae:

$$\sigma_A = \frac{83}{W_a} \cdot \left(m_{k1}^2 - m_a^2\right) \cdot \mathbf{a} \cdot \ell \cdot p + \sigma_h \quad [N/mm^2] \qquad \text{for } 0 \le x_\ell \le \ell_k \text{ with } \left(m_{k1}^2 - m_a^2\right) \ge \frac{m_{k1}^2}{2}$$

$$\sigma_B = c_R \cdot \sigma_A \cdot m_l \quad [N/mm^2] \qquad \text{for } x_\ell = h_s + \ell_b$$

W_a : section modulus $[cm^3]$ of the profile including effective plate width according to D.3.2

m_{k1} : factor to take a shortened unsupported span into account according to B.3.3

m_a : factor to take the load distribution into account according to B.3.2

p : design pressure $[kN/m^2]$

σ_h : additional stress occurring in asymmetric sections according to B.3.7.1

x_ℓ : distance $[mm]$ from transverse structure at I and J respectively, see Fig. 3.1

ℓ_k : effective supporting length $[mm]$ due to heel stiffeners and brackets according to B.3.3.1

c_R : factor to take curved plates (e.g. in the bilge area) inn way of longitudinals and longitudinal beams into account, according to B.3.6

m_l : factor, defined as:

$$m_l = 1 - 4 \cdot c_3 \cdot \left[1 - 0.75 \cdot c_3\right]$$

c_3 : factor, defined as:

$$c_3 = \frac{h_{sI} + \ell_{bI} - \ell_{kI}}{\ell \cdot m_{k,1} \cdot 10^3}$$ for position B at I

$$c_3 = \frac{h_{sJ} + \ell_{bJ} - \ell_{KJ}}{\ell \cdot m_{k,1} \cdot 10^3}$$ for position B at J

The stresses at point A is not to be less than the stresses in adjacent fields (aft of frame I and forward of frame J respectively).

B.3.8.2 Additional stresses in longitudinals between transverse bulkheads and side transverses

Where necessary, for longitudinals between transverse bulkheads and side transverses additional stresses resulting from the deformation of the side transverses are to be taken into account.

If no special verification of stresses due to web frame deformations is carried out, the following minimum values are to be considered for fatigue strength verification of side longitudinals:

$$\sigma_{DF} = \pm 0.1 \cdot \frac{h_w}{\ell - \Sigma \ell_b} \cdot \left[\frac{\ell_R}{DF} \cdot C_p \cdot (1 - C_p)\right]^2 \quad [N/mm^2]$$

h_w : web height [mm] of profile i (see Fig. 3.7)

$\Sigma\ell_b$: sum of supporting lengths of heel stiffeners and brackets (see Fig. 3.1), defined as:

$$\Sigma \ell_b = \left(h_{sI} + l_{bI} + h_{sJ} + l_{bJ}\right) \cdot 10^{-3} \quad [m]$$

ℓ_R : unsupported web frame length [m] (see Fig. 3.5)

DF : height [m] of web frame (see Fig. 3.5)

C_p : weighting factor regarding location of the profile, defined as:

$$C_p = \frac{(z - z_{Ro}) / \ell_R + C_T}{1 + 2 \cdot C_T}$$

z_{Ro} : z-coordinate [m] of web frame outset above basis (see Fig. 3.5), $z_{Ro} < \mathbf{T}$

C_T : correction regarding location of the profile i to the water line, defined as:

$$C_T = 1.1 - \frac{z}{T}$$ with $0 \le C_T \le 0.1$

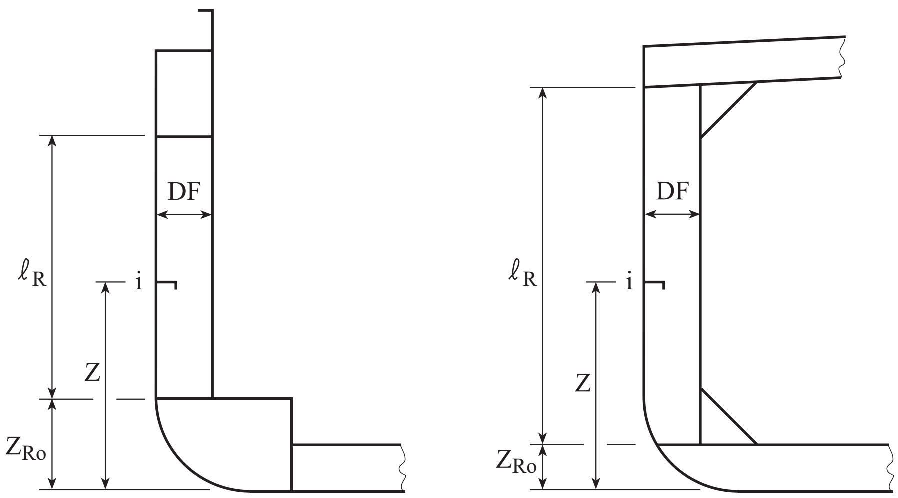


Fig. 3.5 Definitions

B.4 Corrugated bulkhead elements

B.4.1 End attachment

Care is to be taken that the forces acting at the supports of corrugated bulkheads are properly transmitted into the adjacent structure by fitting structural elements such as carlings, girders or floors in line with the corrugations.

Note

Where carlings or similar elements cannot be fitted in line with the web strips of corrugated bulkhead elements, these web strips cannot be included into the section modulus at the support point for transmitting the moment of constraint.

Deviating from the formula stipulated in Section 11, F.3 the section modulus of a corrugated element is then to be determined by the following formula:

$$W = t \cdot b \cdot (d + t) \quad [cm^3]$$

C Effective Breadth of Plating

C.1 Frames and stiffeners

Generally, the spacing of frames and stiffeners may be taken as effective breadth of plating.

C.2 Girders

C.2.1 The effective breadth of plating e_m of frames and girders may be determined according to Table 3.2 considering the type of loading.

Special calculations may be required for determining the effective breadth of one-sided or non-symmetrical flanges.

In Table 3.2 following definitions are used:

e : width of plating supported, measured from centre to centre of the adjacent unsupported fields

e_m : effective breadth of plating, defined as:

$e_m = e_{m1}$ for girders which loaded by uniformly distributed loads or else by not less than 6 equally spaced single loads.

$e_m = e_{m2}$ for girders which are loaded by 3 or less single loads.

ℓ : length between zero-points of bending moment curve, i.e. unsupported span in case of simply supported girders and 0.6 x unsupported span in case of constraint of both ends of girder

C.2.2 The effective cross sectional area of plates is not to be less than the cross sectional area of the face plate.

Table 3.2 Effective breadth e_m of frames and girders

ℓ / e	0	1	2	3	4	5	6	7	≥ 8
e_{m1} / e	0	0.36	0.64	0.82	0.91	0.96	0.98	1.00	1.00
e_{m2} / e	0	0.20	0.37	0.52	0.65	0.75	0.84	0.89	0.90
Intermediate values may be obtained by direct interpolation.									

C.2.3 The effective width of stiffeners and girders subjected to compressive stresses may be determined according to D.3.2, but is in no case to be taken greater than the effective breadth determined by C.2.1.

C.3 Cantilevers

Where cantilevers are fitted at every frame, the effective breadth of plating may be taken as the frame spacing. Where cantilevers are fitted at a greater spacing the effective breadth of plating at the respective cross section may approximately be taken as the distance of the cross section from the point on which the load is acting, however, not greater than the spacing of the cantilevers.

D Proof of Buckling Strength

The calculation method is based on DIN-standard 18 800.

D.1 Application

D.1.1 All structural members which are subjected to compressive and/or shear stresses are to be examined for sufficient resistance to buckling. For this purpose the design stresses according to Section 5, D.2 and the stresses due to local loads are to be considered.

D.1.2 For structural members contributing to the longitudinal strength see also Section 5, E.4.

D.2 Definitions

a : length $[mm]$ of single or partial plate field

b : breadth $[mm]$ of single plate field

K : buckling factor according to Table 3.5 and Table 3.6

F_1 : correction factor for boundary condition at the longitudinal stiffeners, defined as:

$F_1 = 1.00$	for stiffeners sniped at both ends

Guidance values where both ends are effectively connected to adjacent structures:

$F_1 = 1.05$	for flat bars
$F_1 = 1.10$	for bulb sections
$F_1 = 1.20$	for angle and tee-sections
$F_1 = 1.30$	for girders of high rigidity (e.g. bottom transverses)

Exact values may be determined by direct calculations

n : number of single plate field breadths b within the partial or total plate field

S : safety factor, defined as:

$S = 1.10$	in general
$S = 1.20$	for structures which are exclusively exposed to local loads
$S = 1.05$	for combinations of statistically independent loads

For constructions of aluminium alloys the safety factors are to be increased in each case by 0.1.

α : aspect ratio of single plate field, defined as:

$$\alpha = \frac{a}{b}$$

λ : reference degree of slenderness, defined as:

$$\lambda = \sqrt{\frac{R_{eH}}{K \cdot \sigma_e}}$$

σ_e : reference stress $[N / mm^2]$, defined as

$$\sigma_e = 0.9 \cdot E \cdot \left(\frac{t_n}{b}\right)^2$$

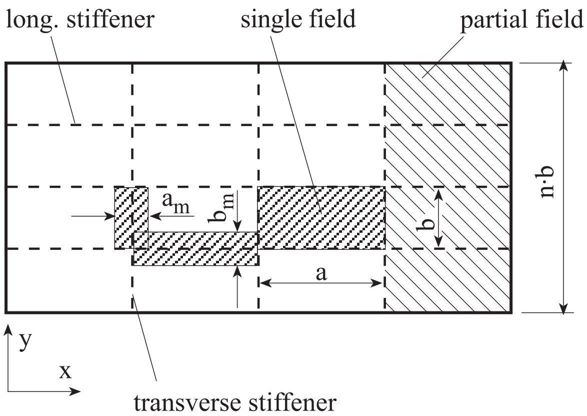
σ_x : membrane stress $[N / mm^2]$ in x-direction

σ_y : membrane stress $[N / mm^2]$ in y-direction

τ : shear stress $[N / mm^2]$ in the x-y plane

Compressive and shear stresses are to be taken positive, tension stresses are to be taken negative.

ψ : edge stress ratio according to Table 3.5



longitudinal : stiffener in the direction of the length a
transverse : stiffener in the direction of the breath b

Fig. 3.6 Definition of plate fields subject to buckling

Note

If the stresses σ_x^* und σ_y^* in the x- and y-direction contain already the Poisson effect, the modified stress values σ_x und σ_y according Table 3.3 may be used for the proof of buckling strength.

Table 3.3 Poisson effect correction

Both σ_x^* and σ_y^* are to be compressive stresses			***At least σ_x^* or σ_y^* is tension stress***
$\sigma_x^* \geq 0.3 \cdot \sigma_y^*$ or $\sigma_y^* \geq 0.3 \cdot \sigma_x^*$	***$\sigma_x^* < 0.3 \cdot \sigma_y$***	***$\sigma_y^* < 0.3 \cdot \sigma_x^*$***	
$\sigma_x = \left(\sigma_x^* - 0.3 \cdot \sigma_y^*\right) / 0.91$	$\sigma_x = 0$	$\sigma_x = \sigma_x^*$	$\sigma_x = \sigma_x^*$
$\sigma_y = \left(\sigma_y^* - 0.3 \cdot \sigma_x^*\right) / 0.91$	$\sigma_y = \sigma_y^*$	$\sigma_y = 0$	$\sigma_y = \sigma_y^*$

D.3 Proof of single plate fields

D.3.1 Proof is to be provided that the following condition is complied with for the single plate field $a \cdot b$:

$$\left(\frac{|\sigma_x| \cdot S}{\kappa_x \cdot R_{eH}}\right)^{e1} + \left(\frac{|\sigma_y| \cdot S}{\kappa_y \cdot R_{eH}}\right)^{e2} - B \cdot \left(\frac{\sigma_x \cdot \sigma_y \cdot S^2}{R_{eH}^2}\right) + \left(\frac{|\tau| \cdot S \cdot \sqrt{3}}{\kappa_\tau \cdot R_{eH}}\right)^{e3} \le 1.0$$

Each term of the above condition is not to exceed 1.0.

κ_x : reduction factor, defined as:

$\kappa_x =$ acc. to Table 3.5 and / or Table 3.6 for $\sigma_x > 0$

$\kappa_x = 1.0$ for $\sigma_x \le 0$

κ_y : reduction factor, defined as:

$\kappa_y =$ acc. to Table 3.5 and / or Table 3.6 for $\sigma_y > 0$

$\kappa_y = 1.0$ for $\sigma_y \le 0$

κ_τ : reduction factor according to Table 3.5 and / or Table 3.6

e_1, e_2, e_3 : exponents according to Table 3.4

B : factor as according to Table 3.4

Table 3.4 Exponents e_1 - e_3 and factor B

Exponents $e_1 - e_3$ and factor B		plate field	
		plane	curved
e_1		$1 + \kappa_x^4$	1.25
e_2		$1 + \kappa_y^4$	1.25
e_3		$1 + \kappa_x \cdot \kappa_y \cdot \kappa_\tau^2$	2.00
B	σ_x and σ_y positive (compression stress)	$(\kappa_x \cdot \kappa_y)^5$	0
	σ_x or σ_y negative (tension stress)	1.00	-

D.3.2 **Effective width of plating**

The effective width of plating may be determined by the following formulae:

$b_m = \kappa_x \cdot b$ for longitudinal stiffeners

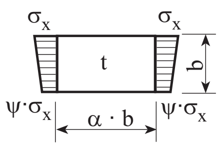
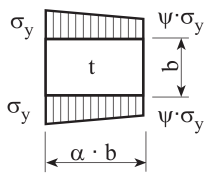
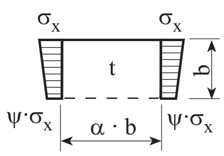
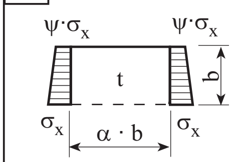
$a_m = \kappa_y \cdot a$ for transverse stiffeners

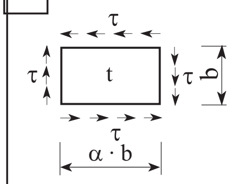
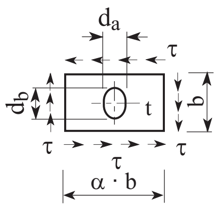
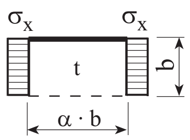
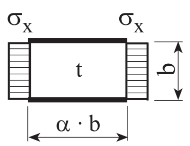
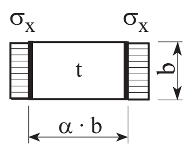
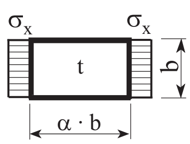
See also Fig. 3.6.

The effective width of plating is not to be taken greater than the effective breadth e_m obtained from C.2.1.

D.3.3 In general, the ratio plate field breadth to plate thickness is not to exceed $b / t = 100$.

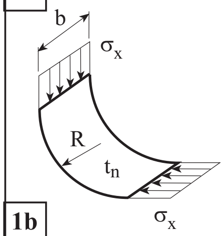
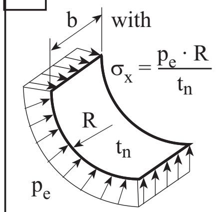
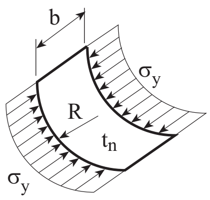
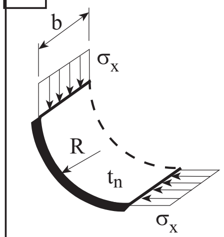
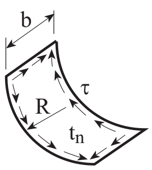
Table 3.5 Plane plate fields

Load case	Edge stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor κ
1 	$1 \geq \psi \geq 0$	$\alpha > 1$	$K = \dfrac{8.4}{\psi + 1.1}$	$\kappa_x = 1$ for $\lambda \leq \lambda_c$ $\kappa_x = c\left(\dfrac{1}{\lambda} - \dfrac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$ $c = (1.25 - 0.12\psi) \leq 1.25$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0.88}{c}}\right)$
	$0 > \psi > -1$		$K = 7.63 - \psi\,(6.26 - 10\,\psi)$	
	$\psi \leq -1$		$K = (1 - \psi)^2 \cdot 5.975$	
2 	$1 \geq \psi \geq 0$	$\alpha \geq 1$	$K = F_1\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2.1}{(\psi + 1.1)}$	$\kappa_y = c\left(\dfrac{1}{\lambda} - \dfrac{R + F^2\,(H - R)}{\lambda^2}\right)$ $c = (1.25 - 0.12\psi) \leq 1.25$ $R = \lambda\left(1 - \dfrac{\lambda}{c}\right)$ for $\lambda < \lambda_c$ $R = 0.22$ for $\lambda \geq \lambda_c$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0.88}{c}}\right)$ $F = \left(1 - \dfrac{\dfrac{K}{0.91} - 1}{\lambda_p^2}\right) c_1 \geq 0$ $\lambda_p^2 = \lambda^2 - 0.5 \qquad 1 \leq \lambda_p^2 \leq 3$ $c_1 = 1$ for σ_y due to direct loads $c_1 = \left(1 - \dfrac{F_1}{\alpha}\right) \geq 0$ for σ_y due to bending (in general) $c_1 = 0$ for σ_y due to bending in extreme load cases (e. g. w. t. bulkheads) $H = \lambda - \dfrac{2\lambda}{c\,(T + \sqrt{T^2 - 4})} \geq R$ $T = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$
	$0 > \psi > -1$	$1 \leq \alpha \leq 1.5$	$K = F_1\left[\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2.1\,(1+\psi)}{1.1} - \dfrac{\psi}{\alpha^2}\,(13.9 - 10\,\psi)\right]$	
		$\alpha > 1.5$	$K = F_1\left[\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2.1\,(1+\psi)}{1.1} - \dfrac{\psi}{\alpha^2}\left(5.87 + 1.87\,\alpha^2 + \dfrac{8.6}{\alpha^2} - 10\,\psi\right)\right]$	
	$\psi \leq -1$	$1 \leq \alpha \leq \dfrac{3\,(1-\psi)}{4}$	$K = F_1\left(\dfrac{1 - \psi}{\alpha}\right)^2 5.975$	
		$\alpha > \dfrac{3\,(1-\psi)}{4}$	$K = F_1\left[\left(\dfrac{1 - \psi}{\alpha}\right)^2 3.9675 + 0.5375\left(\dfrac{1 - \psi}{\alpha}\right)^4 + 1.87\right]$	
3 	$1 \geq \psi \geq 0$	$\alpha > 0$	$K = \dfrac{4\,(0.425 + 1/\alpha^2)}{3\,\psi + 1}$	$\kappa_x = 1$ for $\lambda \leq 0.7$ $\kappa_x = \dfrac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$
	$0 > \psi \geq -1$		$K = 4\left(0.425 + \dfrac{1}{\alpha^2}\right)(1 + \psi) - 5 \cdot \psi\,(1 - 3.42\,\psi)$	
4 	$1 \geq \psi \geq -1$	$\alpha > 0$	$K = \left(0.425 + \dfrac{1}{\alpha^2}\right) \dfrac{3 - \psi}{2}$	

5 	—	$\alpha \geq 1$	$K = K_\tau \cdot \sqrt{3}$ $K_\tau = \left[5.34 + \frac{4}{\alpha^2}\right]$	$\kappa_\tau = 1$ for $\lambda \leq 0.84$ $\kappa_\tau = \frac{0,84}{\lambda}$ for $\lambda > 0.84$
		$0 < \alpha < 1$	$K_\tau = \left[4 + \frac{5.34}{\alpha^2}\right]$	
6 	—		$K = K' \cdot r$ K' = K according to load case 5 r = Reduction factor $r = (1 - \frac{d_a}{a})(1 - \frac{d_b}{b})$ with $\frac{d_a}{a} \leq 0.7$ and $\frac{d_b}{b} \leq 0.7$	
7 	—	$\alpha \geq 1.64$	$K = 1.28$	$\kappa_x = 1$ for $\lambda \leq 0.7$ $\kappa_x = \frac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$
		$\alpha < 1.64$	$K = \frac{1}{\alpha^2} + 0.56 + 0.13\,\alpha^2$	
8 	—	$\alpha \geq \frac{2}{3}$	$K = 6.97$	$\kappa_x = 1$ for $\lambda \leq 0.83$ $\kappa_x = 1.13\left[\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right]$ for $\lambda > 0.83$
		$\alpha < \frac{2}{3}$	$K = \frac{1}{\alpha^2} + 2.5 + 5\,\alpha^2$	
9 	—	$\alpha \geq 4$	$K = 4$	
		$4 > \alpha > 1$	$K = 4 + \left[\frac{4-\alpha}{3}\right]^4 2.74$	
		$\alpha \leq 1$	$K = \frac{4}{\alpha^2} + 2.07 + 0.67\,\alpha^2$	
10 	—	$\alpha \geq 4$	$K = 6.97$	
		$4 > \alpha > 1$	$K = 6.97 + \left[\frac{4-\alpha}{3}\right]^4 3.1$	
		$\alpha \leq 1$	$K = \frac{4}{\alpha^2} + 2.07 + 4\,\alpha^2$	

Explanations for boundary conditions
- - - - - - plate edge free
——— plate edge simply supported
━━━ plate edge clamped

Table 3.6 Curved plate field $R / t \le 2500$[1]

Load case	Aspect ratio b / R	Buckling factor K	Reduction factor κ
1a 	$\frac{b}{R} \le 1.63\sqrt{\frac{R}{t_n}}$	$K = \frac{b}{\sqrt{R \cdot t_n}} + 3\frac{(R \cdot t_n)^{0.175}}{b^{0.35}}$	$\kappa_x = 1$ [2] for $\lambda \le 0.4$ $\kappa_x = 1.274 - 0.686\,\lambda$ for $0.4 < \lambda \le 1.2$ $\kappa_x = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
1b with $\sigma_x = \frac{p_e \cdot R}{t_n}$  p_e = external pressure in [N/mm²]	$\frac{b}{R} > 1.63\sqrt{\frac{R}{t_n}}$	n $K = 0.3\frac{b^2}{R^2} + 2.25\left(\frac{R^2}{b \cdot t_n}\right)^2$	
2 	$\frac{b}{R} \le 0.5\sqrt{\frac{R}{t_n}}$	$K = 1 + \frac{2}{3}\frac{b^2}{R \cdot t_n}$	$\kappa_y = 1$ [2] for $\lambda \le 0.25$ $\kappa_y = 1.233 - 0.933\,\lambda$ for $0.25 < \lambda \le 1$ $\kappa_y = 0.3 / \lambda^3$ for $1 < \lambda \le 1.5$ $\kappa_y = 0.2 / \lambda^2$ for $\lambda > 1.5$
	$\frac{b}{R} > 0.5\sqrt{\frac{R}{t_n}}$	$K = 0.267\frac{b^2}{R \cdot t_n}\left[3 - \frac{b}{R}\sqrt{\frac{t_n}{R}}\right]$ $\ge 0.4\frac{b^2}{R \cdot t_n}$	
3 	$\frac{b}{R} \le \sqrt{\frac{R}{t_n}}$	$K = \frac{0.6 \cdot b}{\sqrt{R \cdot t_n}} + \frac{\sqrt{R \cdot t_n}}{b} - 0.3\frac{R \cdot t_n}{b^2}$	as in load case 1a
	$\frac{b}{R} > \sqrt{\frac{R}{t_n}}$	$K = 0{,}3\frac{b^2}{R^2} + 0.291\left(\frac{R^2}{b \cdot t_n}\right)^2$	
4 	$\frac{b}{R} \le 8.7\sqrt{\frac{R}{t_n}}$	$K = K_\tau \cdot \sqrt{3}$ $K_\tau = \left[28.3 + \frac{0.67 \cdot b^3}{R^{1.5} \cdot t_n^{1.5}}\right]^{0.5}$	$\kappa_\tau = 1$ for $\lambda \le 0.4$ $\kappa_\tau = 1.274 - 0.686\,\lambda$ for $0.4 < \lambda \le 1.2$ $\kappa_\tau = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
	$\frac{b}{R} > 8.7\sqrt{\frac{R}{t_n}}$	$K_\tau = 0.28\frac{b^2}{R\sqrt{R \cdot t_n}}$	

Explanations for boundary conditions:
- - - - - plate edge free
——— plate edge simply supported
▬▬▬ plate edge clamped

1 For curved plate fields with a very large radius the κ-value need not to be taken less than one derived for the expanded plane field.

2 For curved single fields. e.g. the bilge strake, which are located within plane partial or total fields, the reduction factor κ may taken as follow:

Load case 1b: $\kappa_x = 0.8/\lambda^2 \le 1{,}0$: load case 2: $\kappa_y = 0.65/\lambda^2 \le 1.0$

Note

The effective width e'_m of stiffened flange plates of girders may be determined as follows:

$$e'_m = n_1 \cdot b_m$$ *for stiffening parallel to web of girder*

$$e'_m = n_2 \cdot a_m < e_m$$ *for stiffening perpendicular to web of girder*

with $b < e_m$ and $a \geq e_m$. For $b \geq e_m$ or $a < e_m$ respectively, b and a have to be exchanged.

n_1 : *integer number of the stiffener inside the effective breath, defined as:*

$$n_1 = \text{int}\left(\frac{e_m}{b}\right)$$

n_2 : *number, defined as:*

$$n_2 = 2.7 \cdot \frac{e_m}{a}$$ *with* $n_2 \leq 1$

e_m : *effective breadth according to C.2.1*

b : *stiffener spacing, see Fig. 3.7*

a : *spacing of girder, see Fig. 3.7*

a_m : *effective width of plating attached to girder in case stiffening perpendicular to web of girder according to D.3.2*

b_m : *effective width of plating attached to stiffening parallel to web of girder according to D.3.2*

a_m and b_m are in general to be determined for $\psi = 1$.

Stress distribution between two girders:

$$\sigma_x(y) = \sigma_{x1} \cdot \left\{1 - \frac{y}{e} \cdot \left[3 + c_1 - 4 \cdot c_2 - 2 \cdot \frac{y}{e} \cdot (1 + c_1 - 2 \cdot c_2)\right]\right\}$$

σ_{x1}, σ_{x2} : *normal stresses in flange plates of adjacent girder 1 and 2 with spacing e*

c_1, c_2 : *coefficients, defined as:*

$$c_1 = \frac{\sigma_{x2}}{\sigma_{x1}}$$ *with* $0 \leq c_1 \leq 1$

$$c_2 = \frac{1.5}{e} \cdot \left(\frac{e'_{m1}}{e_{m1}} + \frac{e'_{m2}}{e_{m2}}\right) - 0.5$$

y : *distance of considered location from girder 1*

e : *width of plating supported according to C.2.1*

Scantlings of plates and stiffeners are in general to be determined according to the maximum stresses $\sigma_x(y)$ at girder webs and stiffeners respectively. For stiffeners under compression arranged parallel to the girder web with spacing b no lesser value than $0.25 \cdot R_{eH}$ is to be inserted for $\sigma_x(y = b)$.

Shear stress distribution in the flange plates may be assumed linearly.

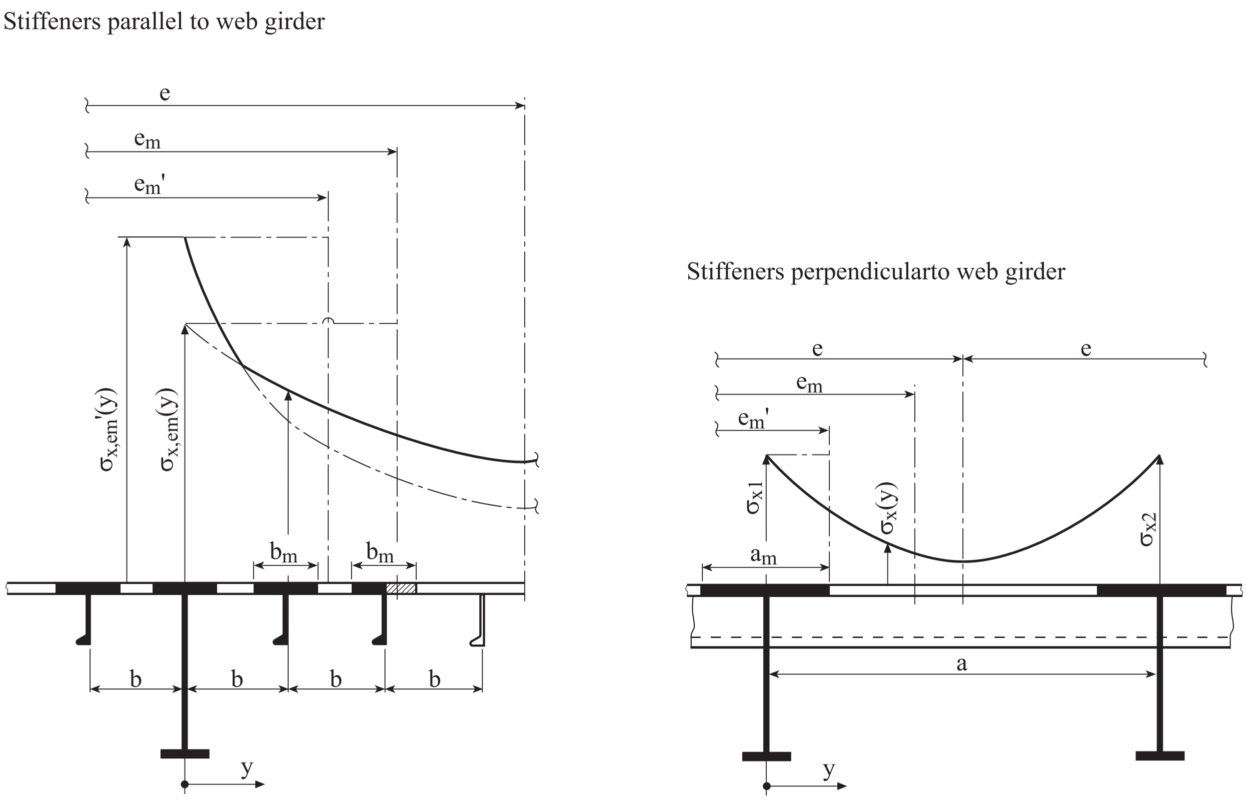


Fig. 3.7 Effective width e'_m of stiffened flange plates of girders

D.3.4 Webs and flanges

For non-stiffened webs and flanges of sections and girders proof of sufficient buckling strength as for single plate fields is to be provided according to D.3.1.

Note

Within $0.6\,\boldsymbol{L}$ amidships the following guidance values are recommended for the ratio web depth to web thickness and/or flange breadth to flange thickness of longitudinals of the upper and lower hull flange:

- *flat bars:*

$$\frac{h_w}{t_w} \le 19.5 \cdot \sqrt{k}$$

- *angle, tee and bulb sections:*

$$\frac{h_w}{t_w} \le 60.0 \cdot \sqrt{k} \qquad \textit{for web}$$

$$\frac{b_i}{t_f} \le 19.5 \cdot \sqrt{k} \qquad \textit{for flange}$$

b_i : b_1 *or* b_2 *according to Fig. 3.7, the larger value is to be taken.*

D.4 Proof of partial and total fields

D.4.1 Longitudinal and transverse stiffeners

Proof is to be provided that the longitudinal and transverse stiffeners of partial and total plate fields comply with the conditions set out in D.4.2 and D.4.3.

D.4.2 Lateral buckling

$$\frac{\sigma_a + \sigma_b}{R_{eH}} \cdot S \le 1.0$$

σ_a : uniformly distributed compressive stress $[N/mm^2]$ in the direction of the stiffener axis, defined as:

$\sigma_a = \sigma_x$ for longitudinal stiffeners

$\sigma_a = \sigma_y$ for transverse stiffeners

σ_b : bending stress $[N/mm^2]$ in the stiffeners, defined as:

$$\sigma_b = \frac{M_o + M_1}{W_{st} \cdot 10^3}$$

M_o : bending moment $[Nmm]$ due to deformation w of stiffener, defined as:

$$M_0 = F_{Ki} \cdot \frac{p_z \cdot w}{c_f - p_z}$$ with $(c_f - p_z) > 0$

M_1 : bending moment $[Nmm]$ due to the lateral load p, defined as:

$$M_1 = \frac{p \cdot b \cdot a^2}{24 \cdot 10^3}$$ for longitudinal stiffeners

$$M_1 = \frac{p \cdot a \cdot (n \cdot b)^2}{c_s \cdot 8 \cdot 10^3}$$ for transverse stiffeners

p : lateral load $[kN/m^2]$ according to Section 4

F_{Ki} : ideal buckling force $[N]$ of the stiffener, defined as:

$$F_{Kix} = \frac{\pi^2}{a^2} \cdot E \cdot I_x \cdot 10^4$$ for longitudinal stiffeners

$$F_{kiy} = \frac{\pi^2}{(n \cdot b)^2} \cdot E \cdot I_y \cdot 10^4$$ for transverse stiffeners

I_x, I_y : moments of inertia $[cm^4]$ of the longitudinal or transverse stiffener including effective width of plating according to D.3.2 with:

$$I_x \ge \frac{b \cdot t_n^3}{12 \cdot 10^4}$$

$$I_y \ge \frac{a \cdot t_n^3}{12 \cdot 10^4}$$

p_z : nominal lateral load $[N/mm^2]$ of the stiffener due to σ_x, σ_y and τ, defined as:

$$p_{zx} = \frac{t_a}{b} \cdot \left(\sigma_{x1} \cdot \left(\frac{\pi \cdot b}{a} \right)^2 + 2 \cdot c_y \cdot \sigma_y + \sqrt{2} \cdot \tau_1 \right)$$ for longitudinal stiffeners

$$p_{zy} = \frac{t_a}{a} \cdot \left(2 \cdot c_x \cdot \sigma_{x1} + \sigma_y \cdot \left(\frac{\pi \cdot a}{n \cdot b} \right)^2 \cdot \left(1 + \frac{A_y}{a \cdot t_a} \right) + \sqrt{2} \cdot \tau_1 \right)$$ for transverse stiffeners

σ_{ax1} : corrected membrane stress in x-direction $[N/mm^2]$

$$\sigma_{x1} = \sigma_x \cdot \left(1 + \frac{A_x}{b \cdot t_a}\right)$$

c_x, c_y : factors taking into account the stresses vertical to the stiffener's axis and distributed variable along the stiffener's length, defined as:

$c_x, c_y = 0.5 \cdot (1 + \psi)$ for $0 \le \psi \le 1$

$c_x, c_y = \dfrac{0.5}{1 - \psi}$ for $\psi < 0$

ψ : edge stress ratio according to Table 3.5

A_x, A_y : sectional areas [mm^2] of the longitudinal or transverse stiffener respectively

τ_1 : corrected shear stress $[N / mm^2]$ in the x-y plane, defined as:

$\tau_1 = \tau - t_n \cdot \sqrt{R_{eH} \cdot E \cdot \left(\dfrac{m_1}{a^2} + \dfrac{m_2}{b^2}\right)}$ with $\tau_1 \ge 0$

m_1, m_2 : coefficients, defined as:

for longitudinal stiffeners:

$m_1 = 1.47, \quad m_2 = 0.49$ for $\dfrac{a}{b} \ge 2.0$

$m_1 = 1.96, \quad m_2 = 0.37$ for $\dfrac{a}{b} < 2.0$

for transverse stiffeners:

$m_1 = 0.37, \quad m_2 = \dfrac{1.96}{n^2}$ for $\dfrac{a}{n \cdot b} \ge 0.5$

$m_1 = 0.49, \quad m_2 = \dfrac{1.47}{n^2}$ for $\dfrac{a}{n \cdot b} < 0.5$

w : total deformation $[mm]$ of stiffener due to imperfection and lateral load, defined as:

$w = w_0 + w_1$

w_0 : assumed imperfection $[mm]$, defined as:

$\dfrac{a}{250} \ge w_0 \le \dfrac{b}{250}$ for longitudinal stiffeners

$\dfrac{n \cdot b}{250} \ge w_0 \le \dfrac{a}{250}$ for transverse stiffeners

However, $w_0 \le 10mm$

For stiffeners sniped at both ends w_0 is not to be taken less than the distance from the mid-point of plating to the neutral axis of the profile including effective width of plating.

w_1 : deformation $[mm]$ of stiffener due to lateral load p at midpoint of stiffener span; In case of uniformly distributed load the following values for w_1 may be used:

$w_1 = \dfrac{p \cdot b \cdot a^4}{384 \cdot 10^7 \cdot E \cdot I_x}$ for longitudinal stiffeners

$w_1 = \dfrac{5 \cdot a \cdot p \cdot (n \cdot b)^4}{384 \cdot 10^7 \cdot E \cdot I_y \cdot c_s^2}$ for transverse stiffeners

c_f : elastic support $[N/mm^2]$ provided by the stiffener, defined as:

$$c_{fx} = F_{Kix} \cdot \frac{\pi^2}{a^2} \cdot \left(1 + c_{px}\right)$$ for longitudinal stiffeners

$$c_{fy} = c_s \cdot F_{Kiy} \cdot \frac{\pi^2}{\left(n \cdot b\right)^2} \cdot \left(1 + c_{py}\right)$$ for transverse stiffeners

c_{px} : coefficient, defined as:

$$c_{px} = \frac{1}{1 + \frac{0.91}{c_{x\alpha}} \cdot \left(\frac{12 \cdot 10^4 \cdot I_x}{t_n^3 \cdot b} - 1\right)}$$

$c_{x\alpha}$: coefficient, defined as:

$$c_{x\alpha} = \left[\frac{a}{2 \cdot b} + \frac{2 \cdot b}{a}\right]^2$$ for $a \ge 2 \cdot b$

$$c_{x\alpha} = \left[1 + \left(\frac{a}{2 \cdot b}\right)^2\right]^2$$ for $a < 2 \cdot b$

c_s : coefficient to take boundary conditions into account, defined as:

$c_s = 1.0$ for simply supported stiffeners

$c_s = 2.0$ for partially constraint stiffeners

c_{py} : coefficient, defined as:

$$c_{py} = \frac{1}{1 + \frac{0.91}{c_{y\alpha}} \cdot \left(\frac{12 \cdot 10^4 \cdot I_y}{t_n^3 \cdot a} - 1\right)}$$

$c_{y\alpha}$: coefficient, defined as:

$$c_{y\alpha} = \left[\frac{n \cdot b}{2 \cdot a} + \frac{2 \cdot a}{n \cdot b}\right]^2$$ for $n \cdot b \ge 2 \cdot a$

$$c_{y\alpha} = \left[1 + \left(\frac{n \cdot b}{2 \cdot a}\right)^2\right]^2$$ for $n \cdot b < 2 \cdot a$

W_{st} : section modulus $[cm^3]$ of stiffener (long. or transverse) including effective width of plating according to D.3.2

If no lateral load p is acting the bending stress σ_b is to be calculated at the midpoint of the stiffener span for that fibre which results in the largest stress value. If a lateral load p is acting, the stress calculation is to be carried out for both fibres of the stiffener's cross sectional area (if necessary for the biaxial stress field at the plating side).

Note

Longitudinal and transverse stiffeners not subjected to lateral load p have sufficient scantlings if their moments of inertia I_x and I_y are not less than obtained by the following formulae:

$$I_x = \frac{p_{zx} \cdot a^2}{\pi^2 \cdot 10^4} \cdot \left(\frac{w_{ox} \cdot h_w}{\frac{R_{eH}}{S} - \sigma_x} + \frac{a^2}{\pi^2 \cdot E}\right) \quad [cm^4]$$

$$I_y = \frac{p_{zy} \cdot (n \cdot b)^2}{\pi^2 \cdot 10^4} \cdot \left(\frac{w_{oy} \cdot h_w}{\frac{R_{eH}}{S} - \sigma_y} + \frac{(n \cdot b)^2}{\pi^2 \cdot E} \right) \quad [cm^4]$$

D.4.3 Torsional buckling

D.4.3.1 Longitudinal stiffeners

$$\frac{\sigma_x \cdot S}{\kappa_T \cdot R_{eH}} \le 1.0$$

κ_T : reduction factor, defined as:

$$\kappa_T = 1.0 \qquad \text{for } \lambda_T \le 0.2$$

$$\kappa_T = \frac{1}{\phi + \sqrt{\phi^2 - \lambda_T^2}} \qquad \text{for } \lambda_T > 0.2$$

ϕ : characteristic value, defined as:

$$\phi = 0.5 \cdot \left(1 + 0.21 \cdot (\lambda_T - 0 \cdot 2) + \lambda_T^2\right)$$

λ_T : reference degree of slenderness, defined as:

$$\lambda_T = \sqrt{\frac{R_{eH}}{\sigma_{KiT}}}$$

σ_{KiT} : critical buckling stress $[N/mm^2]$, defined as:

$$\sigma_{KiT} = \frac{E}{I_P} \cdot \left(\frac{\pi^2 \cdot I_\omega \cdot 10^2}{a^2} \cdot \varepsilon + 0.385 \cdot I_T \right) \quad [N/mm^2]$$

I_P : polar moment of inertia $[cm^4]$ of the stiffener related to the point C according to Table 3.7

I_T : St. Venant's moment of inertia $[cm^4]$ of the stiffener according to Table 3.7

I_ω : sectorial moment of inertia $[cm^6]$ of the stiffener related to the point C according to Table 3.7

ε : degree of fixation, defined as:

$$\varepsilon = 1 + \sqrt{\frac{a^4}{I_\omega \cdot \left(\frac{b}{t_n^3} + \frac{4 \cdot h_w}{3 \cdot t_w^3} \right)}} \cdot 10^{-4}$$

h_w : web height $[mm]$ according to Fig. 3.8

t_w : web thickness $[mm]$ according to Fig. 3.8

b_f : flange breadth $[mm]$ according to Fig. 3.8

t_f : flange thickness $[mm]$ according to Fig. 3.8

A_w : web area $[mm^2]$, defined as:

$$A_w = h_w \cdot t_w$$

A_f : flange area $[mm^2]$, defined as:

$$A_w = b_f \cdot t_f$$

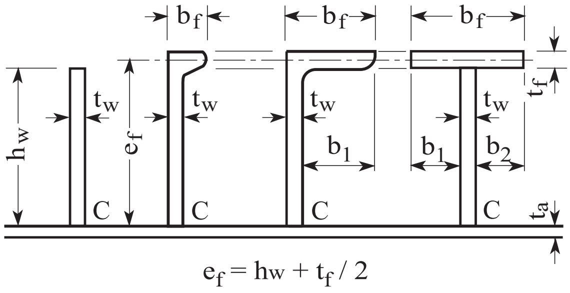


Fig. 3.8 Main dimensions of typical longitudinal stiffeners

Table 3.7 Formulas for the calculation of moments of inertia I_P, I_T and I_ω

Section	I_P	I_T	I_ω
Flat bar	$\dfrac{h_w^3 \cdot t_w}{3 \cdot 10^4}$	$\dfrac{h_w \cdot t_w^3}{3 \cdot 10^4} \cdot \left(1 - 0.63 \cdot \dfrac{t_w}{h_w}\right)$	$\dfrac{h_w^3 \cdot t_w^3}{36 \cdot 10^6}$
Sections with bulb or flange	$\left(\dfrac{A_w \cdot h_w^2}{3} + A_f \cdot e_f^2\right) \cdot 10^{-4}$	$\dfrac{h_w \cdot t_w^3}{3 \cdot 10^4} \cdot \left(1 - 0.63 \cdot \dfrac{t_w}{h_w}\right) + \dfrac{b_f \cdot t_f^3}{3 \cdot 10^4} \cdot \left(1 - 0.63 \cdot \dfrac{t_f}{b_f}\right)$	for bulb and angle sections: $\dfrac{A_f \cdot e_f^2 \cdot b_f^2}{12 \cdot 10^6} \cdot \left(\dfrac{A_f + 2.6 \cdot A_w}{A_f + A_w}\right)$ for tee-sections: $\dfrac{b_f^3 \cdot t_f \cdot e_f^2}{12 \cdot 10^6}$

D.4.3.2 Transverse stiffeners

For transverse stiffeners loaded by compressive stresses and which are not supported by longitudinal stiffeners, proof is to be provided in accordance with D.4.3.1 analogously.

E Structural Details

E.1 Continuity of structure

E.1.1 Continuity of structure is to be maintained throughout the length of the ship. Where significant changes in structural arrangement occur adequate transitional structure is to be provided.

(IACS UR S11.3.2)

E.1.2 Where a longitudinal framing system changes to a transverse framing system, structural continuity or sufficient scarphing is to be provided for.

E.2 Longitudinal members

E.2.1 All longitudinal members taken into account for calculating the midship section modulus are to extend over the required length amidships and are to be tapered gradually to the required end scantlings, see also Section 5, E.1.2.1.

E.2.2 Abrupt discontinuities of strength of longitudinal members are to be avoided as far as practicable. Where longitudinal members having different scantlings are connected with each other, smooth transitions are to be provided.

Special attention is to be paid to the construction of continuous longitudinal hatch coamings forming part of the longitudinal hull structure.

E.2.3 At the ends of longitudinal bulkheads or continuous longitudinal walls suitable scarping brackets are to be provided.

E.2.4 In general, longitudinal structures are to be designed such, that they run through transverse structures continuously. Major discontinuities have to be avoided.

E.2.5 If longitudinal structures are to be staggered, sufficient shifting elements shall be provided.

E.3 Transverses and girders

E.3.1 Where transverses or girders fitted in the same plane are connected to each other, major discontinuities of strength is to be avoided. The web depth of the smaller girder is, in general, not to be less than $60\ \%$ of the web depth of the greater one.

E.3.2 The taper between face plates with different dimensions is to be gradual. In general the taper is not to exceed $1:3$. At intersections the forces acting in the face plates are to be properly transmitted.

E.3.3 For transmitting the acting forces the face plates are to be supported at their knuckles. For supporting the face plates of cantilevers, see Fig. 3.9.

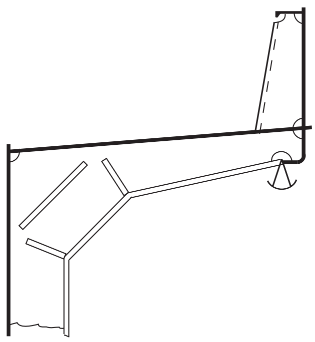


Fig. 3.9 Support of face plates of cantilevers

E.3.4 Upon special approval the stiffeners at the knuckles may be omitted if the following condition is complied with:

$$\sigma_a \le \sigma_p \cdot \frac{b_e}{b_f} \quad [N/mm^2]$$

σ_a : actual stress $[N/mm^2]$ in the face plate at the knuckle

σ_p : permissible stress $[N/mm^2]$ in the face plate

b_e : effective breadth $[mm]$ of face plate, defined as:

$$b_e = t_w + n_1 \cdot \left(t_f + c \cdot (b - t_f)\right)$$

t_w : web thickness $[mm]$

n_1 : coefficient, defined as:

$n_1 = 1$	for unsymmetrical face plates (face plate at one side only)
$n_1 = 2$	for symmetrical face plates

t_f : face plate thickness $[mm]$

c : coefficient, defined as:

$$c = \frac{1}{\left(b - t_f\right)^2 / \left(R \cdot t_f\right) - n_2} + \frac{n_3 \cdot t_f}{\alpha^2 \cdot R}$$ with $c < 1.0$

b : coefficient, defined as:

$$b = \frac{1}{n_1} \cdot (b_f - t_w) \quad [\mathrm{mm}]$$

b_f : breadth $[\mathrm{mm}]$ of face plate

R : radius $[\mathrm{mm}]$ of rounded face plates, defined as:

$R = t_f$ for knuckled face plates

n_2 : coefficient, defined as:

$n_2 = 0$ for face plates not supported by brackets

$n_2 = 0.9 \cdot \frac{\left(b - t_f\right)^2}{R \cdot t_f}$ for face plates of multi-web girders

with $n_2 \le 1.0$

n_3 : coefficient, defined as:

$n_3 = 3$ if no radial stiffener is fitted

$n_3 = 3000$ if two or more radial stiffeners are fitted or if one knuckle stiffener is fitted according to (a) in Fig. 3.10

$n_3 = \left(\frac{d}{t_f} - 8\right)^4$ if one stiffener is fitted according to (b) in Fig. 3.10

with $3 \le n_3 \le 3\,000$

d : distance $[\mathrm{mm}]$ of the stiffener from the knuckle

$2 \cdot \alpha$: knuckle angle $[°]$, see Fig. 3.10, with:

$\alpha \le 45°$

For proof of fatigue strength of the weld seam in the knuckle, the stress concentration factor K_S (angle $2 \cdot \alpha$ according to Fig. 3.10 $< 35\,°$) related to the stress σ_a in the face plate of thickness t_f may be estimated as follows and may be evaluated with case A5 of Section 20, Table 20.3:

$$K_S = \frac{t_f}{t_{f1}} \cdot \left(1 + \frac{6 \cdot n_4}{1 + \left[\frac{t_f}{t_{f1}}\right]^2} \cdot \tan\left(\frac{t_{f1}}{R} \cdot 2\alpha\right) \right)$$

n_4 : coefficient, defined as:

$n_4 = 7.143$ for $8 < \frac{d}{t_f}$

$n_4 = \frac{d}{t_f} - 0.51 \cdot \sqrt[4]{\frac{d}{t_f}}$ for $8 \ge \frac{d}{t_f} > 1.35$

$n_4 = 0.5 \cdot \frac{d}{t_f} + 0.125$ for $1.35 \ge \frac{d}{t_f} \ge -0.25$

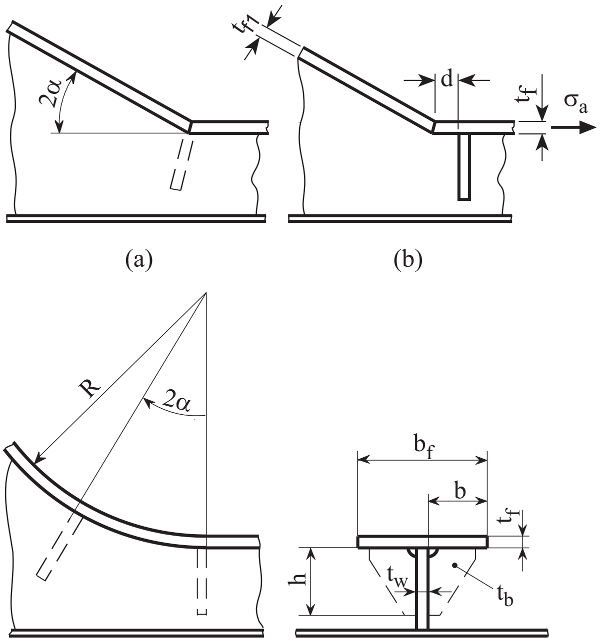


Fig. 3.10 Typical stiffeners of rounded of knuckled face plates

The welding seam has to be shaped according to Fig. 3.11.

The thickness t_b and the height h of stiffeners may be determined as guidance by the following formulae:

$$t_b = \frac{\sigma_a}{\sigma_p} \cdot t_f \cdot 2 \cdot \sin\alpha \quad [\text{mm}]$$

$$h = 1.5 \cdot b \quad [\text{mm}]$$

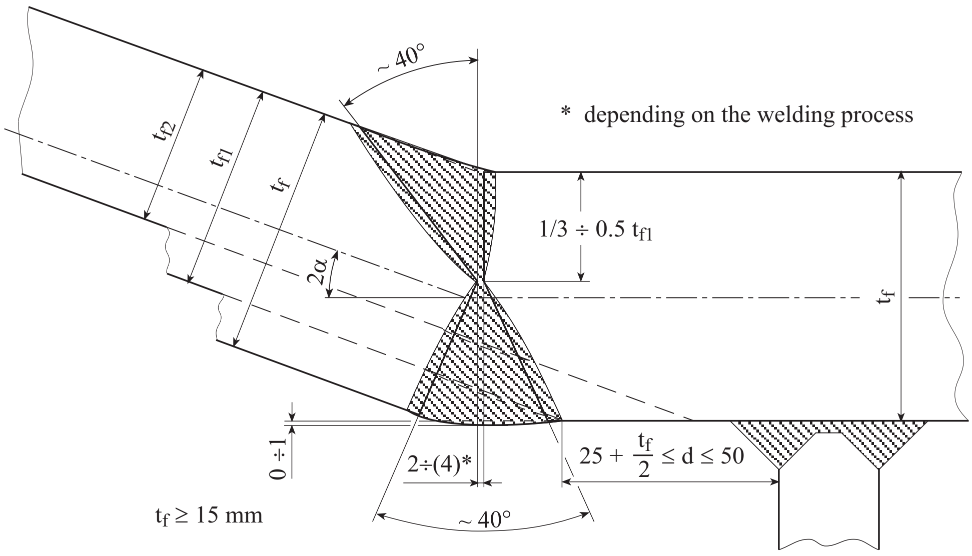


Fig. 3.11 Welding and support of knuckles

E.3.5 For preventing the face plates from tripping adequately spaced stiffeners or tripping brackets are to be provided. The spacing of these tripping elements is not to exceed $12 \cdot b_f$.

E.3.6 The webs are to be stiffened to prevent buckling (see also D).

E.3.7 The location of lightening holes is to be such that the distance from hole edge to face plate is not less than 0.3 x web depth.

E.3.8 In way of high shear stresses lightening holes in the webs are to be avoided as far as possible.

E.3.9 In the fore and aft ship region the stiffness of webframes and girders has to be sufficient to support connected structural parts like decks adequately. If necessary, wing bulkheads have to be arranged, especially in areas with high transverse loads e.g. due to slamming pressures.

E.4 Knuckles (general)

E.4.1 Flanged structural elements transmitting forces perpendicular to the knuckle are to be adequately supported at their knuckle, i.e. the knuckles of the inner bottom are to be located above floors, longitudinal girders or bulkheads.

If longitudinal structures, such as longitudinal bulkheads or decks, include a knuckle which is formed by two butt-welded plates, the knuckle is to be supported in the vicinity of the joint rather than at the exact location of the joint. The minimum distance d to the supporting structure is to be (see Fig. 3.11):

$$d = 25 + \frac{t_f}{2} \quad [\text{mm}] \qquad \text{with } d \le 50 \text{ mm}$$

E.4.2 On bulk carriers at knuckles between inner bottom and tank side slopes in way of floors the welding cut-outs have to be closed by collar plates or insert plates, see Fig. 3.12. In both cases a full penetration weld is required to inner bottom and bottom girder.

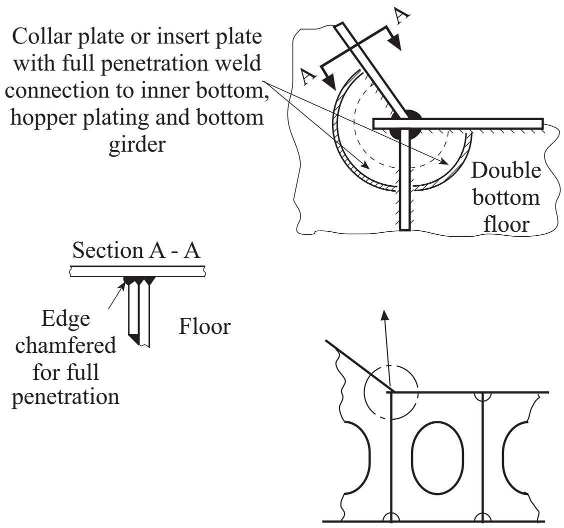


Fig. 3.12 Knuckles of the double bottom

F Evaluation of Notch Stress

The notch stress σ_K evaluated for linear-elastic material behaviour at free plate edges, e.g. at hatch corners, openings in decks, walls, girders etc., should, in general, fulfill the following criterion:

$$\sigma_K \le f \cdot R_{eH}$$

f : factor, defined as:

$f = 1.10$	for normal strength hull structural steel
$f = 0.90$	for higher strength hull structural steel with $R_{eH} = 315 \text{ N/mm}^2$
$f = 0.80$	for higher strength hull structural steel with $R_{eH} = 355 \text{ N/mm}^2$
$f = 0.73$	for higher strength hull structural steel with $R_{eH} = 390 \text{ N/mm}^2$

If plate edges are free of notches and corners are rounded-off, a 20 % higher notch stress σ_K may be permitted.

A further increase of stresses may be permitted on the basis of a fatigue strength analysis as per Section 20.

For some types of openings the notch factors K_t for the calculation of the notch stress σ_K are given in Fig. 3.13 and Fig. 3.14.

They apply to stress conditions with uniaxial or biaxial normal stresses.

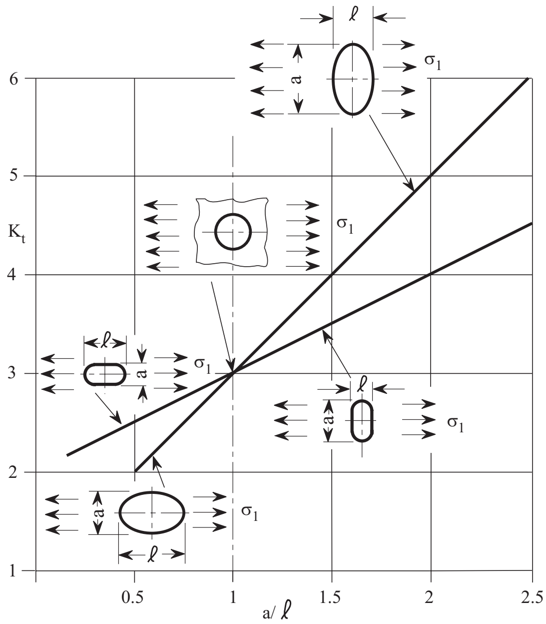


Fig. 3.13 Notch factor K_t for rounded openings

In case of superimposed stresses due to longitudinal and shear loads, the maximum notch stress $\sigma_{K,max}$ of rectangular openings with rounded corners can approximately be calculated as follows:

$\sigma_{K,max}$: maximum notch stress, defined as:

$$\sigma_{K,max} = +K_{tv} \cdot \sqrt{\sigma_1^2 + 3 \cdot \tau_1^2}$$ for σ_1 = tensile stress

$$\sigma_{K,max} = -K_{tv} \cdot \sqrt{\sigma_1^2 + 3 \cdot \tau_1^2}$$ for σ_1 = compressive stress

K_{tv} : notch factor for equivalent stress, defined as:

$$K_{tv} = m \cdot \sqrt{\rho} + c$$

m, c : parameters according to Fig. 3.15

ℓ, a : length and height of opening

τ_1 : shear stress related to gross area of section

σ_1 : longitudinal stress (in direction of length ℓ of opening) related to gross area of section

r : radius of rounded corner

ρ : ratio of smaller length to radius of corner, defined as:

$\rho = \ell / r$ or $\rho = a / r$ with $\rho \geq 3$

Note

Because the notch factor and the equivalent stress are always positive, the sign of σ_1 governs the most unfavourable superposition of the stress components in any of the four corners. A load consisting of *shear only, results in notch stresses of equal size with two positive and two negative values in the opposite corners.*

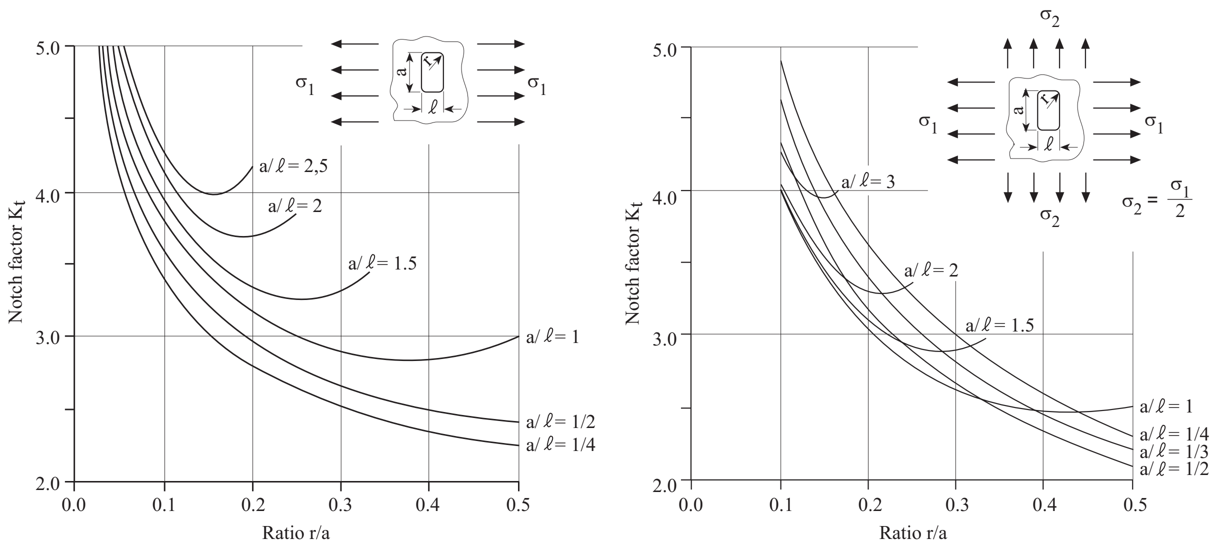


Fig. 3.14 Notch factor K_t for rectangular openings with rounded corners at uniaxial stress conditions (left) and at biaxial stress conditions (right)

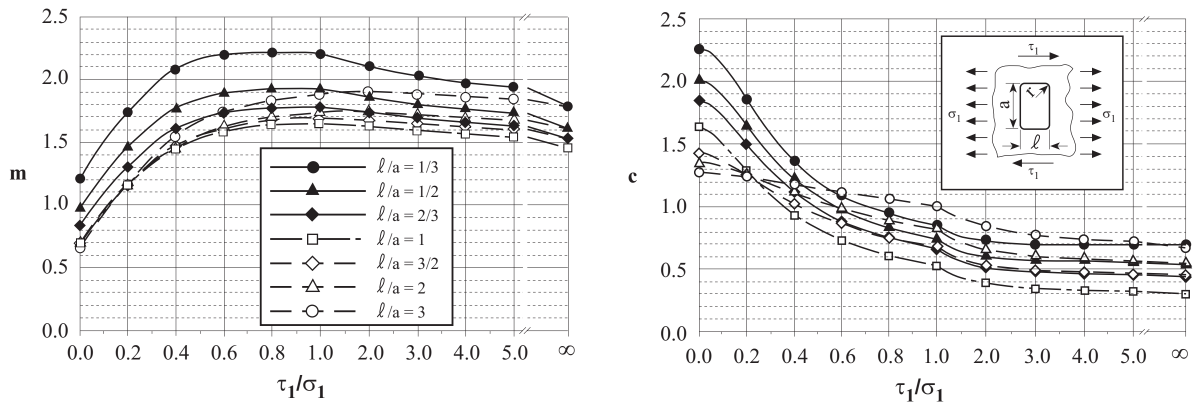


Fig. 3.15 Parameters m and c to determine the notch factors of rectangular openings loaded by superimposed longitudinal and shear stresses

An exact evaluation of notch stresses is possible by means of finite element calculations. For fatigue investigations the stress increase due to geometry of cut-outs has to be considered, see Section 20, Table 20.3.

Note

These notch factors can only be used for girders with multiple openings if there is no correlation between the different openings regarding deformations and stresses.

G Corrosion Additions

G.1 The scantling requirements of the subsequent Sections imply the following general corrosion additions t_K:

$$t_K = 1.5\,\text{mm} \qquad \text{for } t' \le 10\text{ mm}$$

$$t_K = \frac{0.1 \cdot t'}{\sqrt{k}} + 0.5 \le 3.0 \quad [\text{mm}] \qquad \text{for } t' > 10\text{ mm}$$

t' : required rule thickness excluding t_K [mm]

G.2 For structural elements in specified areas t_K is not to be less than given in Table 3.8:

Table 3.8 Minimum corrosion additions $t_{K,min}$

Area	$t_{K,min}$ [mm]
In ballast tanks where the weather deck forms the tanktop, 1.5 m below tanktop [1]	2.5
• In cargo oil tanks where the weather deck forms the tanktop, 1.5 m below tanktop. • Horizontal members in cargo oil and fuel oil tanks.	2.0
Deck plating below elastically mounted deckhouses	3.0
Longitudinal bulkheads of ships assigned to the Notation **G** and exposed to grab operation	2.5
[1] t_{Kmin} = 2.5 mm for all structures within topside tanks of bulk carriers.	

G.3 For structures in dry spaces such as box girders of container ships and for similar spaces the corrosion addition is:

$$t_K = \frac{0.1 \cdot t'}{\sqrt{k}} \ [\text{mm}] \qquad \text{with } 1.0\ \text{mm} \le t_K \le 2.5\ \text{mm}$$

G.4 For inner walls and decks of dry spaces inside accommodation areas of ships, the corrosion addition may be reduced to zero. In this case the decks have to be protected by sheathing.

For other superstructure areas the corrosion addition has to be determined according to G.1 with a minimum thickness of $t_K = 1$ mm.

G.5 Corrosion additions for hatch covers and hatch coamings are to be determined according to Section 17.

G.6 For corrosion protection see Section 35.

H Testing of Watertight and Weathertight Compartments

H.1 Tightness and structural testing of watertight and weathertight compartments has to be done in accordance with the IACS Unified Requirement S14.

H.2 For all tanks an operational test is to be carried out when the ship is afloat or during the trial trip. The proper functioning of filling and suction lines and of the valves as well as functioning and tightness of the vent, sounding and overflow pipes is to be tested.

H.3 Where in case of a tanker a pump room instead of a cofferdam is situated between cargo tank and machinery space the engine room / pump room bulkhead need not be water tested.

Section 4 Design Loads

A General

A.1 Application

This Section provides data regarding design loads for determining the scantlings of the hull structural elements by means of the design formulae given in the following Sections or by means of direct calculations. The dynamic portions of the design loads are design values which can only be applied within the design concept of this Chapter.

A.2 References

International conventions and codes

Paragraphs of this section are based on the following international convention(s) and / or code(s):

IACS UR S3 Rev.1

IACS UR S8 Rev.4

IACS UR S9 Rev.6

ICAS UR S21A Corr.1

At the end of each relevant paragraph of this section, the corresponding paragraphs of the international convention(s) and / or code(s) are given in brackets.

A.3 Definitions

Load centre

The load centre of plates, stiffeners and girders are defined as:

- For vertical stiffened plates:
  - 0.5 x stiffener spacing above the lower support of plate field, or lower edge of plate when the thickness changes within the plate field
- For horizontal stiffened plates:
  - Midpoint of plate field
- For stiffeners and girders:
  - Centre of unsupported span ℓ

Symbols

a_v : acceleration addition, defined as:

$$a_v = F \cdot m$$

F : coefficient, defined as:

$$F = 0.11 \cdot \frac{v_0}{\sqrt{\mathbf{L}}}$$ with $v_0 \ge \sqrt{\mathbf{L}}$ [kn]

m : coefficient, defined as:

$$m = m_0 - 5 \cdot (m_0 - 1) \cdot \frac{x}{\mathbf{L}} \qquad \text{for } 0 \le \frac{x}{\mathbf{L}} \le 0.2$$

$$m = 1.0 \qquad \text{for } 0.2 < \frac{x}{\mathbf{L}} \le 0.7$$

$$m = 1 + \frac{m_0 + 1}{0.3}\left(\frac{x}{\mathbf{L}} - 0.7\right) \qquad \text{for } 0.7 < \frac{x}{\mathbf{L}} \le 1.0$$

m_0 : coefficient, defined as:

$$m_0 = 1.5 + F$$

b' : breadth $[\mathrm{m}]$ of deckhouse at the position considered

B' : actual maximum breadth $[\mathrm{m}]$ of ship on the exposed weather deck at the position considered

c_D, c_F : distribution factors according to Table 4.1

c_{FA} : flare angle coefficient, defined as:

$$c_{FA} = 0.8 \qquad \text{in general}$$

$$c_{FA} = \frac{0.4}{1.2 - 1.09 \cdot \sin\alpha} \qquad \text{for extremely flared sides with } \alpha > 40°$$

α : flare angle $[°]$ at the load centre, which is to be measured in the plane of frame between a vertical line and the tangent to the side shell plating

$\mathbf{L}_{100}$: corresponds to the length of the ship as $\mathbf{L}$, but $\mathbf{L}_{100}$ is not to be taken less than $100\ \mathrm{m}$

$\mathbf{L}_{300}$: corresponds to the length of the ship as $\mathbf{L}$, but $\mathbf{L}_{300}$ is not to be taken greater than $300\ \mathrm{m}$

p_v : pressure $[\mathrm{bar}]$, defined as:

For cargo tanks of tankers equipped with a pressure relief valve:

p_v is the set pressure of pressure relief valve, not to be taken less than $0.2\ \mathrm{bar}$ (see also the Machinery Installations (I-1-2), Section 15). Smaller set pressures than $0.2\ \mathrm{bar}$ may be accepted in special cases. The set pressure will be entered into the class certificate.

For ballast water tanks:

p_v is the working pressure during ballast water exchange, not to be taken less than $0.1\ \mathrm{bar}$ for the sequential method as well as for the flow-through method.

$$p_v = \frac{\Delta z - 2.5}{10} + \Delta p_v$$

If the ballast water exchange is done by using a ring-ballast system and the dilution method, for which an equivalent inflow and outflow is to be ensured, $p_v = 0\ \mathrm{bar}$ can be used.

Δz : distance $[\mathrm{m}]$ from tank top to top of overflow used for ballast water exchange.

Δp_v : pressure losses $[\mathrm{bar}]$ in the overflow line during ballast water exchange, not to be taken less than $0.1\ \mathrm{bar}$ (see also the Guidelines for the Construction, Equipment and Testing of Closed Fuel Oil Overflow Systems (VI-3-6), Annex A, 3.1)

p_0 : basic external dynamic load $[\mathrm{kN/mm^2}]$ for wave directions with or against the ship's heading, defined as:

$$p_0 = 2.1 \cdot (C_B + 0.7) \cdot c_0 \cdot c_L \cdot f$$

p_{01} : basic external dynamic load $[kN/mm^2]$ for wave directions transverse to the ship's heading, defined as:

$$p_{01} = 2.6 \cdot (C_B + 0.7) \cdot c_0 \cdot c_L$$

C_B : block coefficient according to Section 1, A.3.1.1. C_B is not to be taken less than 0.6.

c_0 : wave coefficient, defined as:

$$c_0 = \left[\frac{\mathbf{L}}{25} + 4.1\right] \cdot c_{RW}$$ for $\mathbf{L} < 90\ \text{m}$

$$c_0 = \left[10.75 - \left(\frac{300 - \mathbf{L}}{100}\right)^{1.5}\right] \cdot c_{RW}$$ for $90 \le \mathbf{L} \le 300\ \text{m}$

$$c_0 = 10.75 \cdot c_{RW}$$ for $\mathbf{L} > 300\ \text{m}$

c_L : length coefficient, defined as:

$$c_L = \sqrt{\frac{\mathbf{L}}{90}}$$ for $\mathbf{L} < 90\ \text{m}$

$$c_L = 1.0$$ for $\mathbf{L} \ge 90\ \text{m}$

c_{RW} : service range coefficient, defined as:

$c_{RW} = 1.00$	for unlimited service range
$c_{RW} = 0.90$	for restricted service area **RSA (200)**
$c_{RW} = 0.75$	for restricted service area **RSA (50)**
$c_{RW} = 0.66$	for restricted service area **RSA (20)**
$c_{RW} = 0.60$	for restricted service area **RSA (SW)**

f : probability factor, defined as:

$f = 1.00$	for plate panels of the outer hull (shell plating, weather decks)
$f = 0.75$	for secondary stiffening members of the outer hull (frames, deck beams), but not less than f_Q as defined in Section 5, D.2.3
$f = 0.60$	for girders and girder systems of the outer hull (web frames, stringers, grillage systems), but not less than $f_Q / 1.25$

x : horizontal distance $[m]$ between load centre of element and aft end of length $\mathbf{L}$.

y : horizontal distance $[m]$ between load centre of element and centreline

z : vertical distance $[m]$ between load centre of element and base line

z' : vertical distance $[m]$ between load centre of element and summer load line

ρ_c : density $[t/m^3]$ of cargo as stowed

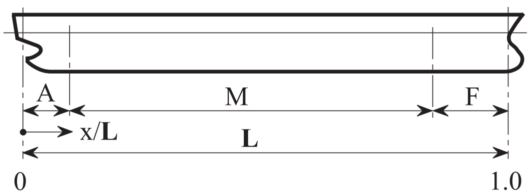
ρ : density $[t/m^3]$ of liquids, defined as:

$\rho = 1.0$ for fresh and sea water

Table 4.1 Distribution factors for sea loads on ship's shell and weather decks

Range		c_D	c_F [1]
A	$0 \le \frac{x}{\mathbf{L}} < 0.2$	$1.2 - \frac{x}{\mathbf{L}}$	$1.0 + \frac{5}{C_B} \cdot \left(0.2 - \frac{x}{\mathbf{L}}\right)$
M	$0.2 \le \frac{x}{\mathbf{L}} < 0.7$	1.0	1.0
F	$0.7 \le \frac{x}{\mathbf{L}} < 1.0$	$1.0 + \frac{c}{3} \cdot \left(\frac{x}{\mathbf{L}} - 0.7\right)$ $c = 0.15 \cdot \mathbf{L} - 10$ $100\ \text{m} \le \mathbf{L} \le 250\ \text{m}$	$1.0 + \frac{20}{C_B} \cdot \left(\frac{x}{\mathbf{L}} - 0.7\right)^2$

1 Within the range **A** the ratio $x / \mathbf{L}$ need not to be taken less than 0.1 and within the range **F** the ratio $x / \mathbf{L}$ need not to be taken greater than 0.93.



B External Sea Loads

B.1 Load on weather decks

The load p_D on weather decks is to be determined by the following formula:

$$p_D = p_0 \cdot \frac{20 \cdot \mathbf{T}}{(10 + z - \mathbf{T}) \cdot \mathbf{H}} \cdot c_D \quad [\text{kN/m}^2]$$

with $p_D \ge p_{D,min}$

$p_{D,min}$: minimum load $[\text{kN/m}^2]$ on weather decks, defined as:

$p_{D,min} = \max[16 \cdot f\ ;\ 0.7 \cdot p_0]$ for strength decks which are to be treated as weather decks and for forecastle decks

$p_{D,min} = p_L + p_Z$ where deck cargo is intended to be carried on the weather deck

p_L : load on cargo decks according to C.1

p_Z : additional load $[\text{kN/m}^2]$ on cargo decks in case of small stowage heights, defined as:

$p_z = 10 \cdot (1 - h_c)$ for $h_c \le 1$ m

$p_z = 0$ for $h_c > 1$ m

h_c : stowage height [m] of the cargo

B.2 Load on ship's sides

The loads p_S and p_{S1} on the ship's sides are to be determined by the following formulae:

For elements having the load centre located below the load waterline:

$$p_S = 10 \cdot (\mathbf{T} - z) + p_0 \cdot c_F \cdot \left(1 + \frac{z}{\mathbf{T}}\right) \quad [\mathrm{kN/m^2}]$$

for wave directions with or against the ship's heading

$$p_{S1} = 10 \cdot (\mathbf{T} - z) + p_{01} \cdot \left(1 + \frac{z}{\mathbf{T}} \cdot \left(2 - \frac{z}{\mathbf{T}}\right)\right) \cdot 2 \cdot \frac{|y|}{\mathbf{B}} \quad [\mathrm{kN/m^2}]$$

for wave directions transverse to the ship's heading including quasi-static pressure increase due to heel

For elements having the load centre located above the load waterline:

$$p_S = p_0 \cdot c_F \cdot \frac{20}{10 + z - \mathbf{T}} \quad [\mathrm{kN/m^2}]$$

for wave directions with or against the ship's heading

$$p_{S1} = p_{01} \cdot \frac{20}{5 + z - \mathbf{T}} \cdot \frac{|y|}{\mathbf{B}} \quad [\mathrm{kN/m^2}]$$

for wave directions transverse to the ship's heading including quasi-static pressure increase due to heel

B.3 Load on bow structures

The load p_E on bow structures in the area from forward to $0.1\ \mathbf{L}$ behind F.P. and above the ballast waterline in accordance with the draft T_b in B.6 is to be determined by the following formula:

$$p_E = c_{FA} \cdot \left(0.20 \cdot v_0 + 0.6 \cdot \sqrt{\mathbf{L}_{300}}\right)^2 \quad [\mathrm{kN/m^2}]$$

with $p_E \geq p_S$

p_S : load on ship's sides according to B.2

Aft of $0.1\ \mathbf{L}$ from F.P. up to $0.15\ \mathbf{L}$ from F.P. the pressure between p_E and p_S is to be graded steadily.

For unusual bow shapes the load p_E can be specially considered.

B.4 Load on stern structures

The load p_E on stern structures in the area from the aft end to $0.1\ \mathbf{L}$ forward of the aft end of $\mathbf{L}$ and above the smallest design ballast draught at the centre of the rudder stock up to $\mathbf{T} + c_0 / 2$ is to be determined by the following formula:

$$p_E = c_A \cdot \mathbf{L}_{300} \quad [\mathrm{kN/m^2}]$$

with $p_E \geq p_S$

p_S : load on ship's sides according to B.2

c_A : coefficient, defined as:

$$c_A = 0.3 \cdot c_{FA}$$

with $c_A \geq 0.36$

B.5 Load on the ship's bottom

The load p_B on the ship's bottom is to be determined by the following formula:

$$p_B = 10 \cdot \mathbf{T} + p_0 \cdot c_F \quad [\mathrm{kN/m^2}]$$

B.6 Design bottom slamming pressure

The design bottom slamming pressure p_{SL} in the fore body may be determined by the following formula:

$$p_{SL} = c_1 \cdot c_2 \cdot c_{SL} \cdot c_A \left(\frac{1+c_{RW}}{2}\right) \quad [kN/m^2]$$

c_1 : coefficient, defined as:

$$c_1 = 3.6 - 6.5 \cdot \left(\frac{T_b}{\mathbf{L}}\right)^{0.2} \qquad \text{with } 0 \le c_1 \le 1$$

T_b : smallest design ballast draught $[m]$ at **F.P.** for normal ballast conditions, according to which the strengthening of bottom forward is to be determined (see also Section 6, D.2)

This value has to be recorded in the Annex to the Class Certificate and in the loading manual.

Where the sequential method for ballast water exchange is intended to be applied, T_b is to be considered for the sequence of exchange.

c_2 : coefficient, defined as:

$$c_2 = 162 \cdot \sqrt{\mathbf{L}} \qquad \text{for } \mathbf{L} \le 150 \text{ m}$$

$$c_2 = 1984 \cdot (.3 - 0.002 \cdot \mathbf{L}) \qquad \text{for } \mathbf{L} > 150 \text{ m}$$

c_{SL} : distribution factor (see also Fig. 4.1), defined as

$$c_{SL} = 0 \qquad \text{for } \frac{x}{\mathbf{L}} \le 0.50$$

$$c_{SL} = \frac{\frac{x}{\mathbf{L}} - 0.5}{c_3} \qquad \text{for } 0.50 < \frac{x}{\mathbf{L}} \le 0.50 + c_3$$

$$c_{SL} = 1.0 \qquad \text{for } 0.50 + c_3 < \frac{x}{\mathbf{L}} \le 0.65 + c_3$$

$$c_{SL} = 0.5 \cdot \left(1 + \frac{1 - \frac{x}{\mathbf{L}}}{0.35 - c_3}\right) \qquad \text{for } 0.65 + c_3 < \frac{x}{\mathbf{L}}$$

c_3 : coefficient, defined as:

$$c_3 = 0.33 \cdot C_B + \frac{\mathbf{L}}{2\,500} \qquad \text{with } c_3 \le 0.35$$

c_A : coefficient, defined as:

$$c_A = \frac{10}{A} \qquad \text{with } 0.3 \le c_A \le 1.0$$

$$c_A = 1.0 \qquad \text{for plate panels and stiffeners}$$

A : loaded area $[m^2]$ between the supports of the structure considered

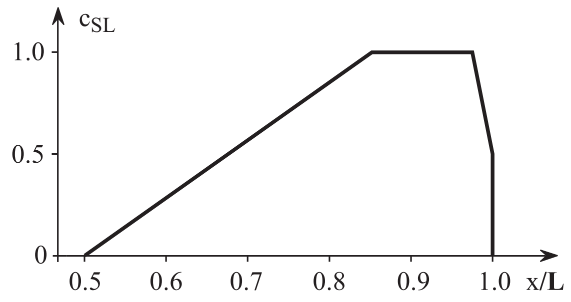


Fig. 4.1 Distribution factor c_{SL}

Note

With respect to the observation of the smallest design ballast draught T_b, an exception is possible, if during the exchange of ballast water weather conditions are observed the parameters of which are put down in the Annex to the Certificate of Class.

B.7 Load on exposed decks of superstructures and deckhouses

Depending on the type of superstructure and type of deck, the load p_{DA} is to be determined according to B.7.1 and B.7.2.

B.7.1 The load p_{DA} on exposed decks and parts of superstructure and deckhouse decks, which are not to be treated as strength deck, is to be determined by the following formula:

$$p_{DA} = n \cdot c \cdot p_D \quad [kN/m^2] \qquad \text{with } p_{DA} \geq p_{DA,min}$$

$p_{DA,min}$: minimum load $[kN/m^2]$ on exposed decks, defined as:

$$p_{DA,min} = 4.0$$

p_D : load on weather decks according to B.1

n : distribution factor, defined as:

$$n = 1 - \frac{z - \mathbf{H}}{10} \qquad \text{with } n \geq 0.5$$

c : coefficient to take into account set back superstructures and deckhouses, defined as:

$$c = 0.3 + 0.7 \cdot \frac{b'}{B'} \qquad \text{with } \frac{b'}{B'} \geq 0.25$$

B.7.2 The load p_{DA} on exposed wheel house tops is not to be taken less than determined by the following formula:

$$p_{DA} = 2.5 \text{ kN/m}^2$$

B.8 Load on superstructure end bulkheads, deckhouse walls, transverse hatch coamings and hatch cover skirt plates

The load p_A on superstructure end bulkheads, deckhouse walls, transverse hatch coamings and hatch cover skirt plates is to be determined by the following formula:

$$p_A = n \cdot c \cdot (b \cdot c_L \cdot c_o - z') \quad [kN/m^2] \qquad \text{with } p_A \geq p_{A,min}$$

$p_{A,min}$: minimum design load according to Table 4.2

For hatch coamings of bulk carriers according to Section 23 the horizontal load is not to be less than determined by the following formula:

$p_{A,min} = 175 \ \ kN/m^2$ in general for outer edge girders of hatch covers

$p_{A,min} = 220 \ \ kN/m^2$ in general for hatch coamings

$p_{A,min} = 230 \ \ kN/m^2$ for the forward edge girder of the hatch 1 cover, if no forecastle according to Section 23, E is arranged

$p_{A,min} = 290 \ \ kN/m^2$ for the forward transverse coaming of hatch 1, if no forecastle according to Section 23, E is arranged

n : distribution factor, defined as:

$n = 20 + \frac{\mathbf{L}_{300}}{12}$ for the lowest tier of unprotected fronts of superstructures and deckhouse walls. The lowest tier is normally that tier which is directly situated above the uppermost continuous deck to which the Rule depth $\mathbf{H}$ is to be measured. However, where the actual distance $\mathbf{H} - \mathbf{T}$ exceeds the minimum non-corrected tabular freeboard according to **ICLL** by at least one standard superstructure height h_N, this tier may be defined as the 2^{nd} tier and the tier above as the 3^{rd} tier;

and for unprotected front coamings and hatch cover skirt plates

$n = 10 + \frac{\mathbf{L}_{300}}{12}$ for 2^{nd} tier unprotected fronts of superstructures and deckhouse walls;

and for unprotected front coamings and hatch cover skirt plates, where the distance from the actual freeboard deck to the summer load line exceeds the minimum non-corrected tabular freeboard according to **ICLL** by at least one standard superstructure height h_N

$n = 5 + \frac{\mathbf{L}_{300}}{15}$ for 3^{rd} tier and tiers above of unprotected fronts

and for sides and protected fronts of superstructures and deckhouse walls;

and for side and protected front coamings and hatch cover skirt plates

$n = 7 + \frac{\mathbf{L}_{300}}{100} - 8 \cdot \frac{x'}{\mathbf{L}}$ for aft ends of superstructures and deckhouse walls abaft amidships;

and for aft ends of coamings and aft hatch cover skirt plates abaft amidships

$n = 5 + \frac{\mathbf{L}_{300}}{100} - 4 \cdot \frac{x'}{\mathbf{L}}$ for aft ends of superstructures and deckhouse walls forward amidships;

and for aft ends of coamings and aft hatch cover skirt plates forward of amidships

h_N : standard superstructure height [m], defined as:

$$h_N = 1.05 + 0.01 \cdot \mathbf{L} \qquad \text{with } 1.8 \le h_N \le 2.3$$

x' : distance [m] between the bulkhead, transverse hatch coaming or hatch cover skirt plate considered and aft end of length **L**. When determining sides of a deckhouse, side coamings or side hatch cover skirt plates, the side 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 aft end of the length **L** and the centre of each part considered.

c : coefficient to take set back superstructures and deckhouses into account, defined as:

$$c = 0.3 + 0.7 \cdot \frac{b'}{B'} \qquad \text{in general with } \frac{b'}{B'} \ge 0.25$$

$$c = 1.0 \qquad \text{for exposed parts of machinery casings}$$

b : distribution factor, defined as:

$$b = 1.0 + \left(\frac{\frac{x'}{\mathbf{L}} - 0.45}{C_B + 0.2}\right) \qquad \text{for } \frac{x'}{\mathbf{L}} < 0.45$$

$$b = 1.0 + 1.5 \cdot \left(\frac{\frac{x'}{\mathbf{L}} - 0.45}{C_B + 0.2}\right)^2 \qquad \text{for } \frac{x'}{\mathbf{L}} \ge 0.45$$

C_B : moulded block coefficient according to Section 1, A.3.1.1, with:

$$0.6 \le C_B \le 0.8$$

For determining scantlings of aft ends forward of amidships, C_B need not to taken less than 0.8.

(IACS UR S.3.2 and ICAS UR S21A.2.2)

Table 4.2 Minimum design load $p_{A,min}$

L	$p_{A,min}$ [kN / m²] for				
	unprotected fronts		**other areas**		
	lowest tier	**higher tiers**	**tier ≤ 3rd**	**4th tier**	**tier ≥ 5th**
≤ 50	30	12.5 but not less than in other areas	15	12.5	8.5
> 50 ≤ 250	$25 + \frac{\mathbf{L}}{10}$		$12.5 + \frac{\mathbf{L}}{20}$		
> 250	50		25		

(IACS UR S.3 Table 1 and ICAS UR S21A Table 2)

B.9 Loads on breakwaters and whalebacks

B.9.1 Breakwaters with $\alpha_w \le 90°$ and whalebacks with $\alpha_w > 20°$

The load p_{BW} on breakwaters with $\alpha_w \le 90°$ and whalebacks with $\alpha_w > 20°$ is to be determined by the following formula:

$$p_{BW} = n \cdot d \cdot (b \cdot c_L \cdot c_o - z') \quad [kN/m^2] \qquad \text{with } p_{BW} \ge p_{BW,min}$$

$p_{BW,min}$: the minimum design load is to be the same as $p_{A,min}$ for the lowest tier of unprotected fronts according to Table 4.2

n : distribution factor, defined as:

$$n = 10 + \frac{L_{300}}{20}$$

d : coefficient to take the inclining angle of breakwaters into account, defined as:

$$d = \sin \alpha_w$$

α_w : inclining angle [°], determined on centre line, see Fig. 16.3

b : distribution factor, defined as:

$$b = 1.0 + 2.75 \cdot \left(\frac{\frac{x}{L} - 0.45}{C_B + 0.2} \right)^2$$

B.9.2 Whalebacks with $\alpha_w < 20°$

The load p_{BW} on whalebacks with an inclining angle of $\alpha_w < 20°$ on the centre line is to be taken as:

$$p_{BW} = p_D \quad [kN/m^2]$$

p_D : load on forecastle decks according to B.1

C Loads on Inner Decks

C.1 Load on cargo decks

C.1.1 The load p_L on cargo decks is to be determined by the following formula:

$$p_L = p_C \cdot (1 + a_v) \quad [kN/m^2]$$

p_C : static cargo load $[kN/m^2]$. If no cargo load is given:

$$p_C = 7 \cdot h \ge 15 \qquad \text{for 'tween decks}$$

h . mean 'tween deck height $[m]$. In way of hatch casings the increased height of cargo is to be taken into account.

C.1.2 The load p_L for timber deck cargo is to be determined by the following formula:

$$p_L = 5 \cdot h_s \cdot (1 + a_v) \quad [kN/m^2]$$

h_s : stowing height $[m]$ of cargo

C.1.3 The loads P_L due to single forces P (e.g. in case of containers) are to be determined by following formula:

$$P_L = P \cdot (1 + a_v) \quad [kN]$$

P : single force $[kN]$ acting on cargo deck

C.1.4 The load p_L due to bulk cargoes is to be determined by the following formula:

$$p_L = p_C \cdot (1 + a_v) \quad [kN/m^2]$$

p_C : static bulk cargo load $[kN/m^2]$, defined as:

$$p_C = 9.81 \cdot \rho_c \cdot h \cdot n$$

h : distance $[m]$ between upper edge of cargo and the load centre

n : coefficient, defined as:

$$n = \tan^2\left(45° - \frac{\gamma}{2}\right) \cdot \sin^2\alpha + \cos^2\alpha$$

α : angle [°] between the structural element considered and a horizontal plane

γ : angle [°] of repose of the cargo

C.2 Load on inner bottom

C.2.1 The load p_I on the inner bottom is to be determined by the following formula:

$$p_I = 9.81 \cdot \frac{G}{V} \cdot h \cdot (1 + a_v) \quad [kN/m^2]$$

G : mass $[t]$ of cargo in the hold

V : volume $[m^3]$ of the hold (hatchways excluded)

h : height $[m]$ of the highest point of the cargo above the inner bottom, assuming hold to be completely filled

a_v : acceleration addition according to A.3. For calculating a_v the distance between the centre of gravity of the hold and the aft end of the length $\mathbf{L}$ is to be taken.

For inner bottom load in case of ore stowed in conical shape, see C.1.4.

C.2.2 The load $p_{f\ell}$ on the inner bottom in flooded condition is to be determined by the following formula:

$$p_{f\ell} = 10 \cdot (\mathbf{T} - h_{DB})$$

h_{DB} : double bottom height $[m]$

C.3 Loads on accommodation and machinery decks

The load p_{AD} in accommodation and service spaces and the load p_{MD} on machinery decks are to be determined by the following formulae:

$$p_{AD} = 3.5 \cdot (1 + a_v) \quad [kN/m^2]$$

$$p_{MD} = 8.0 \cdot (1 + a_v) \quad [kN/m^2]$$

Significant single forces on accommodation and machinery decks are also to be considered, if necessary.

D Loads on Tank Structures

D.1 Loads for filled tanks

D.1.1 The load p_{T1} on tank structures for service conditions is to be determined by the following formula:

$$p_{T1} = \max\left[p_{T11}\ ;\ p_{T12}\right]$$

$$p_{T11} = 9.81 \cdot h_1 \cdot \rho \cdot \left(1 + a_v\right) + 100 \cdot p_v \quad [\mathrm{kN/m^2}]$$

$$p_{T12} = 9.81 \cdot \rho \cdot \left(h_1 \cdot \cos\varphi + \left(0.3 \cdot b + y'\right) \cdot \sin\varphi\right) + 100 \cdot p_v \quad [\mathrm{kN/m^2}]$$

h_1 : distance from load centre to tank top $[\mathrm{m}]$

φ : design heeling angle $[°]$ for tanks, defined as:

$\varphi = \arctan\left(f_{bk} \cdot \dfrac{\mathbf{H}}{\mathbf{B}}\right)$ in general

$\varphi \geq 20°$ for hatch covers of holds carrying liquids

f_{bk} : coefficient, defined as:

$f_{bk} = 0.5$ for ships with bilge keel

$f_{bk} = 0.6$ for ships without bilge keel

b : upper breadth $[\mathrm{m}]$ of tank

y' : distance $[\mathrm{m}]$ of load centre from the vertical longitudinal central plane of tank

D.1.2 The maximum static load p_{T2} on tank structures is to be determined by the following formula:

$$p_{T2} = 9.81 \cdot h_2 \quad [\mathrm{kN/m^2}]$$

h_2 : load height $[\mathrm{m}]$, defined as:

$$h_2 = \max\left[h_{2,1}\ ;\ h_{2,2}\ ;\ h_{2,3}\ ;\ h_{2,4}\right]$$

$h_{2,1}$: distance $[\mathrm{m}]$ from load centre to top of overflow according to Section 21, F. Tank venting pipes of cargo tanks of tankers are not to be regarded as overflow pipes.

$h_{2,2}$: distance $[\mathrm{m}]$ from load centre to a point $2.5 \cdot \rho$ $[\mathrm{m}]$ above tank top. Density of liquid intended to be carried is not to be taken less than $1\ \mathrm{t/m^3}$.

$h_{2,3}$: distance $[\mathrm{m}]$ from load centre to the highest point of overflow system, if the tank is connected to such a system.

The dynamic pressure increase due to overflowing is to be taken into account (see also the Guidelines for the Construction, Equipment and Testing of Closed Fuel Oil Overflow Systems (VI-3-6)).

$h_{2,4}$: distance $[\mathrm{m}]$ from load centre to a point $10 \cdot p_v$ $[\mathrm{m}]$ above tank top, if a pressure relief valve is fitted. Set pressure p_v of pressure relief valve is not to be taken less than $0.25 \cdot \rho$ $[\mathrm{bar}]$.

D.2 Load for partially filled tanks

D.2.1 For tanks which may be partially filled between 20 % and 90 % of their height, the design pressure p_{T3} is not to be taken less than determined by the following formulae:

D.2.1.1 For structures located within $\ell_t / 4$ from the bulkheads limiting the free liquid surface in the ship's longitudinal direction:

$$p_{T3} = \left(4.0 - \frac{\mathbf{L}}{150}\right) \cdot \ell_t \cdot \rho \cdot n_x + 100 \cdot p_v \quad [\text{kN/m}^2]$$

ℓ_t : distance $[\text{m}]$ between transverse bulkheads or effective transverse wash bulkheads at the height where the structure is located

n_x : distribution factor, defined as:

$$n_x = 1 - \frac{4}{\ell_t} \cdot x_1$$

x_1 : distance $[\text{m}]$ of structural element from the tank's ends in the ship's longitudinal direction

D.2.1.2 For structures located within $b_t / 4$ from the bulkheads limiting the free liquid surface in the ship's transverse direction:

$$p_{T3} = \left(5.5 - \frac{\mathbf{L}}{20}\right) \cdot b_t \cdot \rho \cdot n_y + 100 \cdot p_v \quad [\text{kN/m}^2]$$

b_t : distance $[\text{m}]$ between tank sides or effective longitudinal wash bulkhead at the height where the structure is located

n_y : distribution factor, defined as:

$$n_y = 1 - \frac{4}{b_t} \cdot y_1$$

y_1 : distance $[\text{m}]$ of structural element from the tank's sides in the ship's transverse direction

D.2.2 For tanks with ratios $\ell_t / \mathbf{L} > 0.1$ or $b_t / \mathbf{B} > 0.6$ a direct calculation of the pressure p_{T3} may be required.

E Design Values of Acceleration Components

E.1 Acceleration components

The following formulae may be taken for guidance when calculating the acceleration components owing to ship's motions. The accelerations a_x, a_y and a_z are maximum dimensionless accelerations (i.e., relative to the acceleration of gravity g) in the related directions x, y and z. For calculation purposes they are considered to act separately.

$$a_x = \pm a_0 \cdot \sqrt{0.06 + A^2 - 0.25 \cdot A}$$

for longitudinal acceleration (in longitudinal direction) due to surge and pitch including gravity component of pitch

$$a_y = \pm a_0 \cdot \sqrt{0.6 + 2.5 \cdot \left(\frac{x}{\mathbf{L}} - 0.45\right)^2 + k \cdot \left(1 + 0.6 \cdot k \cdot \frac{z - \mathbf{T}}{\mathbf{B}}\right)^2}$$

for transverse acceleration (vertical to the ship's side) due to sway, yaw and roll including gravity component of roll

$$a_z = \pm a_0 \cdot \sqrt{1 + \left(5.3 - \frac{45}{\mathbf{L}}\right)^2 \cdot \left(\frac{x}{\mathbf{L}} - 0.45\right)^2 \cdot \left(\frac{0.6}{C_B}\right)^{1.5}}$$

for vertical acceleration (vertical to the base line) due to heave and pitch

a_0 : basic acceleration, defined as:

$$a_0 = \left(0.2 \cdot \frac{v_0}{\sqrt{\mathbf{L}_{100}}} + \frac{3 \cdot c_0 \cdot c_L}{\mathbf{L}_{100}}\right) \cdot f_Q$$

f_Q : probability factor for a straight-line spectrum of seaway-induced stress ranges depending on probability level Q, defined as:

$f_Q = 1.000$ for $Q = 10^{-8}$

$f_Q = 0.875$ for $Q = 10^{-7}$

$f_Q = 0.750$ for $Q = 10^{-6}$

$f_Q = 0.625$ for $Q = 10^{-5}$

$f_Q = 0.500$ for $Q = 10^{-4}$

A : coefficient, defined as:

$$A = \left(0.7 - \frac{\mathbf{L}}{1200} + 5 \cdot \frac{z - \mathbf{T}}{\mathbf{L}}\right) \cdot \frac{0.6}{C_B}$$

k : factor to take the ratio of metacentric height to breath of the ship into account, defined as:

$$k = \frac{13 \cdot \overline{GM}}{\mathbf{B}}$$ with $k \geq 1.0$

$\overline{GM}$: metacentric height $[m]$

E.2 Combined acceleration

The combined acceleration a_φ may be determined by means of the "acceleration ellipse" according to Fig. 4.2 (e.g. y-z-plane).

φ : heeling angle

φ_{max} : maximum heeling angle

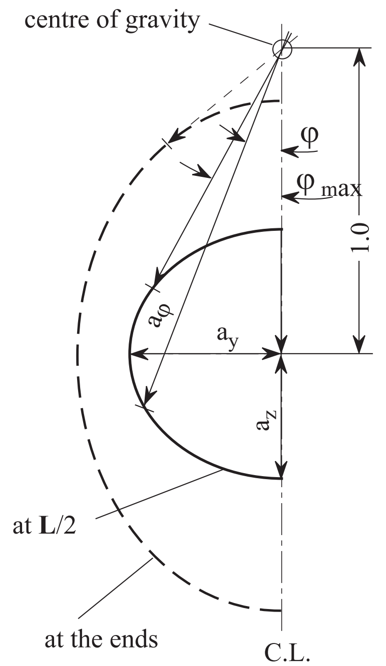


Fig. 4.2 Acceleration ellipse

Section 5 Longitudinal Strength

A General

A.1 Application

A.1.1 For ships of $65\ \mathrm{m}$ in length and more the scantlings of the longitudinal hull structure are to be determined on the basis of longitudinal bending moments and shear forces calculations according to this section. For ships of less than $65\ \mathrm{m}$ in length, the minimum midship section modulus according to E.1.2.2 is to be fulfilled.

A.1.2 For ships having one or more of the following characteristics, GL may require determination of wave bending moments as well as their distribution over the ship's length and a complex stress analysis by approved calculation procedures (see also Guideline for Analysis Techniques V). Such calculation procedures have to take into account the ship's motions in a natural seaway and all relevant loading conditions.

Ship characteristics:

- unusual type or design
- unusual form (e.g. $\mathbf{L}/\mathbf{B} \le 5$, $\mathbf{B}/\mathbf{H} \ge 2.5$, $\mathbf{L} \ge 500\ \mathrm{m}$, $C_B < 0.6$)
- ships with large deck openings
- ships with large bow and stern flare and cargo on deck in these areas
- carriage of heated cargoes
- ship speed of $v_0 \ge 1.6 \cdot \sqrt{\mathbf{L}}\quad [\mathrm{kn}]$

  (IACS UR S11.1)

A.1.3 The wave bending moments and shear forces specified under D.1.3 are design values which, in connection with the scantling formulae, correspond to a probability level of $Q = 10^{-8}$. Reduced values may be used for the purpose of determining combined stresses as specified under D.2.

A.2 References

A.2.1 Paragraphs of this section are based on the following international convention(s) and / or code(s):

IACS UR S1 Rev.7

IACS UR S5 Rev.1

IACS UR S7 Rev.4

IACS UR S11 Rev.7

ICLL Annex 1, II, 10

At the end of each relevant paragraph, the corresponding paragraphs of the international convention(s) and / or code(s) are given in brackets.

A.2.2 For specific ship types reference is made to:

- for bulk carriers, ore carriers and combination carriers see Section 23, C.2
- for liquefied gas tankers see Liquefied Gas Tankers (I-1-6), Section 4, 4.2.6.4

A.3 Definitions

c_0 : wave coefficient according to Section 4, A.3

C_B : block coefficient according to Section 1, A.3.1.1. C_B is not to be taken less than 0.6.

c_L : length coefficient according to Section 4, A.3

e_B : distance $[m]$ between neutral axis of hull section and base line

e_D : distance $[m]$ between neutral axis of hull section and deck line at side

e_y : horizontal distance $[m]$ of the structure considered from the vertical, neutral axis (e_y is positive at the port side and negative at the starboard side)

e_z : vertical distance $[m]$ of the structural element considered from the horizontal neutral axis (positive sign for above the neutral axis, negative sign for below)

I_y : moment of inertia $[m^4]$ of the midship section around the horizontal axis at the position $x / \mathbf{L}$

I_z : moment of inertia $[m^4]$ of the transverse ship section considered around the vertical axis at the position $x / \mathbf{L}$

k : material factor according to Section 2, A.2

x : distance $[m]$ between aft end of $\mathbf{L}$ and the position considered

$\mathbf{L}_{100}$: corresponds to the length of the ship as $\mathbf{L}$, but $\mathbf{L}_{100}$ is not to be taken less than 100 m

$\mathbf{L}_{200}$: corresponds to the length of the ship as $\mathbf{L}$, but $\mathbf{L}_{200}$ is not to be taken greater than 200 m

M_{SW} : vertical still water bending moment at position $x / \mathbf{L}$ as according to D.1.2

$M_{SW} = M_{SW,max}$ for maximum still water bending moment

$M_{SW} = M_{SW,min}$ for minimum still water bending moment

M_{WV} : vertical wave bending moment at position $x / \mathbf{L}$ according to D.1.3.1

$M_{WV} = M_{WV,hog}$ for hogging condition

$M_{WV} = M_{WV,sag}$ for sagging condition

M_T : total vertical bending moment at position $x / \mathbf{L}$ according to D.1.1.3

M_{WH} : horizontal wave bending moment at position $x / \mathbf{L}$ according to D.1.3.3

M_{ST} : static torsional moment at position $x / \mathbf{L}$ according to D.1.2.1.2

M_{STmax} : maximum static torsional moment according to D.1.2.1.2

M_{WT} : wave induced torsional moment at position $x / \mathbf{L}$ according to D.1.3.5

M_{WTmax} : maximum wave induced torsional moment according to D.1.3.5

Q_{SW} : vertical still water shear force at position $x / \mathbf{L}$ according to D.1.2

$Q_{SW} = Q_{SW,max}$ for maximum still water shear force

$Q_{SW} = Q_{SW,min}$ for minimum still water shear force

Q_{WV} : vertical wave shear force at position $x / \mathbf{L}$ according to D.1.3.2

$Q_{WV} = Q_{SW,max}$ for maximum wave shear force

$Q_{WV} = Q_{SW,min}$ for minimum wave shear force

Q_T : total vertical shear force at position $x / \mathbf{L}$ according to D.1.1.3

Q_{WH} : horizontal wave shear force at position $x / \mathbf{L}$ according to D.1.3.4

σ_{SW} : normal stresses due to still water bending moment according to D.2.4.1.1

$\sigma_{SW} = \sigma_{SW,max}$ in case of maximum still water bending moment

$\sigma_{SW} = \sigma_{SW,min}$ in case of minimum still water bending moment

σ_{WV} : normal stresses due to vertical wave bending moment according to D.2.4.1.1

$\sigma_{WV} = \sigma_{SW,hog}$ in case of hogging condition

$\sigma_{WV} = \sigma_{SW,sag}$ in case of sagging condition

σ_{WH} : normal stresses due to horizontal bending moment according to D.2.4.1.2

σ_{ST} : normal stresses due to static torsional moment according to D.2.4.1.3

σ_{WT} : normal stresses due to wave induced torsional moment according to D.2.4.1.3

τ_{SW} : shear stress due to vertical still water shear force according to D.2.4.2.1

$\tau_{SW} = \tau_{SW,max}$ in case of maximum still water shear force

$\tau_{SW} = \tau_{SW,min}$ in case of minimum still water shear force

τ_{WV} : shear stress due to vertical wave shear force according to D.2.4.2.1

$\tau_{WV} = \tau_{WV,max}$ in case of maximum vertical wave shear force

$\tau_{WV} = \tau_{WV,min}$ in case of minimum vertical wave shear force

τ_{WH} : shear stress due to horizontal wave shear force according to D.2.4.2.2

τ_{ST} : shear stress due to static torsional moment according to D.2.4.2.3

τ_{WT} : shear stress due to wave induced torsional moment according to D.2.4.2.3

Sign rule see Fig. 5.1.

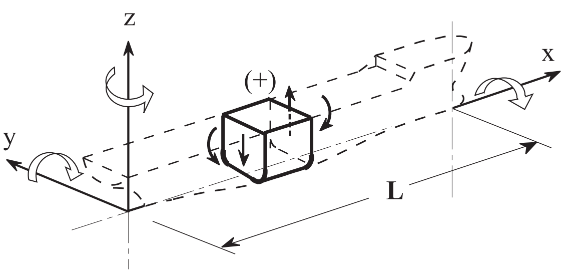


Fig. 5.1 Sign rule

Note

According to Fig. 5.1 hogging moments have positive signs and sagging moments negative signs. The denotation of moments by maximum or minimum respectively relates to true values (considering signs).

B Design Loading Conditions

B.1 General

B.1.1 In general, the design cargo and ballast loading conditions, based on amount of bunker, fresh water and stores at departure and arrival, as defined in B.2, are to be considered for the still water bending moment M_{SW} and shear force Q_{SW} calculations.

Where the amount and disposition of consumables at any intermediate stage of the voyage are considered to result in a more severe loading condition, 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 conditions 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.

(IACS UR S11.2.1.2)

B.2 Ship type related loading conditions

For Dry-Cargo Ships, Containerships, Ro-Ro Ships, 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 voyages or harbour conditions, where applicable
- docking conditions afloat
- loading and unloading transitory conditions, where applicable
- all loading conditions specified in Section 23, G for ships with Notations **BC-A**, **BC-B** or **BC-C**, where applicable

For oil tankers (see also Section 24, H):

- 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 conditions afloat
- loading and unloading transitory conditions

For chemical tankers:

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

For 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 conditions for which an increased vapour pressure has been approved (see the GL Rules for Liquefied Gas Tankers (I-1-6), Section 4, 4.2.6.4),

- docking conditions afloat

For combination carriers:

- conditions as specified for oil tankers and cargo ships

  (IACS UR S11.2.1.2 and IACS UR S1 Annex 1)

B.3 Special ship types and cargos

B.3.1 For other ship types than listed in B.2 and special ships, the calculation of bending moments and shear forces for loading conditions according to the intended service may be required to be investigated.

B.3.2 When a ship is intended to carry special cargoes (e.g. logs) the loading, stowage and discharging of which may cause considerable stressing of structures in way of the cargo holds, such structures are to be investigated for their ability to withstand these loads.

B.4 Ballast conditions

For ballast water exchange see also the GL Guidelines on Ballast Water Management (VI-11-10)

B.4.1 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 considered as design conditions, unless:

- design stress limits are not exceeded in all filling levels between empty and full;
- for bulk carriers, where applicable, the requirements of Section 23, C.2 are 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 C.3.3.1 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 $0.03\,\mathbf{L}$, or
- trim by bow of $0.015\,\mathbf{L}$, or
- any trim that cannot maintain propeller immersion (I / D) not less than $25\ \%$

I : the distance from propeller centreline to the waterline

D : propeller diameter

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

(IACS UR S11.2.1.3)

B.4.2 Partially filled ballast tanks in cargo loading conditions

In such cargo loading conditions, the requirements in B.4.1 apply to the peak tanks only.

(IACS UR S11.2.1.4)

B.4.3 Sequential ballast water exchange

Requirements of B.4.1 and B.4.2 are not applicable to ballast water exchange using the sequential method. However, bending moment and shear force calculations for each (reasonable, scantling determining) deballasting or ballasting stage in the ballast water exchange sequence are to be included in the loading manual or ballast water management plan of any vessel that intends to employ the sequential ballast water exchange method.

(IACS UR S11.2.1.5)

C Loading Guidance Information

C.1 General

C.1.1 The master of every new ship is to be supplied with information to arrange for the loading and ballasting of his ship in such a way as to avoid the creation of any unacceptable stresses in the ship's structure, provided that this requirement need not apply to any particular length, design or class of ship where the Administration considers it to be unnecessary.

(ICLL Annex 1, II, 10 (1))

C.1.2 Information are to be provided to the master in a form that is approved by the Administration or a recognised organisation. Stability information and loading information also related to ship strength when required under C.1.1, are to be carried on board at all times together with evidence that the information has been approved by the Administration.

(ICLL Annex 1, II, 10 (2))

Note

Upon request, GL will prepare the loading guidance information.

C.1.3 Where any alterations are made to a ship so as to materially affect the loading or stability information supplied to the master, amended information is to be provided. If necessary, the ship is to be re-inclined.

(ICLL Annex 1, II, 10 (4))

C.2 Category I and II ships

Ship categories are defined for all classed seagoing ships of 65 m in length and above which were contracted for construction on or after 1st July 1998 as follows:

- Category I Ships:
  - Ships with large deck openings where, according to E.8, combined stresses due to vertical and horizontal hull girder bending and torsional and lateral loads have to be considered.
  - Chemical tankers and gas carriers.
  - Ships liable to carry non-homogeneous loadings, where the cargo and/or ballast may be unevenly distributed. Ships less than 120 m in length, when their design takes into account uneven distribution of cargo or ballast, belong to Category II.
- Category II Ships:
  - Ships with arrangement giving small possibilities for variation in the distribution of cargo and ballast (e.g. passenger vessels).
  - Ships on regular and fixed trading patterns where the loading manual gives sufficient guidance.
  - The exception given under Category I.

(IACS UR S1.1.1 and S1.1.2)

C.3 Loading manual

C.3.1 General

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

(IACS UR S1.2.1)

C.3.2 Definition

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 and shear force correction values and, where applicable, permissible limits related to still water torsional moment and lateral loads
- the results of calculations of still water bending moments, shear forces and still water torsional moments if unsymmetrical loading conditions with respect to the ships centreline
- the allowable local loadings for the structure (hatch covers, decks, double bottom, etc.)

(IACS UR S1.1.2)

C.3.3 Content

The loading manual should contain the design and ballast conditions as defined in B, subdivided into departure and arrival conditions, and ballast exchange at sea conditions, where applicable, upon which the approval of the hull scantlings is based.

(IACS UR S1 Annex 1)

C.3.4 Conditions of approval

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.

B contains, as guidance only, a list of the loading conditions which, in general, are to be included in the loading manual.

In case of modifications resulting in changes in the main data of the ship, a newly approved loading manual is to be issued.

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

(IACS UR S1.2.2)

C.4 Loading instrument

C.4.1 General

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

(IACS UR S1.2.1)

In special cases, e.g. extreme loading conditions or unusual structural configurations, GL may also require an approved loading instrument for ships of Category I less than 100 m in length.

Note

For definition of the whole loading computer system, which may consist of further modules e.g. stability computer according to IACS UR L5, see the GL Guidelines for Loading Computer Systems (VI-11-7).

C.4.2 Definition

A loading instrument is an approved analogue or digital instrument consisting of

- loading computer (hardware) and
- loading program (software)

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

Single point loading programs are not acceptable.

(IACS UR S1.1.2)

C.4.3 Approval

For approval of the loading instrument see GL Guidelines for Loading Computer Systems VI-11-7.

C.5 Class maintenance of loading guidance information

At each Annual and Class Renewal 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 Class Renewal Survey this checking is to be checked in the presence of the Surveyor.

(UR S1.1.3)

D Global Loads on the Ship's Hull and Design Stresses

D.1 Global loads

D.1.1 General

D.1.1.1 The global loads on the ship's hull in a seaway are to be based on still water and wave induced bending moments and shear forces for intact condition of the ship and if required also for damage conditions (see Section 23, C.2.).

If static torsional moments M_{ST} are likely to be expected from the loading or construction of the ship, they have to be taken into account.

D.1.1.2 Still water bending moments M_{SW} and still water shear forces Q_{SW} are to be calculated at each cross section along the ship length for design cargo and ballast loading conditions as specified in B.

(IACS UR S11.2.1.1)

D.1.1.3 For the calculation of the minimum hull girder scantlings at each cross section along the ship length, the envelope curves of the total vertical bending moment M_T and vertical still water shear force Q_T are to be considered.

The total vertical loads (M_T and Q_T) are to be determined by superimposition of the envelope curves of still water loads (M_{SW} and Q_{SW}) with the curves of wave loads (M_{WV} and Q_{WV}) such that the most unfavourable values result.

Related to the design verifications in E the most unfavourable values of the total vertical bending moment M_T can be the minimum or the maximum vertical bending moment. These moments are to be determined by the following combinations:

- $M_T = M_{SW,max} + M_{WV,hog}$ for the maximum vertical bending moment, or
- $M_T = M_{SW,min} + M_{WV,sag}$ for the minimum vertical bending moment

The total vertical shear force Q_T is to be determined by the following formula:

- $Q_T = \max\begin{bmatrix} Q_{SW,max} + Q_{WV,max} \; ; \\ \left|Q_{SW,min} + Q_{WV,min}\right| \end{bmatrix}$

D.1.2 Still water loads

D.1.2.1 Ships with container loading

D.1.2.1.1 Still water bending moments for container ships for initial design

When determining the required section modulus of the midship section of container ships in the range

$$\frac{x}{\mathbf{L}} = 0.3 \quad \text{to} \quad \frac{x}{\mathbf{L}} = 0.55$$

it is recommended to use at least the following initial value for the hogging still water bending moment:

$$M_{SW,ini} = n_1 \cdot c_0 \cdot \mathbf{L}^2 \cdot \mathbf{B} \cdot \left(0.123 - 0.015 \cdot C_B\right) \quad [\text{kNm}]$$

n_1 : factor to take into account the total mass of 20'-containers (TEU) the ship can carry, taken as:

$$n_1 = 1.07 \cdot \left(1 + 15 \cdot \left(\frac{n}{10^5}\right)^2\right) \qquad \text{with } n_1 \le 1.2$$

n : maximum number of 20'-containers (TEU) of the mass G the ship can carry

The initial hogging still water bending moment M_{SWini} is to be graduated regularly to ship's ends.

D.1.2.1.2 Static torsional moment

The maximum static torsional moment may be determined by the following formula:

$$M_{ST,max} = \pm 20 \cdot \mathbf{B} \cdot \sqrt{CC} \quad [\text{kNm}]$$

For the purpose of a direct calculation the following envelope curve of the static torsional moments over the ship's length is to be determined by the following formula:

$$M_{ST} = 0.568 \cdot M_{ST,max} \cdot \left(\left|c_{T1}\right| + c_{T2}\right) \quad [\text{kNm}]$$

CC : maximum permissible cargo capacity $[t]$ resulting from the maximum number n of 20'-containers (TEU) of the mass G the ship can carry, taken as:

$$CC = n \cdot G$$

c_{T1}, c_{T2} : distribution factors according to Table 5.1 and Table 5.2

Table 5.1 Distribution factor c_{T1}

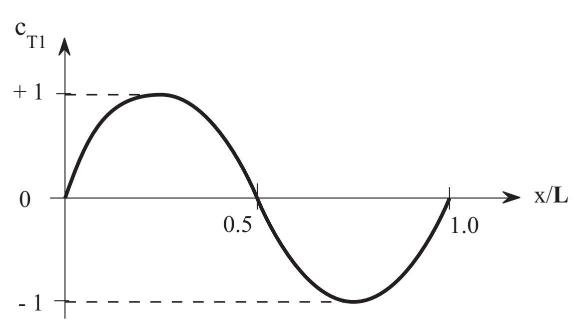
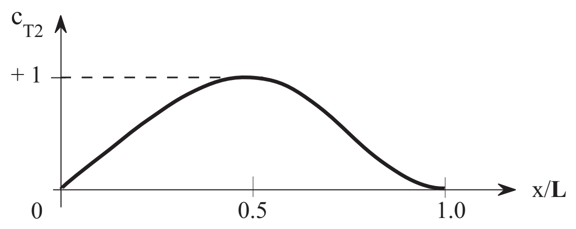
Range	Value	Distribution over the ship's length
$0 \le \frac{x}{\mathbf{L}} < 0.25$	$c_{T1} = \sin^{0.5} \cdot \left(2 \cdot \pi \cdot \frac{x}{\mathbf{L}}\right)$	
$0.25 \le \frac{x}{\mathbf{L}} \le 1$	$c_{T1} = \sin \cdot \left(2 \cdot \pi \cdot \frac{x}{\mathbf{L}}\right)$	

Table 5.2 Distribution factor c_{T2}

Range	Value	Distribution over the ship's length
$0 \le \frac{x}{\mathbf{L}} < 0.5$	$c_{T2} = \sin\cdot\left(\pi\cdot\frac{x}{\mathbf{L}}\right)$	
$0.5 \le \frac{x}{\mathbf{L}} \le 1$	$c_{T2} = \sin^2\cdot\left(\pi\cdot\frac{x}{\mathbf{L}}\right)$	

D.1.3 Wave induced loads

D.1.3.1 Vertical wave bending moments

The vertical wave bending moments M_{WV} over the ship's length for hogging and sagging condition are to be determined by the following formula:

$$M_{WV} = \mathbf{L}^2\cdot\mathbf{B}\cdot c_0\cdot c_1\cdot c_L\cdot c_M \quad [\text{kNm}]$$

c_1 : coefficient, defined as:

$c_1 = 0.19\cdot C_B$ for hogging condition

$c_1 = -0.11\cdot(C_B + 0.7)$ for sagging condition

c_M : distribution factors according to Table 5.3

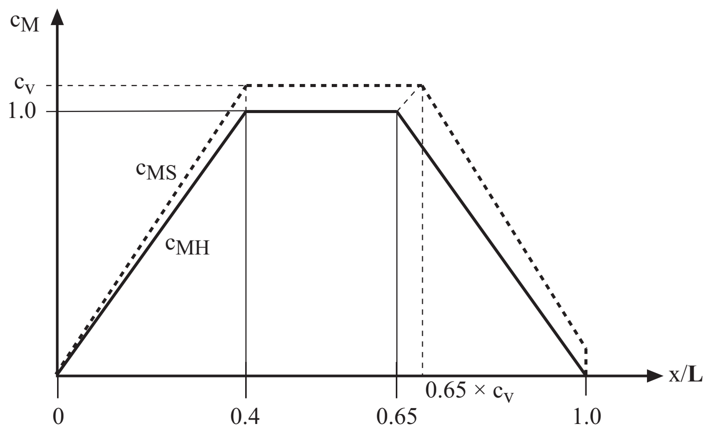
c_v : factor to take into account the ship's speed v_0, defined as:

$c_v = \sqrt[3]{\frac{v_0}{1.4\cdot\sqrt{\mathbf{L}_{100}}}} \ge 1.0$ for intact condition

$c_v = 1$ for damaged condition

Table 5.3 Distribution factor c_M

hogging condition		sagging condition	
Range	**Value**	**Range**	**Value**
$0 \le \frac{x}{\mathbf{L}} < 0.40$	$2.5\cdot\frac{x}{\mathbf{L}}$	$0 \le \frac{x}{\mathbf{L}} < 0.40$	$2.5\cdot c_v\cdot\frac{x}{\mathbf{L}}$
$0.40 \le \frac{x}{\mathbf{L}} \le 0.65$	1	$0.40 \le \frac{x}{\mathbf{L}} \le 0.65\cdot c_v$	c_v
$0.65 < \frac{x}{\mathbf{L}} \le 1$	$\frac{1-\frac{x}{\mathbf{L}}}{0.35}$	$0.65\cdot c_v < \frac{x}{\mathbf{L}} \le 1$	$c_v - \frac{\frac{x}{\mathbf{L}} - 0.65\cdot c_v}{1-0.65\cdot c_v}$

Distribution over the ship's length


(IACS UR S11.2.2.1)

D.1.3.2 Vertical wave shear forces

The vertical wave shear forces Q_{WV} over the ship's length are to be determined by the following formula:

$$Q_{WV} = c_0 \cdot c_L \cdot \mathbf{L} \cdot \mathbf{B} \cdot \left(C_B + 0.7\right) \cdot c_Q \quad [\mathrm{kN}]$$

c_Q : distribution factor according to Table 5.4

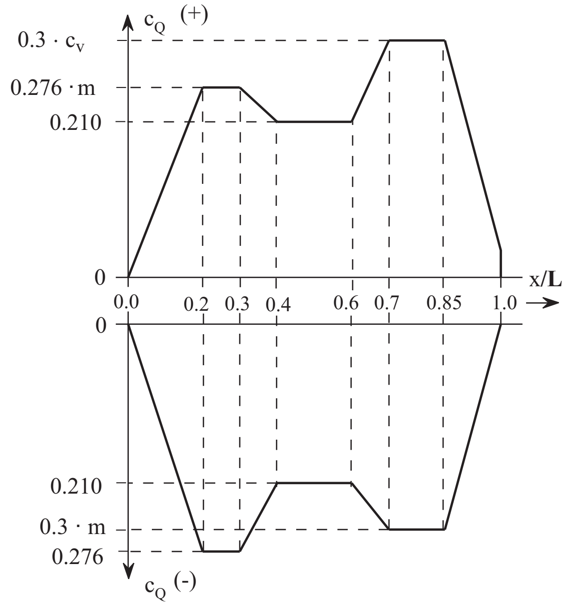
m : coefficient, defined as:

$$m = -\frac{c_1 \text{ for hogging condition}}{c_1 \text{ for sagging condition}}$$

c_1 : coefficients according to D.1.3.1

Table 5.4 Distribution factor c_Q

Range	for positive shear forces	for negative shear forces
$0 \le \frac{x}{\mathbf{L}} < 0.20$	$1.38 \cdot m \cdot \frac{x}{\mathbf{L}}$	$-1.38 \cdot \frac{x}{\mathbf{L}}$
$0.20 \le \frac{x}{\mathbf{L}} < 0.30$	$0.276 \cdot m$	-0.276
$0.30 \le \frac{x}{\mathbf{L}} < 0.40$	$1.104 \cdot m - 0.63 + \left(2.1 - 2.76 \cdot m\right) \cdot \frac{x}{\mathbf{L}}$	$-\left(0.474 - 0.66 \cdot \frac{x}{\mathbf{L}}\right)$
$0.40 \le \frac{x}{\mathbf{L}} < 0.60$	0.21	-0.21
$0.60 \le \frac{x}{\mathbf{L}} < 0.70$	$\left(3 \cdot c_v - 2.1\right) \cdot \left(\frac{x}{\mathbf{L}} - 0.6\right) + 0.21$	$-\left(1.47 - 1.8 \cdot m + 3 \cdot \left(m - 0.7\right) \cdot \frac{x}{\mathbf{L}}\right)$
$0.70 \le \frac{x}{\mathbf{L}} < 0.85$	$0.3 \cdot c_v$	$-0.3 \cdot m$
$0.85 \le \frac{x}{\mathbf{L}} \le 1$	$\frac{1}{3} \cdot \left[c_v \cdot \left(14 \cdot \frac{x}{\mathbf{L}} - 11\right) - 20 \cdot \frac{x}{\mathbf{L}} + 17\right]$	$-2 \cdot m \cdot \left(1 - \frac{x}{\mathbf{L}}\right)$

Distribution over the ship's length


(IACS UR S11.2.2.2)

D.1.3.3 Horizontal bending moments

The horizontal bending moments M_{WH} over the ship's length are to be determined by the following formula:

$$M_{WH} = 0.32 \cdot \mathbf{L} \cdot Q_{WH,max} \cdot c_M \quad [kNm]$$

$Q_{WH,max}$: maximum horizontal shear force according to D.1.3.4

c_M : distribution factors according to Table 5.3, but in case of sagging condition for $c_v = 1$

D.1.3.4 Horizontal shear forces

The maximum horizontal shear force $Q_{WH,max}$ is to be determined by the following formula:

$$Q_{WH,max} = \pm c_N \cdot \sqrt{\mathbf{L} \cdot \mathbf{T}} \cdot \mathbf{B} \cdot C_B \cdot c_0 \cdot c_L \quad [kN]$$

The horizontal shear forces Q_{WH} over the ship's length are to be determined by the following formula:

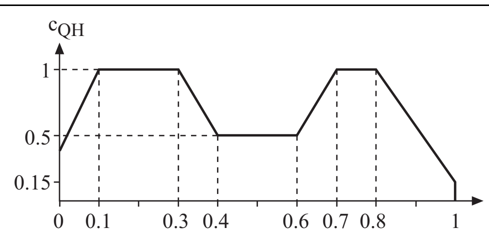
$$Q_{WH} = Q_{WH,max} \cdot c_{QH} \quad [kN]$$

c_N : coefficient, defined as:

$$c_N = 1 + 0.15 \cdot \frac{\mathbf{L}}{\mathbf{B}} \qquad \text{with } c_N \geq 2.0$$

c_{QH} : distribution factor according to Table 5.5

Table 5.5 Distribution factor c_{QH}

Range	c_{QH}	Distribution over the ship's length
$0 \leq \frac{x}{\mathbf{L}} < 0.1$	$0.4 + 6 \cdot \frac{x}{\mathbf{L}}$	
$0.1 \leq \frac{x}{\mathbf{L}} \leq 0.3$	1	
$0.3 < \frac{x}{\mathbf{L}} < 0.4$	$1.0 - 5 \cdot \left(\frac{x}{\mathbf{L}} - 0.3\right)$	

$0.4 \le \frac{x}{\mathbf{L}} \le 0.6$	0.5	
$0.6 < \frac{x}{\mathbf{L}} < 0.7$	$0.5 + 5 \cdot \left(\frac{x}{\mathbf{L}} - 0.6\right)$	
$0.7 \le \frac{x}{\mathbf{L}} \le 0.8$	1	
$0.8 < \frac{x}{\mathbf{L}} \le 1$	$1 - 4.25 \cdot \left(\frac{x}{\mathbf{L}} - 0.8\right)$	

D.1.3.5 Torsional moments

The maximum wave induced torsional moment $M_{WT,max}$ is to be determined by the following formula:

$$M_{WT,max} = \pm\mathbf{L} \cdot \mathbf{B}^2 \cdot C_B \cdot c_0 \cdot c_L \cdot \left[0.11 + \sqrt{a^2 + 0.012}\right] \quad [\text{kNm}]$$

For the purpose of a direct calculation the envelope curve of the wave induced torsional moments M_{WT} over the ship's length are to be determined by the following formula:

$$M_{WT} = \pm\mathbf{L} \cdot \mathbf{B}^2 \cdot C_B \cdot c_0 \cdot c_L \cdot c_{WT} \quad [\text{kNm}]$$

c_{WT} : distribution factor (see also Fig. 5.2), defined as:

$$c_{WT} = \left(a \cdot |c_{T1}| + 0.22 \cdot c_{T2}\right) \cdot \left(0.9 + 0.08 \cdot a\right)$$

a : coefficient, defined as:

$$a = \sqrt{\frac{\mathbf{T}}{\mathbf{L}} \cdot \frac{c_N \cdot z_Q}{\mathbf{B}}} \qquad \text{with } a \ge 0.1$$

c_N : coefficient according to D.1.3.4

z_Q : distance $[m]$ between shear centre and a level at $0.2 \cdot \frac{\mathbf{B} \cdot \mathbf{H}}{\mathbf{T}}$ above the basis

c_{T1}, c_{T2} : distribution factors according to Table 5.1 and Table 5.2

Note

The envelope can be approximated by superposition of both distributions according to the figures in Table 5.1 and Table 5.2.

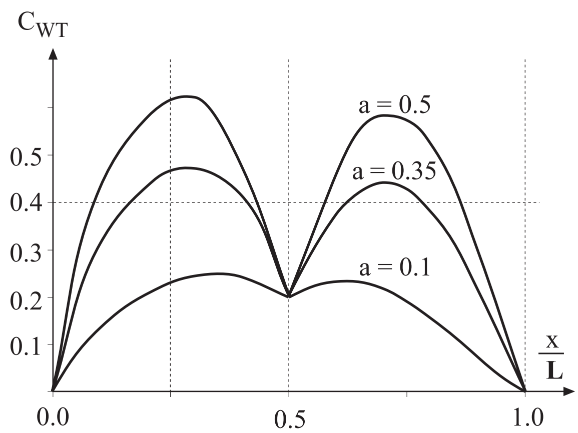


Fig. 5.2 Distribution factor c_{WT}

D.2 Design Stresses

D.2.1 Definition

Design stresses are global load stresses, which are acting:

- as normal stresses σ_L in ship's longitudinal direction:
  - for plates as membrane stresses
  - for longitudinal profiles and longitudinal girders in the bar axis
- shear stresses τ_L in the plate level

D.2.2 Calculation

The calculation of the design stresses σ_L and τ_L can be carried out by approved calculation procedures (see A.1.2 and also Guidelines for Analysis Techniques V).

If no such calculation is carried out, the standard load cases according to D.2.3 are to be considered to determine the design stresses σ_L and τ_L.

D.2.3 Standard load cases

D.2.3.1 The standard load cases $L_{1a} - L_{3b}$ are listed in Table 5.6 and they cover the following combinations of global moments and shear forces:

- $L_{1a,b}$: load caused by vertical bending moments and static torsional moment
- $L_{2a,b}$: vertical and horizontal bending moments as well as static torsional moment
- $L_{3a,b}$: vertical and horizontal bending moments as well as static and wave induced torsional moments

The denotations a and b are representing different weightings of moments and shear forces in a load case.

The stresses and factors included in Table 5.6 are defined as:

f_F : weighting factor for the simultaneousness of global and local loads, defined as:

$f_F = 0.80$ for dimensioning of longitudinal structures

$$f_F = 0.75 + \frac{x}{\mathbf{L}} \cdot \left(1 - \frac{x}{\mathbf{L}}\right)$$ for fatigue strength calculations

f_Q : probability factor according to Section 4, E.1, with:

$f_{Q,min} = 0.75$ for $Q = 10^{-6}$

Note

f_Q is a function of the design lifetime. For a lifetime of n > 20 years, f_Q may be determined by the following formula for a straight-line spectrum of seaway-induced stress ranges:

$$f_Q = -0.125 \cdot \log\left(\frac{2 \cdot 10^{-5}}{n}\right)$$

Note

For the preliminary determination of the scantlings, it is generally sufficient to consider load case 1, assuming the simultaneous presence of σ_{L1a} and τ_{L1b} but disregarding stresses due to torsion.

D.2.3.2 For each load case the stress components (with the proper signs: tension positive, compression negative) are to be added such, that for σ_L and τ_L extreme values are resulting. For different design verifications the most unfavourable combinations of the extreme values of σ_L and τ_L are to be used.

For the calculation of the most unfavourable values for the shear stresses σ_L the shear stress components σ_{SW} and σ_{WV} are to be combined as follows:

- $\sigma_{SW,max}$ and $\sigma_{WV,hog}$ for the determination of the maximum normal stress σ_L, or
- $\sigma_{SW,min}$ and $\sigma_{WV,sag}$ for the determination of the minimum normal stress σ_L

For the calculation of the most unfavourable values for the shear stresses τ_L the shear stress components τ_{SW} and τ_{WV} are to be combined as follows:

- $\tau_{SW,max}$ and $\tau_{WV,max}$
- $\tau_{SW,min}$ and $\tau_{WV,min}$

D.2.3.3 In case of load cases L_{3a} and L_{3b} the normal stresses due to vertical wave bending moment σ_{WV} and the shear stresses due to vertical wave shear force τ_{WV} are corrected as follows:

For the maximum vertical wave bending moment:

$$\sigma'_{WV} = (0.43 + C) \cdot \sigma_{WV,hog}$$

$$\tau'_{WV} = (0.43 + C) \cdot \tau_{WV,hog}$$

For the minimum vertical wave bending moment:

$$\sigma'_{WV} = \left[0.43 + C \cdot (0.5 - C)\right] \cdot \sigma_{WV,hog} + C \cdot (0.43 + C) \cdot \sigma_{WV,sag}$$

$$\tau'_{WV} = \left[0.43 + C \cdot (0.5 - C)\right] \cdot \tau_{WV,hog} + C \cdot (0.43 + C) \cdot \tau_{WV,sag}$$

C : coefficient, defined as:

$$C = \left(\frac{x}{\mathbf{L}} - 0.5\right)^2$$

Table 5.6 Load cases and stress combinations

Load case	Design stresses σ_L and τ_L
L_{1a}	$\sigma_{L1a} = \sigma_{SW} + \sigma_{ST} + f_Q \cdot \sigma_{WV}$ $\tau_{L1a} = 0.7 \cdot \tau_{SW} + \tau_{ST} + 0.7 \cdot f_Q \cdot \tau_{WV}$
L_{1b}	$\sigma_{L1b} = 0.7 \cdot \sigma_{SW} + \sigma_{ST} + 0.7 \cdot f_Q \cdot \sigma_{WV}$ $\tau_{L1b} = \tau_{SW} + \tau_{ST} + f_Q \cdot \tau_{WV}$
L_{2a}	$\sigma_{L2a} = \sigma_{SW} + \sigma_{ST} + f_Q \cdot (0.6 \cdot \sigma_{WV} + \sigma_{WH})$ $\tau_{L2a} = 0.7 \cdot \tau_{SW} + \tau_{ST} + 0.7 \cdot f_Q \cdot (0.6 \cdot \tau_{WV} + \tau_{WH})$
L_{2b}	$\sigma_{L2b} = 0.7 \cdot \sigma_{SW} + \sigma_{ST} + 0.7 \cdot f_Q \cdot (0.6 \cdot \sigma_{WV} + \sigma_{WH})$ $\tau_{L2b} = \tau_{SW} + \tau_{ST} + f_Q \cdot (0.6 \cdot \tau_{WV} + \tau_{WH})$
L_{3a}	$\sigma_{L3a} = f_F \cdot \left[\sigma_{SW} + \sigma_{ST} + f_Q \cdot \left(\sigma'_{WV} + \sigma_{WH} + \sigma_{WT}\right)\right]$ $\tau_{L3a} = f_F \cdot \left\{0.7 \cdot \tau_{SW} + \tau_{ST} + f_Q \cdot \left[0.7 \cdot \left(\tau'_{WV} + \tau_{WH}\right) + \tau_{WT}\right]\right\}$
L_{3b}	$\sigma_{L3b} = f_F \cdot \left\{0.7 \cdot \sigma_{SW} + \sigma_{ST} + f_Q \cdot \left[0.7 \cdot \left(\sigma'_{WV} + \sigma_{WH}\right) + \sigma_{WT}\right]\right\}$ $\tau_{L3b} = f_F \cdot \left[\tau_{SW} + \tau_{ST} + f_Q \cdot \left(\tau'_{WV} + \tau_{WH} + \tau_{WT}\right)\right]$

D.2.4 Stress components

D.2.4.1 Normal stresses in the ship's longitudinal direction

D.2.4.1.1 Normal stresses due to vertical bending moments M_{SW} and M_{WV}

The normal stresses σ_{SW} due to still water bending moment M_{SW} and the normal stresses σ_{WV} due to vertical wave bending moment M_{WV} are to be determined by the following formulae:

$$\sigma_{SW} = \frac{M_{SW} \cdot e_z}{I_y \cdot 10^3} \quad [N/mm^2]$$

$$\sigma_{WV} = \frac{M_{WV} \cdot e_z}{I_y \cdot 10^3} \quad [N/mm^2]$$

D.2.4.1.2 Normal stresses due to horizontal wave bending moment M_{WH}

The normal stresses σ_{WH} due to horizontal wave bending moment M_{WH} are to be determined by the following formula:

$$\sigma_{WH} = -\frac{M_{WH} \cdot e_y}{I_z \cdot 10^3} \quad [N/mm^2]$$

D.2.4.1.3 Normal stresses due to torsional moments M_{ST} and M_{WT}

When assessing the cross sectional properties the effect of wide deck strips between hatches constraining the torsion may be considered, e.g. by equivalent plates at the deck level having the same shear deformation as the relevant deck strips.

The normal stresses σ_{ST} due to maximum static torsional moment $M_{ST,max}$ and the normal stresses σ_{WT} due to maximum wave induced torsional moment $M_{WT,max}$ are to be determined by the following formulae:

$$\sigma_{ST} = \frac{0.65 \cdot C_{Tor} \cdot M_{ST,max} \cdot \omega_i}{\lambda \cdot I_\omega \cdot 10^3} \cdot \left(1 - \frac{2}{e^a + 1}\right) \quad [N/mm^2]$$

$$\sigma_{WT} = \frac{C_{Tor} \cdot M_{WT,max} \cdot \omega_i}{\lambda \cdot I_\omega \cdot 10^3} \cdot \left(1 - \frac{2}{e^a + 1}\right) \quad [N/mm^2]$$

C_{Tor} : distribution factor, defined as:

$$C_{Tor} = 4 \cdot \left(\sqrt{C_B} - 0.1\right) \cdot \frac{x}{\mathbf{L}} \qquad \text{for } 0 \le \frac{x}{\mathbf{L}} < 0.25$$

$$C_{Tor} = \sqrt{C_B} - 0.1 \qquad \text{for } 0.25 \le \frac{x}{\mathbf{L}} \le 0.65$$

$$C_{Tor} = \frac{\sqrt{C_B} - 0.1}{0.35} \cdot \left(1 - \frac{x}{\mathbf{L}}\right) \qquad \text{for } 0.65 < \frac{x}{\mathbf{L}} \le 1$$

ω_I : sectorial coordinate $[m^2]$ of the structure considered

λ : warping value $[1/m]$, defined as:

$$\lambda = \sqrt{\frac{I_T}{2.6 \cdot I_\omega}}$$

I_T : torsional moment of inertia $[m^4]$ of the ship's transverse section at the position $x/\mathbf{L}$

I_ω : sectorial moment of inertia $[m^6]$ of the ship's transverse section at the position $x/\mathbf{L}$

e : Euler number, defined as:

$e = 2.718...$

a : exponent, defined as:

$a = \lambda \cdot l_c$

ℓ_c : characteristical torsion length [m], defined as:

$\ell_c = 0.5 \cdot \mathbf{L} \cdot C_c$ for $\frac{\mathbf{L}}{\mathbf{B}} < 6.0$

$\ell_c = \left(1.22 - 0.12 \cdot \frac{\mathbf{L}}{\mathbf{B}}\right) \cdot \mathbf{L} \cdot C_c$ for $\frac{\mathbf{L}}{\mathbf{B}} \le 8.5$

$\ell_c = 0.2 \cdot \mathbf{L} \cdot C_c$ for $\frac{\mathbf{L}}{\mathbf{B}} > 8.5$

However, $\ell_c \ge \mathbf{L} - x_A$

C_c : coefficient, defined as:

$C_c = 0.8 - \frac{x_A}{\mathbf{L}} + \left(0.5 + 2.5 \cdot \frac{x_A}{\mathbf{L}}\right) \cdot \frac{x}{\mathbf{L}}$ for $0 \le \frac{x}{\mathbf{L}} < 0.40$ and $0 \le \frac{x_A}{\mathbf{L}} \le 0.40$

$C_c = 1$ for $0.40 \le \frac{x}{\mathbf{L}} \le 0.55$

$C_c = 1 - \frac{1}{0.45} \cdot \left(\frac{x}{\mathbf{L}} - 0.55\right)$ for $0.55 < \frac{x}{\mathbf{L}} \le 1$

x_A : factor to take into account cargo hatches, defined as:

$x_A = 0$ for ships without cargo hatches

x_A = distance [m] between the aft end of the length $\mathbf{L}$ and the aft edge of the hatch forward of the engine room front bulkhead on ships with cargo hatches, see also Figures in Table 5.7 and Table 5.8

The stresses σ_{ST} and σ_{WT} are related to the distributions torsional moments M_{ST} and M_{WT}. For other distributions the stresses have to be determined by direct calculations.

D.2.4.2 Shear stresses

The shear stress distribution is to be calculated by calculation procedures approved by GL. For ships with multi-cell transverse cross sections (e.g. double hull ships), the use of such a calculation procedure, especially with non-uniform distribution of the load over the ship's transverse section, may be stipulated.

D.2.4.2.1 Shear stresses due to vertical shear forces Q_{SW} and Q_{WV}

As a first approximation for ships without longitudinal bulkheads or with 2 longitudinal bulkheads, the distribution of the shear stress in the shell and in the longitudinal bulkheads can be determined as follows.

The shear stresses τ_{SW} due to still water shear force Q_{SW} and the shear stresses τ_{WV} due to vertical wave shear force Q_{WV} can be determined by the following formulae:

$$\tau_{SW} = \frac{Q_{SW} \cdot S_y(z)}{I_y \cdot t} \cdot (0.5 - \alpha) \quad [N/mm^2]$$

$$\tau_{WV} = \frac{Q_{WV} \cdot S_y(z)}{I_y \cdot t} \cdot (0.5 - \alpha) \quad [N/mm^2]$$

$S_y(z)$: first moment [m^3] of the sectional area considered, above or below, respectively, the level z considered, and related to the horizontal, neutral axis

t : thickness $[mm]$ of side shell plating respectively of the plating of the longitudinal bulkhead considered

α : factor to take longitudinal bulkheads into account

for ships without longitudinal bulkheads:

$\alpha = 0$

for ships with two longitudinal bulkheads:

$$\alpha = 0.16 + 0.08 \cdot \frac{A_S}{A_L}$$ for the longitudinal bulkhead

$$\alpha = 0.34 - 0.08 \cdot \frac{A_S}{A_L}$$ for the shell

A_S : area $[m^2]$ of cross section of the shell within depth $\mathbf{H}$

A_L : area $[m^2]$ of cross section of longitudinal bulkhead within depth $\mathbf{H}$

For ships of normal shape and construction, the ratio S_y / I_y determined for the midship section can be used for all cross sections.

(IACS UR S11.4.2 and IACS UR S11.4.3)

D.2.4.2.2 Shear stresses due to horizontal shear forces Q_{WH}

The shear stresses τ_{WH} are to be determined correspondingly to D.2.4.2.

D.2.4.2.3 Shear stresses due to torsional moments M_{ST} and M_{WT}

The shear stresses τ_{ST} due to maximum static torsional $M_{ST,max}$ and the shear stresses τ_{WT} due to maximum waved induced torsional moment $M_{WT,max}$ are to be determined by the following formula:

$$\tau_{ST} = 0.65 \cdot C_{Tor} \cdot M_{ST,max} \cdot \frac{S_{\omega}i}{I_{\omega} \cdot t_i} \quad [N/mm^2]$$

$$\tau_{WT} = C_{Tor} \cdot M_{WT,max} \cdot \frac{S_{\omega i}}{I_{\omega} \cdot t_i} \quad [N/mm^2]$$

C_{Tor} : distribution factor according to D.2.4.1.3

$S_{\omega I}$: statical sector moment $[m^4]$ of the structure considered

I_{ω} : sectional moment of inertia according to D.2.4.1.3

t_i : thickness $[mm]$ of the plate considered

The shear stresses τ_{ST} and τ_{WT} are related to the distributions of the torsional moments M_{ST} and M_{WT}. For other distributions the shear stresses have to be determined by direct calculations.

E Design Verification

E.1 Section moduli and moment of inertia

E.1.1 Calculation of section moduli

E.1.1.1 General calculation

E.1.1.1.1 When calculating the section modulus, 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 is not reducing 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 75 mm at most (see Fig. 5.3).

A deduction-free sum of smaller opening breadths in one transverse section in the bottom or deck area of $0.06 \cdot (B - \sum b)$ may be considered equivalent to the above reduction in section modulus by 3 %.

B : breadth [m] of the ship at the considered transverse section

$\sum b$: sum of breadth [m] of large openings

The shadow area will be obtained by drawing two tangent lines with an opening angle of 30 °, see Fig. 5.3.

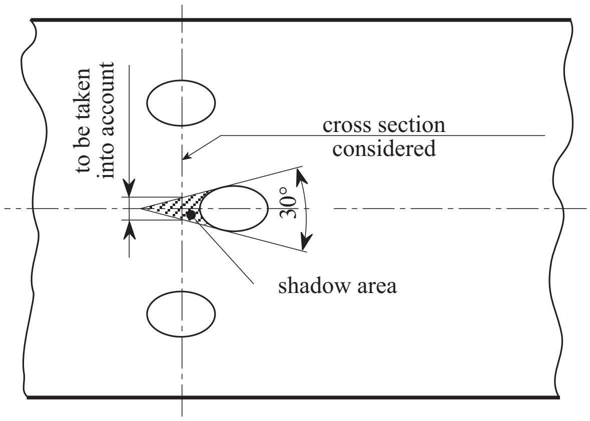


Fig. 5.3 Shadow area

(IACS UR S5)

Note

In case of large openings local strengthening may be required which will be considered in each individual case (see also Section 7, B.3.1.1).

E.1.1.1.2 The bottom section modulus W_B and the deck section modulus W_D are to be determined by the following formulae:

$$W_B = \frac{I_y}{e_B} \quad [m^3]$$

$$W_D = \frac{I_y}{e_D} \quad [m^3]$$

Continuous structural elements above e_D (e.g. trunks, longitudinal hatch coamings, decks with a large camber, longitudinal stiffeners and longitudinal girders arranged above deck, bulwarks contributing to longitudinal strength etc.) may be considered when determining the section modulus, provided they have shear connection with the hull and are effectively supported by longitudinal bulkheads or by rigid longitudinal or transverse deep girders.

The fictitious deck section modulus is then to be determined by the following formula:

$$W_D' = \frac{I_y}{e_D'} \quad [m^3]$$

e_B : distance [m] from neutral axis of hull section to base line

e_D : distance [m] from neutral axis of hull section to deck line at side

e'_D : distance [m] from neutral axis of hull section to fictitious top of deck section, defined as:

$$e'_D = z \cdot \left(0.9 + 0.2 \cdot \frac{y}{\mathbf{B}}\right) \quad [m] \qquad \text{with } e'_D > e_D$$

y : distance [m] from centre line to top of continuous strength member

z : distance [m] from neutral axis of the cross section considered to top of continuous strength member

(IACS UR S5)

E.1.1.2 Calculation for ships with multi-hatchways

For the determination of section moduli the effectiveness of the longitudinal hatchway girders between the hatchways is to be determined by direct calculation.

E.1.2 Required section modulus and moment of inertia

E.1.2.1 Section modulus as a function of the longitudinal bending moments

E.1.2.1.1 The section moduli related to deck W_D respectively W_D' or bottom W_B are not to be less than:

$$W = f_r \cdot \frac{|M_T|}{\sigma_p \cdot 10^3} \quad [m^3]$$

f_r : factor to take the degree of deck opening into account, defined as:

$f_r = 1$ in general

f_r = according to E.8.2 for ships with large openings

σ_p : permissible longitudinal bending stress $[N/mm^2]$, defined as:

$$\sigma_p = c_s \cdot \sigma_{p0}$$

c_s : distribution factor, defined as:

$$c_s = 0.5 + \frac{5}{3} \cdot \frac{x}{\mathbf{L}} \qquad \text{for } 0 \le \frac{x}{\mathbf{L}} < 0.3$$

$$c_s = 1 \qquad \text{for } 0.3 \le \frac{x}{\mathbf{L}} \le 0.7$$

$$c_s = \frac{5}{3} \cdot \left(1.3 - \frac{x}{\mathbf{L}}\right) \qquad \text{for } 0.7 < \frac{x}{\mathbf{L}} \le 1$$

σ_{p0} : permissible longitudinal bending stress $[N/mm^2]$ in the mid ship area, defined as:

$$\sigma_{p0} = \frac{18.5 \cdot \sqrt{\mathbf{L}}}{k} \qquad \text{for } \mathbf{L} < 90 \text{ m}$$

$$\sigma_{p0} = \frac{175}{k} \qquad \text{for } \mathbf{L} \ge 90 \text{ m}$$

(IACS UR S11.3.1.1)

E.1.2.1.2 For the calculation of the section moduli related to deck W_D respectively W_D' or bottom W_B the relevant total bending moments M_T as defined in D.1.1.3 are to be considered.

E.1.2.1.3 The required section moduli have to be fulfilled inside and outside $0.4 \cdot \mathbf{L}$ amidships in general. Outside $0.4 \cdot \mathbf{L}$ particular attention is to be paid for the following locations:

- in way of the forward end of the engine room

- in way of the forward end of the foremost cargo hold
- at any locations where there are significant changes in hull cross-section
- at any locations where there are changes in the framing system
- for ships with large deck openings such as containerships, locations at or near $0.25\,\mathbf{L}$ and $0.75\,\mathbf{L}$
- for ships with cargo holds aft of the superstructure, deckhouse or engine room, sections in way of the aft end of the aft-most hold and in way of the aft end of the superstructure, deckhouse or engine room

(IACS UR S11.3.2)

E.1.2.1.4 For the ranges outside $0.4\,\mathbf{L}$ amidships the factor c_s may be increased up to $c_s = 1$ if this is justified under consideration of combined stresses due to longitudinal hull girder bending (including bending due to impact loads), horizontal bending, torsion and local loads and also under consideration of the buckling strength.

E.1.2.2 Minimum midship section modulus

E.1.2.2.1 The minimum section modulus W_{min} related to deck and bottom is not to be less than the following minimum value:

$$W_{min} = k \cdot c_o \cdot \mathbf{L}^2 \cdot \mathbf{B} \cdot (C_B + 0.7) \cdot c_{RS} \cdot 10^{-6} \quad [m^3]$$

c_0 : wave and length coefficient according to Section 4, A.3 for unlimited service range ($c_{RW} = 1.0$)

c_{RS} : service range coefficient, defined as:

$c_{RS} = 1.00$ for unlimited service range

$c_{RS} = 0.95$ for restricted service area **RSA (200)**

$c_{RS} = 0.85$ for restricted service area **RSA (50)**

$c_{RS} = 0.80$ for restricted service area **RSA (20)**

$c_{RS} = 0.75$ for restricted service area **RSA (SW)**

(IACS UR S7.1)

E.1.2.2.2 The scantlings of all continuous longitudinal members based on the minimum section modulus requirement are to be maintained within $0.4\,\mathbf{L}$ 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 $0.4\,\mathbf{L}$ part, bearing in mind the desire not inhabit the vessel's loading flexibility.

(IACS UR S7.2)

E.1.2.3 Midship section moment of inertia

The moment of inertia related to the horizontal axis is not to be less than determined by the following formula:

$$I_y = 3 \cdot 10^{-2} \cdot W \cdot \frac{\mathbf{L}}{k} \quad [m^4]$$

W : section moduli according to E.1.2.1 and / or E.1.2.2, the greater value is to be taken

(IACS UR S11.3.1.2)

E.2 Permissible stresses

The equivalent stresses σ_v resulting from σ_L and τ_L are not to exceed the following value:

$$\sigma_v = \sqrt{\sigma_L^2 + 3\cdot\tau_L^2} \le \frac{190}{k} \quad [N/mm^2]$$

The shear stresses τ in longitudinal structures due to the total vertical shear forces Q_T are not to exceed the following value:

$$\tau \le \frac{110}{k} \quad [N/mm^2]$$

σ_L, τ_L : design stresses according to D.2

For ships with large deck openings and/or for ships with large static torsional moments, also the shear stresses due to $M_{ST,max}$ have to be considered adversely, i.e. increasing the stress level.

(IACS UR S11.4.1)

E.3 Fatigue assessment

E.3.1 The required welding details and classifying of notches result from the fatigue strength analysis according to Section 20.

E.3.2 Within the upper and lower hull girder flange, the detail categories for the welded joints (see Section 20, Table 20.3) should not be less than:

$$\Delta\sigma_{R\,min} = \frac{(M_{WVhog} - M_{WVsag})\cdot|e_z|}{(4110 - 29\cdot n)\cdot I_y} \quad [N/mm^2]$$

n : design lifetime of the ship, defined as

$$n \ge 20 \text{ [years]}$$

E.4 Proof of buckling strength

In case of structural members contributing to the longitudinal strength and subjected to compressive stresses resulting from the total vertical bending moment M_T and/or subjected to shear forces resulting from the total vertical shear force Q_T are to be examined for sufficient resistance to buckling according to Section 3, D. For this purpose the following load combinations are to be investigated:

- M_T and $0.7\cdot Q_T$
- $0.7\cdot M_T$ and Q_T

The stresses are to be determined according to D.2

(IACS UR S11.3.2)

E.5 Ultimate load calculation of the ship's transverse sections

E.5.1 In extreme conditions, larger loads than referred to in D.1 may occur. Therefore, dimensioning of longitudinal structures is to be verified by proving the ultimate capacity according to E.5.2 and E.5.3. The calculations are to include those structural elements contributing to the hull girder longitudinal strength and are to be based on gross scantlings.

The following safety factors are to be assumed:

$$\gamma_R = 1.20$$

$$\gamma_{WV} = 1.20$$

E.5.2 Ultimate vertical bending moment

$$\left| M_{SW} + \frac{\gamma_{WV}\cdot M_{WV}}{c_s} \right| \le \left| \frac{M_U}{\gamma_R} \right|$$

$$\left| M_{SWf} + \frac{0.8 \cdot \gamma_{WV} \cdot M_{WV}}{c_s} \right| \le \left| \frac{M_{Uf}}{\gamma_R} \right|$$

M_{SWf} : maximum vertical still water bending moment $[kNm]$ in flooded conditions. For a transverse section under consideration, the most severe levels of vertical still water bending moments are to be selected from those cases of flooding used in the damage stability calculations (see Section 28).

c_s : distribution factor as defined in E.1.2.1.1

M_U : ultimate vertical bending moments $[kNm]$ of the ship's transverse section in the hogging ($M_{U,H}$) and sagging ($M_{U,S}$) conditions. See E.5.2.1.

M_{Uf} : ultimate vertical bending moments $[kNm]$ of the ship's damaged transverse section in the hogging ($M_{Uf,H}$) and sagging ($M_{Uf,S}$) conditions. If no assumptions regarding the extent of damage are prescribed, $M_{Uf} = \kappa_{dM} \cdot M_U$, where κ_{dM} is a reduction factor for the ultimate moments in damaged conditions ($\kappa_{dM} \le 1$). The reduction factor κ_{dM} equals 1 unless a smaller value is specified by the owner or shipyard.

E.5.2.1 Progressive collapse analysis

A progressive collapse analysis is to be used to calculate the ultimate vertical bending moments of a ship's transverse section. The procedure is to be based on a simplified incremental-iterative approach where the capacities are defined as the peaks of the resulting moment-curvature curve (M - χ) in hogging (positive) and sagging (negative) conditions, i.e. χ is the hull girder curvature $[1 / m]$. See Fig. 5.4.

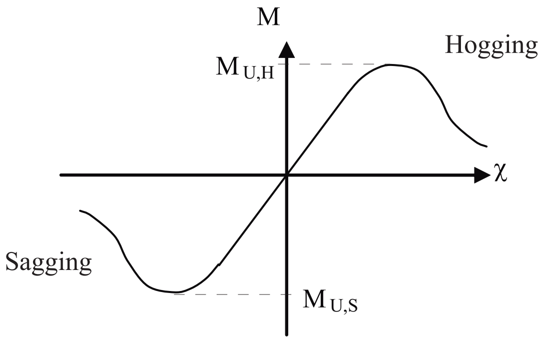


Fig. 5.4 Moment-curvature curve

The main steps to be used in the incremental-iterative approach are summarised as follows:

Step 1

The ship's transverse section is to be divided into plate-stiffener combinations (see E.5.2.2.2 (a)) and hard corners (see E.5.2.2.2 (b)).

Step 2

The average stress – average strain relationships σ_{CRk} - ε for all structural elements (i.e. stiffener-plate combinations and hard corners) are to be defined, where the subscript k refers to the modes 0, 1, 2, 3 or 4, as applicable (see E.5.2.2).

Step 3

The initial and incremental value of curvature $\Delta\kappa$ is to be defined by the following formula:

$$\Delta\chi = \frac{0.05 \cdot \dfrac{R_{eH}}{E}}{z_D - z_{NA,e}}$$

z_D : z co-ordinate $[m]$ of strength deck at side (see also Fig. 5.1)

$z_{NA,e}$: z co-ordinate $[m]$ of elastic neutral axis for the ship's transverse section

Step 4

For the value of curvature, $\chi_j = \chi_{j-1} + \Delta\chi$, the average strain $\varepsilon_{Ei,j} = \chi_j \cdot z_i$ and corresponding average stress $\sigma_{i,j}$ is to be defined for each structural element i (see E.5.2.2). For structural elements under tension, $\sigma_{i,j} = \sigma_{CR0}$ (see E.5.2.2.1). For plate-stiffener combinations under compression, $\sigma_{i,j} = \min[\sigma_{CR1}; \sigma_{CR2}; \sigma_{CR3}]$ (see E.5.2.2.2 (a)). For hard corners under compression, $\sigma_{i,j} = \sigma_{CR4}$ (see E.5.2.2.2 (b)).

z_i : z co-ordinate of i^th structural element [m] relative to basis, see also Fig. 5.6

Step 5

For the value of curvature, $\chi_j = \chi_{j-1} + \Delta\chi$, the height of the neutral axis $z_{NA,j}$ is to be determined iteratively through force equilibrium over the ship's transverse section:

$$\sum_{i=1}^{m} A_i \cdot \sigma_{i,j} = \sum_{i=1}^{n} A_i \cdot \sigma_{i,j}$$

m : number of structural elements located above $z_{NA,j}$

n : number of structural elements located below $z_{NA,j}$

A_i : cross-sectional area of i^th plate-stiffener combination or hard corner

Step 6

For the value of curvature, $\chi_j = \chi_{j-1} + \Delta\chi$, the corresponding bending moment is to be calculated by summing the contributions of all structural elements within the ship's transverse section:

$$M_{U,j} = \sum \sigma_{i,j} \cdot A_i \cdot (z_{NA,j} - z_i)$$

Steps 4 through 6 are to be repeated for increasing increments of curvature until the peaks in the $M - \chi$ curve are well defined. The ultimate vertical bending moments $M_{U,H}$ and $M_{U,S}$ are to be taken as the peak values of the $M - \chi$ curve.

E.5.2.2 Average stress - average strain curves

A typical average stress – average strain curve $\sigma_{CRk} - \varepsilon$ for a structural element within a ship's transverse section is shown in Fig. 5.5, where the subscript k refers to the modes 0, 1, 2, 3 or 4, as applicable.

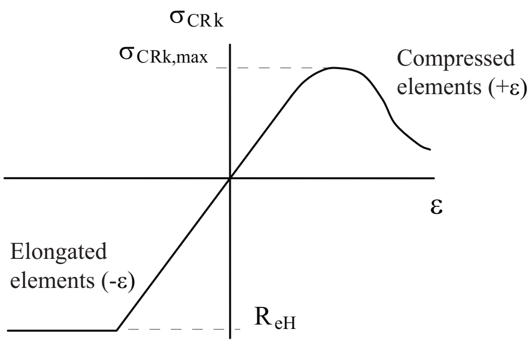


Fig. 5.5 Typical average stress - average strain curve

E.5.2.2.1 Negative strain ($\sigma_{CR0} - \varepsilon$)

The portion of the curve corresponding to negative strain (i.e. tension) is in every case to be based on elasto-plastic behaviour (i.e. material yielding) according to the following:

$$\sigma_{CR0} = \Phi \cdot R_{eH} \quad [N/mm^2]$$

Φ : edge function, defined as:

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

$\Phi = \varepsilon$ for $-1 \le \varepsilon \le 0$

ε : relative strain, defined as:

$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E : element strain

ε_Y : strain at yield stress in the element, defined as:

$$\varepsilon_y = \frac{R_{eH}}{E}$$

E.5.2.2.2 Positive strain

The portion of the curve corresponding to positive strain (i.e. compression) is to be based on some mode of collapse behaviour (i.e. buckling) for two types of structural elements; (a) plate-stiffener combinations and (b) hard corners. See Fig. 5.6.

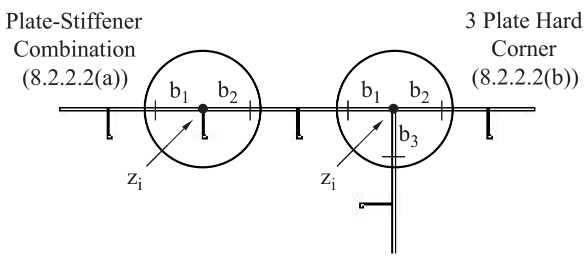


Fig. 5.6 Structural elements

(a) Plate-stiffener combinations (σ_{CR1} - ε, σ_{CR2} - ε, σ_{CR3} - ε)

Plate-stiffener combinations are comprised of a single stiffener together with the attached plating from adjacent plate fields. Under positive strain, three average stress – average strain curves are to be defined for each plate-stiffener combination based on beam column buckling (σ_{CR1} - ε), torsional buckling (σ_{CR2} - ε) and web / flange local buckling (σ_{CR3} - ε).

(i) Beam column buckling σ_{CR1} - ε

The positive strain portion of the average stress – average strain curve σ_{CR1} - ε based on beam column buckling of plate-stiffener combinations is described according to the following:

$$\sigma_{CR1} = \Phi \cdot R_{eH} \cdot \kappa_{BC} \cdot \frac{A_{Stif} + b_{m,1} \cdot t_1 / 2 + b_{m,2} \cdot t_2 / 2}{A_{Stif} + b_1 \cdot t_1 / 2 + b_2 \cdot t_2 / 2}$$

Φ : edge function, defined as:

$\Phi = \varepsilon$ for $0 \le \varepsilon \le 1$

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

κ_{BC} : reduction factor, defined as:

$\kappa_{BC} = 1$ for $\lambda_K \le 0.2$

$\kappa_{BC} = \dfrac{1}{k_D + \sqrt{k_D^2 - \lambda_K^2}}$ for $\lambda_K > 0.2$

λ_K : slenderness ratio, defined as:

$$\lambda_K = \sqrt{\frac{\varepsilon_E \cdot a^2 \cdot A_x}{\pi^2 \cdot I_x} \cdot 10^{-4}}$$

k_D : parameter, defined as:

$$k_D = \frac{1+0.21\cdot(\lambda_K - 0.2)+\lambda_K^2}{2}$$

a : length [mm] of stiffener

A_x : sectional area [mm^2] of stiffener with attached shell plating of breadth $(b_{m,1}/2 + b_{m,2}/2)$

I_x : moment of inertia [cm^4] of stiffener with attached shell plating of breadth $(b_{m,1}/2 + b_{m,2}/2)$

$b_{m,1}$, $b_{m,2}$: effective widths [mm] of single plate fields on sides 1 and 2 of stiffener according to Section 3, D.3.2, in general based on Load Case 1 of Section 3, Table 3.5, where the reference degree of slenderness is to be defined as:

$$\lambda = \sqrt{\frac{\varepsilon_E}{0.9\cdot\left(\frac{t}{b}\right)^2\cdot K}}$$

b_1, b_2 : breadths [mm] of single plate fields on sides 1 and 2 of stiffener, see also Fig. 5.6

t_1, t_2 : thicknesses [mm] of single plate fields on sides 1 and 2 of stiffener

A_{Stif} : sectional area [mm^2] of the stiffener without attached plating

(ii) Torsional buckling σ_{CR2} - ε

The positive strain portion of the average stress – average strain curve σ_{CR2} - ε based on torsional buckling of plate-stiffener combinations is described according to the following:

$$\sigma_{CR2} = \Phi\cdot R_{eH}\cdot\frac{A_{Stif}\cdot\kappa_T + b_{m,1}\cdot t_1/2 + b_{m,2}\cdot t_2/2}{A_{Stif} + b_1\cdot t_1/2 + b_2\cdot t_2/2}$$

κ_T : reduction factor according to Section 3, D.4.3.1

(iii) Web / flange local buckling σ_{CR3} - ε

The positive strain portion of the average stress – average strain curve σ_{CR3} - ε based on web/flange local buckling of plate-stiffener combinations is described according to the following:

$$\sigma_{CR3} = \Phi\cdot R_{eH}\cdot\frac{h_{w,m}\cdot t_w + b_{f,m}\cdot t_f + b_{m,1}\cdot t_1/2 + b_{m,2}\cdot t_2/2}{h_w\cdot t_w + b_f\cdot t_f + b_1\cdot t_1/2 + b_2\cdot t_2/2}$$

$h_{w,m}$, $b_{f,m}$: effective width of web/flange plating [mm] according to Section 3, D.3.2 (generally based on Load Case 3 of Section 3, Table 3.5 for flat bars and flanges, otherwise Load Case 1) where the reference degree of slenderness is to be defined as:

$$\lambda = \sqrt{\frac{\varepsilon_E}{0.9\cdot\left(\frac{t}{b}\right)^2\cdot K}}$$

h_w : web height [mm]

t_w : web thickness [mm]

b_f : flange breadth [mm], where applicable

t_f : flange thickness [mm], where applicable

(b) Hard corners (σ_{CR4} – ε)

Hard corners are sturdy structural elements comprised of plates not lying in the same plane. Bilge strakes (i.e. one curved plate), sheer strake-deck stringer connections (i.e. two plane plates) and bulkhead-deck connections (i.e. three plane plates) are typical hard corners. Under positive strain, single average stress – average strain curves are to be defined for hard corners based on plate buckling (σ_{CR4} – ε).

(i) Plate buckling σ_{CR4} - ε

$$\sigma_{CR4} = \Phi \cdot R_{eH} \cdot \frac{\sum_{i=1}^{n} b_{m,i} \cdot t_i}{\sum_{i=1}^{n} b_i \cdot t_i}$$

$b_{m,i}$: effective widths of single plate fields $[mm]$ according to Section 3, D.3.2, as applicable, in general based on applicable Load Cases in Section 3, Table 3.5 and Section 3, Table 3.6, where the reference degree of slenderness is to be defined as:

$$\lambda = \sqrt{\frac{\varepsilon_E}{0.9 \cdot \left(\frac{t}{b}\right)^2 \cdot K}}$$

b_i : breadth $[mm]$ of single plate fields, see also Fig. 5.6

t_i : thickness $[mm]$ of single plate fields

n : number of plates comprising hard corner

E.5.3 Ultimate vertical shear force

$$\left| Q_{SW} + \frac{\gamma_{WV} \cdot Q_{WV}}{c_s} \right| \le \left| \frac{Q_U}{\gamma_R} \right|$$

$$\left| Q_{SWf} + \frac{0.8 \cdot \gamma_{WV} \cdot Q_{WV}}{c_s} \right| \le \left| \frac{Q_{Uf}}{\gamma_R} \right|$$

Q_{SWf} : maximum vertical still water shear force in flooded conditions $[kN]$. For a transverse section under consideration, the most severe levels of vertical still water shear forces are to be selected from those cases of flooding used in the damage stability calculations (see Section 28).

c_s : stress factor according to E.1.2.1.1

Q_U : ultimate vertical shear force of the ship's transverse section $[kN]$, defined as:

$$Q_U = \frac{1}{\sqrt{3}} \cdot 10^{-3} \cdot \sum_{i=1}^{q} \kappa_{\tau i} \cdot b_i \cdot t_i \cdot R_{eH,i}$$

q : number of shear force transmitting plate fields (in general, these are only the vertical plate fields of the ship's transverse section, e.g. shell and longitudinal bulkhead plate fields)

$\kappa_{\tau i}$: reduction factor of the i^{th} plate field according to Section 3, D.3.1

b_i : breadth $[mm]$ of the i^{th} plate field

t_i : thickness $[mm]$ of the i^{th} plate field

Q_{Uf} : ultimate vertical shear force $[kN]$ of the ship's undamaged transverse section. If no assumptions regarding the extent of damage are prescribed, $Q_{Uf} = \kappa_{dM} \cdot Q_U$, where κ_{dM} is a reduction factor for the ultimate force in damaged conditions ($\kappa_{dM} \le 1$).

E.6 Permissible still water loads

E.6.1 Vertical bending moments

The permissible still water bending moments $M_{SW,perm}$ over the ship's length $\mathbf{L}$ are to be determined by the following formula:

$$M_{SW,perm} = M_{T,perm} - M_{WV} \quad [kNm]$$

$M_{T,perm}$: permissible total bending moment $[kNm]$, defined as:

$$M_{T,perm} = \min\left[\sigma_D \cdot W_{D(a)} \cdot \frac{1}{f_r} \cdot 10^3 \; ; \; \sigma_B \cdot W_{B(a)} \cdot \frac{1}{f_r} \cdot 10^3\right]$$

σ_D : maximum normal stress $[kN / mm^2]$ in the upper girder flange

σ_B : maximum normal stress $[kN / mm^2]$ in the lower girder flange

$W_{D(a)}$: actual section modulus $[m^3]$ in the deck

$W_{B(a)}$: actual section modulus $[m^3]$ in the bottom

f_r : correction factor, defined as:

$f_r = 1.0$ in general

f_r = according to E.8 for ships with large deck openings

M_{WV} : vertical wave bending moment according to D.1.3.1. For harbour- and offshore terminal conditions the wave loads may be multiplied with the following factors:

- harbour conditions (normally): 0.1
- offshore terminal conditions: 0.5

In the range between $x / \mathbf{L} = 0.3$ and $x / \mathbf{L} = 0.7$ the permissible still water bending moment are generally not exceed the value obtained for $x / \mathbf{L} = 0.5$.

E.6.2 Vertical shear forces

E.6.2.1 Permissible still water shear force

The permissible still water shear forces $Q_{SW,perm}$ over the ship's length $\mathbf{L}$ are to be determined by the following formula:

$$Q_{SW,perm} = Q_{T,perm} - Q_{WV} \quad [kN]$$

$Q_{T,perm}$: total shear force $[kN]$, for which the permissible shear stress $\tau = \tau_{SW} + \tau_{WV}$ will be reached but not exceeded at any point of the section considered

Q_{WV} : vertical wave shear force according to D.1.3.4. For harbour and offshore terminal conditions see E.6.1

E.6.2.2 Correction of the shear force curve in cases with empty cargo holds

In cases with empty cargo holds, the conventional shear force curve may be corrected according to the direct load transmission by the longitudinal bottom structure at the transverse bulkheads. See also Fig. 5.7.

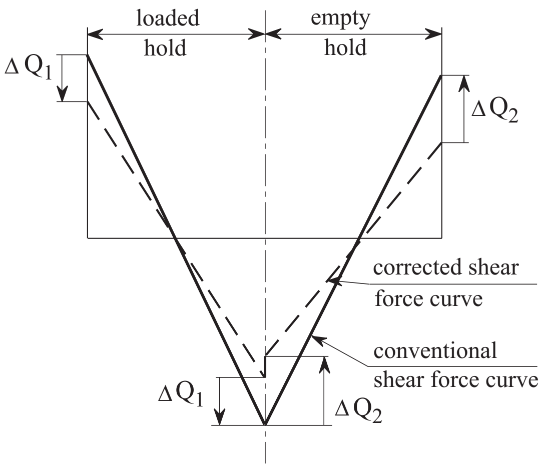


Fig. 5.7 Correction of the shear force curve

E.6.2.3 Supporting forces at the bottom grillage

The supporting forces of the bottom grillage at the transverse bulkheads may either be determined by direct calculation or by approximation as follows.

The sum of the supporting forces of the bottom grillage at the aft or forward boundary bulkhead of the hold considered may be determined by the following formulae:

$$\Delta Q = u \cdot P - v \cdot T^* \quad [kN]$$

u, v : correction coefficients for cargo and buoyancy as follows:

$$u = \frac{10 \cdot \kappa \cdot \ell \cdot b \cdot h}{V} \quad [kN/t]$$

$$v = 10 \cdot \kappa \cdot \ell \cdot b \quad [kN/m]$$

κ : coefficient, taken as:

$$\kappa = \frac{\mathbf{B}}{2.3 \cdot (\mathbf{B} + \ell)}$$

ℓ : length $[m]$ of the flat part of the double bottom

b : breadth $[m]$ of the flat part of the double bottom

h : vertical distance $[m]$ between inner bottom and top of hatch coaming

V : volume $[m^3]$ of cargo hold including volume enclosed by hatch coaming

P : mass $[t]$ of cargo or ballast in the hold considered, including any contents of bottom tanks within the flat part of the double bottom

T^* : draught $[m]$ at mid length of the cargo hold

E.6.3 Static torsional moments

E.6.3.1 The permissible static torsional moments have to be determined on the basis of the design stresses in Table 5.6 together with the formula in D.2.4.1.3.

E.6.3.2 For ships with torsional moments according to D.1.2.3 it has to be proved by means of the loading computer, that the maximum permissible values are exceeded at no location. Excess values are permissible, if the actual torsional moments at the adjacent calculation points are correspondingly less than the permissible values.

E.6.3.3 Unless shown by a particular proof, during loading and unloading the static torsional moments are not to be higher than 75 % of the wave induced torsional moment according to D.1.3.5.

E.7 Shear stress due to loads from transverse bulkheads stringers

Where stringers of transverse bulkheads are supported at longitudinal bulkheads or at the side shell, the supporting forces of these stringers are to be considered when determining the shear stress in the longitudinal bulkheads or side shell respectively. Likewise, where vertical girders of transverse bulkheads are supported at deck or inner bottom, the supporting forces of these vertical girders are to be considered when determining the shear stresses in the deck or inner bottom respectively.

The shear stress introduced by the stringer into the longitudinal bulkhead or side shell may be determined by the following formula:

$$\tau_{St} = \frac{P_{St}}{2 \cdot b_{St} \cdot t} \quad [N/mm^2]$$

P_{St} : supporting force $[kN]$ of stringer or vertical girder

b_{St} : breadth $[m]$ of stringer or depth of vertical girder including end bracket (if any) at the supporting point

t : thickness of tank boundaries according to Section 12, B.1.2

The additional shear stress τ_{St} is to be added to the shear stress τ_L due to longitudinal bending in the following area:

- 0.5 m on both sides of the stringer in the ship's longitudinal direction
- $0.25 \times b_{St}$ above and below the stringer

Thereby the following requirement is to be satisfied:

$$\tau_{St} + \tau_L \le \frac{110}{k} \quad [N/mm^2]$$

τ_L : shear stress due to longitudinal bending according to D.2.2

E.8 Guidance Values for Large Deck Openings

E.8.1 General

E.8.1.1 Displacements of the upper hull girder flange mainly caused by torsional loads, induce additional local bending moments and forces acting in the deck strips. These moments act about the z-axis, see Fig. 5.1. After consultation with GL stresses resulting from that have to be calculated for longitudinal and transverse girders and to be taken into account for the design.

The calculation of these stresses can be dispensed with, if the guidance values according to E.8.2 and E.8.3 are observed.

E.8.1.2 A ship is regarded as one with large deck openings if one of the following conditions applies to one or more hatch openings:

$$\frac{b_L}{B_M} > 0.6$$

$$\frac{\ell_L}{\ell_M} > 0.7$$

b_L : breadth of hatchway, in case of multi-hatchways, b_L is the sum of the individual hatchway-breadths

B_M : breadth of deck measured at the mid length of hatchway

ℓ_L : length of hatchway

ℓ_M : distance between centres of transverse deck strips at each end of hatchway. Where there is no further hatchway beyond the one under consideration, ℓ_M will be specially considered.

E.8.2 Guidance values for the determination of the section modulus

The section moduli of the transverse sections of the ship are to be determined according to E.1.2.1 and E.1.2.2 The increase of the stress level due to torsion of the ship's hull is taken into account by the factor f_r, The factor is to be determined for the structural member at which the maximum normal stress due to static torsion occurs by the following formula:

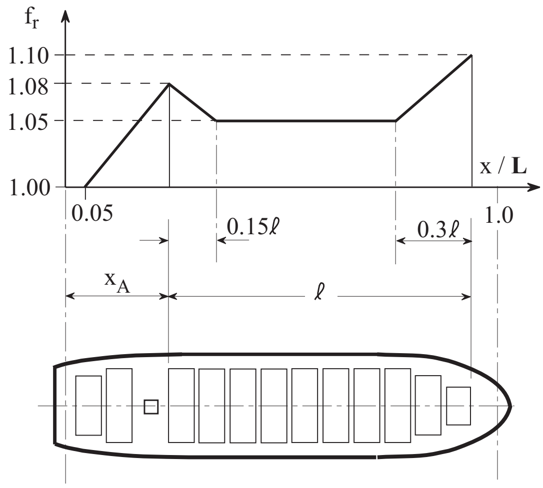
$$f_r = \frac{\sigma_{L1a}}{\sigma_{SW} + 0.75 \cdot \sigma_{WV}}$$

σ_{L1a} : normal stress according to Table 5.6

σ_{SW}, σ_{WV} : normal stresses related to the design stress σ_{L1a}

The calculation of the factor f_r may be dispensed with, if f_r is selected according to Table 5.7.

Table 5.7 Correction factor f_r

Range	Value	Distribution over the ship's length
$\frac{x}{\mathbf{L}} \le 0.05$	1.00	
$0.05 < \frac{x}{\mathbf{L}} \le \frac{x_A}{\mathbf{L}}$	$1.00 + 0.08 \cdot \frac{x - 0.05 \cdot \mathbf{L}}{x_A - 0.05 \cdot \mathbf{L}}$	
$\frac{x_A}{\mathbf{L}} < \frac{x}{\mathbf{L}} \le \frac{x_A + 0.15 \cdot \ell}{\mathbf{L}}$	$1.08 + 0.2 \cdot \frac{x_A - x}{\ell}$	
$\frac{x_A + 0.15 \cdot \ell}{\mathbf{L}} < \frac{x}{\mathbf{L}} \le \frac{x_A + 0.70 \cdot \ell}{\mathbf{L}}$	1.05	
$\frac{x_A + 0.70 \cdot \ell}{\mathbf{L}} < \frac{x}{\mathbf{L}} \le \frac{x_A + \ell}{\mathbf{L}}$	$1.10 + \frac{x - x_A - \ell}{6 \cdot \ell}$	
$\frac{x_A + \ell}{\mathbf{L}} < \frac{x}{\mathbf{L}}$	1.00	

E.8.3 Guidance values for the design of transverse box girders of container ships

The scantlings of transverse box girders are to be determined by using the following design criteria:

- support forces of hatch covers, see Section 17, B.2
- support forces of the containers stowed in the hold place (e.g. due to longitudinal acceleration)
- stresses due to the torsional deformations of the hull
- stresses resulting from the water pressure, if the transverse box girder forms part of a watertight bulkhead, see Section 11

In general the plate thickness is not to be less than determined by the following formulae, see also Fig. 5.8:

$$t = \max\left[t_1 \; ; \; t_2\right]$$

$$t_1 = \max\left[\sqrt{\mathbf{L}_{200}} \; ; \; 0.5 \cdot t_0\right] \quad [\text{mm}]$$

$$t_2 = \max\left[0.85 \cdot \sqrt{\mathbf{L}_{200}} \; ; \; 12 \cdot a\right] \quad [\text{mm}]$$

t_0 : thickness [mm] of longitudinal hatch coaming or of the uppermost strake of the longitudinal bulkhead

a : spacing [m] of stiffeners

For coamings on the open deck see also Section 17, B.1.

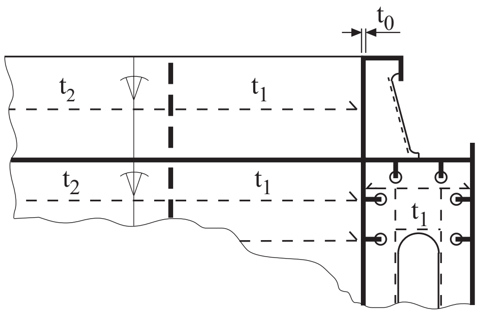


Fig. 5.8 Plate thickness of the transverse box girder

E.8.4 Guidance values for the displacements of the upper hull girder flange of the ship

In general, the relative displacement Δu between the ship sides is to be determined by direct calculations. For the dimensioning of hatch cover bearings and seals, the following value may be used for the displacement:

$$\Delta u = \frac{6}{10^5} \cdot \left(M_{ST,max} + M_{WT,max}\right) \cdot \left(1 - \frac{\mathbf{L}}{450}\right) \cdot \left[4 + 0.1 \cdot \frac{\mathbf{L}^2}{\mathbf{B}^2}\right] \cdot c_u + 20 \quad [\mathrm{mm}]$$

c_u : distribution factor according to Table 5.8

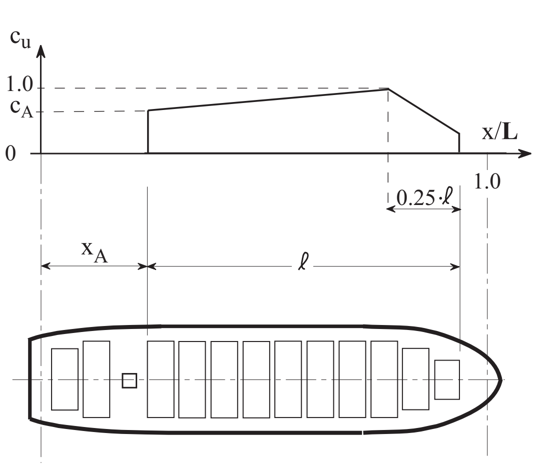
c_A : value for c_u at the aft part of the open region, see also Table 5.8

$$c_A = \left(1.25 - \frac{\mathbf{L}}{400}\right) \cdot \left(1.6 - \frac{3 \cdot x_A}{\mathbf{L}}\right) \leq 1$$

x_A : distance [m] between aft perpendicular and aft part of the open region according to D.2.4.1.3; with:

$$0.15 \cdot \mathbf{L} \leq x_A \leq 0.3 \cdot \mathbf{L}$$

Table 5.8 Distribution factor c_u

Range	Value	Distribution over the ship's length
$\frac{x}{\mathbf{L}} < \frac{x_A}{\mathbf{L}}$	0	
$\frac{x_A}{\mathbf{L}} \leq \frac{x}{\mathbf{L}} < \frac{x_A + 0.75 \cdot \ell}{\mathbf{L}}$	$\frac{1 - c_A}{0.75} \cdot \frac{x - x_A}{\ell} + c_A$	
$\frac{x_A + 0.75 \cdot \ell}{\mathbf{L}} \leq \frac{x}{\mathbf{L}} \leq \frac{x_A + \ell}{\mathbf{L}}$	$\frac{\mathbf{L} - x}{\mathbf{L} - x_A - 0.75 \cdot \ell}$	
$\frac{x_A + \ell}{\mathbf{L}} < \frac{x}{\mathbf{L}}$	0	

Section 6 Shell Structures

A General

A.1 References

Paragraphs of this section are based on the following international convention(s) and / or code(s):

IACS UR S8 Rev.4

IACS UR S9 Rev.6

At the end of each relevant paragraph, the corresponding paragraphs of the international convention(s) and / or code(s) are given in brackets.

A.2 Definitions

Securing device

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

Supporting device

Supporting device is 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

Locking device is a device that locks a securing device in the closed position.

(IACS UR S8.1.3 and IACS UR S9.1.3)

Symbols

c_{RW} : service range coefficient according to Section 4, A.3

k : material factor according to Section 2, A.2

ℓ : unsupported span $[m]$ of longitudinal or transverse, respectively

$\mathbf{L}_{200}$: corresponds to the length of the ship as $\mathbf{L}$, but $\mathbf{L}_{200}$ is not to be taken greater than 200 m

n_f : factor to take the framing system into account, defined as:

$n_f = 1.00$ for transverse framing

$n_f = 0.83$ for longitudinal framing

p_B : load on bottom according to Section 4, B.5

p_E : load on bow structures according to Section 4, B.3 or on stern structures according to Section 4, B.4

p_S, p_{S1} : loads on ship's sides according to Section 4, B.2

p_{SL} : design bottom slamming pressure according to Section 4, B.6

t_K : corrosion addition according to Section 3, G

$\sigma_{p\ell}$: permissible local design stress $[N/mm^2]$, defined as:

$$\sigma_{p\ell} = \sqrt{\sigma_{perm}{}^2 - 3 \cdot \tau_L^2} - 0.89 \cdot \sigma_L$$

$\sigma_{p\ell,max}$: maximum permissible local design stress $[N/mm^2]$, defined as:

$$\sigma_{p\ell,max} = \sqrt{\left(\frac{230}{k}\right)^2 - 3 \cdot \tau_L^2} - 0.89 \cdot \sigma_L$$

σ_L : maximum design hull girder bending stress according to Section 5, D.2.2

τ_L : maximum design shear stress due to longitudinal hull girder bending according to Section 5, D.2.2

σ_{perm} : permissible design stress $[N/mm^2]$, defined as:

$$\sigma_{perm} = \left(0.8 + \frac{\mathbf{L}}{450}\right) \cdot \frac{230}{k} \qquad \text{for } \mathbf{L} < 90 \text{ m}$$

$$\sigma_{perm} = \frac{230}{k} \qquad \text{for } \mathbf{L} \geq 90 \text{ m}$$

B Bottom Plating

B.1 Plate thickness

The thickness t_B of the bottom shell plating is not to be less than determined by the following formulae:

For ships without proven longitudinal strength:

$$t_B = t_{B1} \qquad \text{within } 0.4\,\mathbf{L} \text{ amidships}$$

$$t_B = \max\left[t_{B1}\ ;\ t_{B2}\right] \qquad \text{within } 0.1\,\mathbf{L} \text{ forward of the aft end of the length } \mathbf{L} \text{ and within } 0.05\,\mathbf{L} \text{ aft of } \mathbf{F.P.}$$

$$t_{B1} = 1.9 \cdot n_f \cdot \mathbf{a} \cdot \sqrt{p_B \cdot k} + t_K \quad [mm]$$

$$t_{B2} = 1.21 \cdot \mathbf{a} \cdot \sqrt{p_B \cdot k} + t_K \quad [mm]$$

For ships with proven longitudinal strength:

$$t_B = \max\left[t_{B1}\ ;\ t_{B2}\right]$$

$$t_{B1} = 18.3 \cdot n_f \cdot \mathbf{a} \cdot \sqrt{\frac{p_B}{\sigma_{p\ell}}} + t_K \quad [mm]$$

$$t_{B2} = 1.21 \cdot \mathbf{a} \cdot \sqrt{p_B \cdot k} + t_K \quad [mm]$$

B.2 Minimum plate thickness

At no point the thickness t_B of the bottom shell plating is to be less than t_{min} determined by the following formulae:

$$t_{min} = c_1 \cdot \sqrt{\mathbf{L} \cdot k} + t_K \quad [mm] \qquad \text{with } t_{min} \le 16 \text{ mm}$$

c_1 : coefficient, defined as:

$$c_1 = (1.5 - 0.01 \cdot \mathbf{L}) \qquad \text{for } \mathbf{L} < 50 \text{ m}$$

$$c_1 = 1.00 \qquad \text{for } \mathbf{L} \ge 50 \text{ m}$$

For bulk carriers see Section 23, C.4.3 and for tankers see Section 24, G.

B.3 Bilge strake

B.3.1 The thickness of the bilge strake is to be determined as required for the bottom plating according to B.1. The thickness so determined is to be verified for sufficient buckling strength according to the requirements of Section 5, E.4 and Section 3, D, see Section 3, Table 3.6, load cases 1 a, 1 b, 2 and 4.

If this verification shows that a smaller thickness than that of the bottom plating is possible, such smaller thickness is sufficient.

B.3.2 If according to Section 2, B. a higher steel grade than A / AH is required for the bilge strake, the width of the bilge strake is not to be less than determined by the following formulae:

$$b = 800 + 5 \cdot \mathbf{L} \quad [mm]$$

B.3.3 At the end of the curved bilge strake longitudinal stiffeners or girders are to be arranged. When the stiffeners are arranged outside the bilge radius sufficient buckling resistance according to Section 3, D. is to be shown for the plane plate fields between the bilge strake and the longitudinal stiffeners. For the proof of buckling strength the longitudinal stresses according to Section 5, D.2 and the transverse compression stresses σ_q are to be taken into account.

$$\sigma_q = \frac{p \cdot R}{t} \cdot 10^{-3} \quad [N/mm^2]$$

p : load $[kN/m^2]$ on bilge strake, defined as:

$p = p_S$, p_{S1} or p_B at the end of corner radius or p_{SL} as the case may be

R : bilge radius $[mm]$

t : plate thickness $[mm]$

a_L : spacing $[mm]$ of the floors or transverse stiffeners respectively

b_L : distance $[mm]$ of the longitudinal stiffener from the end of corner radius

The thickness of these plate fields is not to be less than the thickness determined according to from B.1, B.2 and C.1 respectively.

For the frame spacing $\mathbf{a}$ and the field length ℓ, a_L and $b_L + R/4$ are to be taken accordingly, see Fig. 6.1.

If the derived thickness for the plane plate field is larger than that for the curved bilge strake according to B.3.1 the reinforcement is to be expanded by a minimum of $R/6$ into the radius.

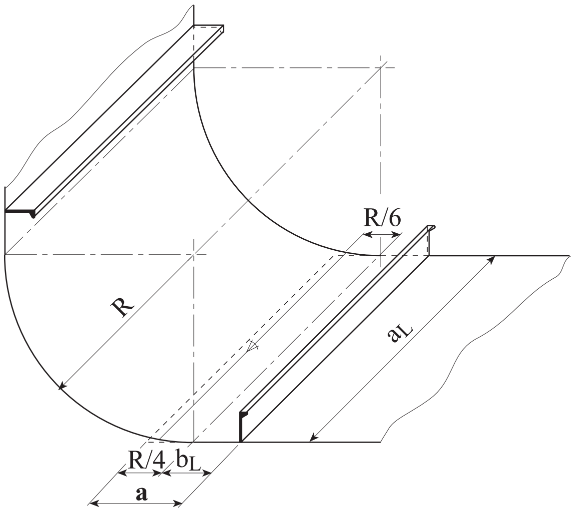


Fig. 6.1 Bilge strake

B.4 Flat plate keel and garboard strake

B.4.1 The width b of the flat plate keel is not to be less than determined by the following formula:

$$b = 800 + 5 \cdot \mathbf{L} \quad [\text{mm}]$$

The thickness t_{FK} of the flat plate keel is not to be less than be determined by the following formulae:

$$t_{FK} = t_B + 2.0 \quad [\text{mm}]$$ within 0.7 **L** amidships and in way of the engine seating

$$t_{FK} = t_B \quad [\text{mm}]$$ otherwise

t_B : thickness of the bottom plating according to B.1 and B.2

B.4.2 For ships exceeding 100 m in length, the bottom of which is longitudinally framed, the flat plate keel is to be stiffened by additional longitudinal stiffeners fitted at a distance of approximately 500 mm from centre line. The sectional area of one longitudinal stiffener should not be less than 0.2 **L** [cm^2].

B.4.3 Where a bar keel is arranged, the adjacent garboard strake is to have the scantlings of a flat plate keel.

C Side Shell Plating

C.1 Plate thickness

The thickness t_S of the side shell plating is not to be less than determined by the following formulae:

For ships without proven longitudinal strength:

$$t_S = t_{S1}$$ within 0.4 **L** amidships

$$t_S = \max\left[t_{S1}\ ;\ t_{S2}\right]$$ within 0.1 **L** forward of the aft end of the length **L** and within 0.05 **L** aft of **F.P.**

$$t_{S1} = 1.9 \cdot n_f \cdot \mathbf{a} \cdot \sqrt{p_S \cdot k} + t_K \quad [\text{mm}]$$

$$t_{S2} = 1.21 \cdot \mathbf{a} \cdot \sqrt{p \cdot k} + t_K \quad [\text{mm}]$$

For ships with proven longitudinal strength:

$$t_S = \max\left[t_{S1}\ ;\ t_{S2}\ ;\ t_{S3}\right]$$

$$t_{S1} = 18.3 \cdot n_f \cdot \mathbf{a} \cdot \sqrt{\frac{p_S}{\sigma_{p\ell}}} + t_K \quad [\text{mm}]$$

$$t_{S2} = 1.21 \cdot \mathbf{a} \cdot \sqrt{p \cdot k} + t_K \quad [\text{mm}]$$

$$t_{S3} = 18.3 \cdot n_f \cdot \mathbf{a} \cdot \sqrt{\frac{p_{S1}}{\sigma_{p\ell,\max}}} + t_K \quad [\text{mm}]$$

p : loads $[\text{kN}/\text{m}^2]$ on shell plating, defined as:

$p = p_S$ or p_E as the case may be

C.2 Minimum plate thickness

At no point the thickness t_S of the side shell plating is to be less than t_{min} determined according to B.2. Above a level $\mathbf{T} + c_0/2$ above base line smaller thicknesses than t_{min} may be accepted if the stress level permits such reduction.

c_0 : wave coefficient according to Section 4, A.3

C.3 Sheerstrake

C.3.1 The width b of the sheerstrake is not to be less than determined by the following formula:

$$b = 800 + 5 \cdot \mathbf{L} \quad [\text{mm}] \qquad \text{with } b \le b_{max}$$

b_{max} : maximum width of the sheerstake $[\text{mm}]$, defined as:

$$b_{max} = 1\,800$$

C.3.2 The thickness t of the sheerstrake is, in general, not to be less than determined by the following formula:

$$t = 0.5 \cdot \left(t_D + t_S\right) \quad [\text{mm}] \qquad \text{with } t \ge t_s$$

t_D : required thickness of strength deck according to Section 7, B.4

t_S : required thickness of side shell according to C.1

C.3.3 Where the connection of the deck stringer with the sheerstrake is rounded, the radius is to be at least 15 times the plate thickness.

C.3.4 Welds on upper edge of sheerstrake are subject to special approval.

Regarding welding between sheerstrake and deck stringer see Section 7, B.2.

Holes for scuppers and other openings are to be carefully rounded and free of notches.

C.4 Strengthenings for harbour and tug manoeuvres

C.4.1 In those zones of the side shell which may be exposed to concentrated loads due to harbour manoeuvres the plate thickness is not to be less than required by C.4.2. These zones are mainly the plates in way of the ship's fore and aft shoulder and in addition amidships. The exact locations where the tugs have to push are to be defined in the building specification. They are to be identified in the shell expansion plan. The length of the strengthened areas is not to be less than approximately 5 m. The height of the strengthened areas is to extend from about 0.5 m above ballast draught to about 4.0 m above scantling draught.

Where the side shell thickness so determined exceeds the thickness required by C.1 – C.3 it is recommended to specially mark these areas.

C.4.2 The plate thickness t in the strengthened areas is to be determined by the following formula:

$$t = 0.65 \cdot \sqrt{P_{f\ell} \cdot k} + t_K \quad [mm]$$

$P_{f\ell}$: local design force [kN], defined as:

$$P_{f\ell} = D/100 \qquad \text{with } 200 \le P_{f\ell} \le 1\,000 \text{ kN}$$

D : displacement [t] of the ship at scantling draught

Any reductions in thickness for restricted service are not permissible.

C.4.3 In the strengthened areas the section modulus W of side longitudinals is not to be less than determined by the following formula:

$$W = 0.35 \cdot P_{f\ell} \cdot \ell \cdot k \quad [cm^3]$$

$P_{f\ell}$: local design force according to C.4.2

C.4.4 'Tween decks, transverse bulkheads, stringer and transverse walls are to be investigated for sufficient buckling strength against loads acting in the ship's transverse direction. For scantlings of side transverses supporting side longitudinals see Section 9, B.5.4.

D Strengthening of Bottom Forward

D.1 Arrangement of floors and girders

D.1.1 For the purpose of arranging floors and girders the following areas are defined:

Forward of $\frac{x}{\mathbf{L}} = 0.7$ for $\mathbf{L} \le 100$ m

Forward of $\frac{x}{\mathbf{L}} = (0.6 + 0.001 \cdot \mathbf{L})$ for $100 < \mathbf{L} \le 150$ m

Forward of $\frac{x}{\mathbf{L}} = 0.75$ for $\mathbf{L} > 150$ m

D.1.2 In case of transverse framing, plate floors are to be fitted at every frame. Where the longitudinal framing system or the longitudinal girder system is adopted the spacing of plate floors may be equal to three transverse frame spaces.

D.1.3 In case of transverse framing, the spacing of side girders is not to exceed $\mathbf{L}/250 + 0.9$ [m], up to a maximum of 1.4 m.

In case of longitudinal framing, the side girders are to be fitted not more than two longitudinal frame spacings apart.

D.1.4 Distances deviating from those defined in D.1.2 and D.1.3 may be accepted on the basis of direct calculations.

D.1.5 Within the areas defined in D.1.1 any scalloping is to be restricted to holes for welding and for limbers.

D.2 Bottom plating forward of $\frac{x}{\mathbf{L}} = 0.5$

The thickness t of the bottom plating of the flat part of the ship's bottom up to a height of $0.05 \cdot T_b$ or $0.3\ m$ above base line, whichever is the smaller value, is not to be less than determined by the following formula:

$$t = 0.9 \cdot f_2 \cdot \mathbf{a} \cdot \sqrt{p_{SL} \cdot k} + t_K \quad [mm]$$

T_b : smallest design ballast draft $[m]$ at the forward perpendicular

f_2 : aspect ratio factor according to Section 3, B.2.2

Above $0.05\ T_b$ or $0.3\ m$ above base line the plate thickness may gradually be tapered to the rule thickness determined according to B. For ships with a rise of floor the strengthened plating is at least to extend to the bilge curvature.

D.3 Stiffeners forward of $\frac{x}{\mathbf{L}} = 0.5$

The section modulus W and the shear area A of transverse or longitudinal stiffeners is not to be less than determined by the following formula:

$$W = 0.155 \cdot p_{SL} \cdot \mathbf{a} \cdot \ell^2 \cdot k \quad [cm^3]$$

$$A = 0.028 \cdot p_{SL} \cdot \mathbf{a} \cdot (\ell - 0.5 \cdot \mathbf{a}) \cdot k \quad [cm^2]$$

The area of the welded connection has to be at least twice this value.

E Strengthenings in Way of Propellers and Propeller Shaft Brackets, Bilge Keels

E.1 Strengthenings in way of propellers and propeller shaft brackets

E.1.1 The thickness of the shell plating in way of propellers is to be determined according to C.

Note

It is recommended that plate fields and stiffeners of shell structures in the vicinity of the propeller(s) be specially considered from a vibration point of view (see also Section 12, B.6). For vessels with a single propeller, plate fields and stiffeners should fulfil the following frequency criteria. To fulfil the criteria the lowest natural frequencies of plate fields and stiffeners are to be higher than the denoted propeller blade passage excitation frequencies.

Table 6.1 ***Frequency criteria***

	$\alpha \geq 0.3$			$\alpha < 0.3$	
	$0 < d_r \leq 1$	$1 < d_r \leq 2$	$2 < d_r \leq 3$	$0 < d_r \leq 1$	$1 < d_r \leq 3$
$f_{plate} >$	$4.40 \cdot f_{blade}$	$3.45 \cdot f_{blade}$	$2.40 \cdot f_{blade}$	$3.45 \cdot f_{blade}$	$2.40 \cdot f_{blade}$
$f_{stiff} >$	$4.40 \cdot f_{blade}$	$3.45 \cdot f_{blade}$	$2.40 \cdot f_{blade}$	$3.45 \cdot f_{blade}$	$2.40 \cdot f_{blade}$

α : *ratio, defined as:*

$$\alpha = \frac{P}{\Delta}$$

P : *nominal main engine output* $[kW]$

Δ : *ship's design displacement* $[t]$

f_{plate} : *lowest natural frequency* $[Hz]$ *of isotropic plate field under consideration of additional outfitting and hydrodynamic masses*

f_{stiff} : *lowest natural frequency* $[Hz]$ *of stiffener under consideration of additional outfitting and hydrodynamic masses*

The natural frequencies of plate fields and stiffeners can be estimated by POSEIDON or by means of the software tool GL LocVibs which can be downloaded from the GL homepage www.gl-group.com/en/gltools/GL-Tools.php.

d_r : *ratio, defined as:*

$$d_r = \frac{r}{d_p} \qquad \text{with } d_r \geq 1.0$$

r : *distance* $[m]$ *of plate field or stiffener to 12 o'clock propeller blade tip position*

d_p : *propeller diameter* $[m]$

f_{blade} : *propeller blade passage excitation frequency* $[Hz]$ *at* n*, defined as:*

$$f_{blade} = \frac{1}{60} \cdot n \cdot z$$

n : *maximum propeller shaft revolution rate* $[1 / min]$

z : *number of propeller blades*

E.1.2 In way of propeller shaft brackets, Section 19, B.4.3 is to be observed.

E.2 Bilge keels

E.2.1 Where bilge keels are provided they are to be welded to continuous flat bars, which are connected to the shell plating with their flat side by means of a continuous watertight welded seam, see bottom of Fig. 6.2.

E.2.2 The ends of the bilge keels are to have soft transition zones according to Fig. 6.2, top. The ends of the bilge keels have to terminate above an internal stiffening element.

E.2.3 Any scallops or cut-outs in the bilge keels are not allowed.

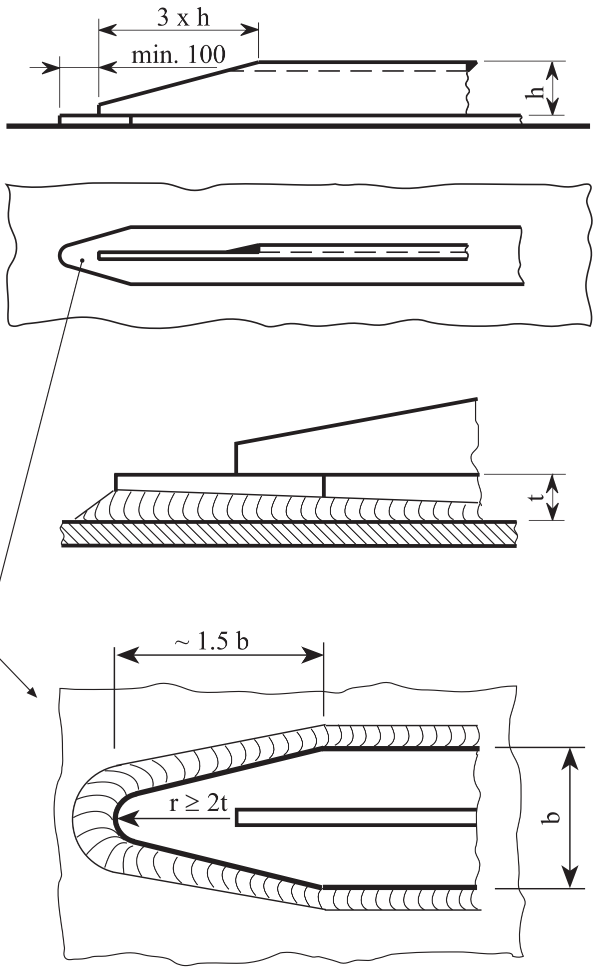


Fig. 6.2 Soft transition zones at the ends of bilge keels

F Openings in the Shell Plating

F.1 General

F.1.1 Where openings are cut in the shell plating for windows or side scuttles, hawses, scuppers, sea valves etc., they are to have well rounded corners. If they exceed 500 mm in width in ships up to **L** = 70 m, and 700 mm in ships having a length **L** of more than 70 m, the openings are to be surrounded by framing, a thicker plate or a doubling.

F.1.2 Above openings in the sheer strake within 0.4 **L** amidships, generally a strengthened plate or a continuous doubling is to be provided compensating the omitted plate sectional area. For shell doors and similar large openings see H. Special strengthening is required in the range of openings at ends of superstructures.

F.1.3 The shell plating in way of the hawse pipes is to be reinforced.

F.2 Pipe connections at the shell plating

Scupper pipes and valves are to be connected to the shell by weld flanges. Instead of weld flanges short flanged sockets of adequate thickness may be used if they are welded to the shell in an appropriate manner. Reference is made to Section 21, E.

Construction drawings are to be submitted for approval.

G Bow Doors and Inner Doors

G.1 General

G.1.1 Applicability

G.1.1.1 These requirements are for the arrangement, strength and securing of bow doors and inner doors leading to a complete or long forward enclosed superstructure.

(IACS UR S8.1.1a)

G.1.1.2 Two types of bow door are covered by these requirements:

- 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 doors will be specially considered in association with the applicable requirements of these Rules.

(IACS UR S8.1.1b)

G.1.2 Arrangement

G.1.2.1 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.

(IACS UR S8.1.2a)

G.1.2.2 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 collision bulkhead below, provided it is located within the limits specified in Section 11, B.3 for the position of the collision bulkhead. A vehicle ramp may be arranged for this purpose, provided its position complies with Section 11, B.3. If this is not possible, a separate inner weatherthight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

(IACS UR S8.1.2b)

G.1.2.3 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.

(IACS UR S8.1.2c)

G.1.2.4 Bow doors and inner doors are to be so arranged 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 G.1.2.2.

(IACS UR S8.1.2d)

G.1.2.5 The requirements for inner doors are based on the assumption that the vehicles are effectively lashed and secured against movement in stowed position.

(IACS UR S8.1.2e)

G.2 Strength criteria

G.2.1 Primary structure and securing and supporting devices

G.2.1.1 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 G.3, using the following stresses are not exceeded:

$$\sigma_v = \sqrt{\sigma^2 + 3 \cdot \tau^2} = \frac{150}{k} \quad [N/mm^2]$$ for equivalent stresses

$$\sigma = \frac{120}{k} \quad [N/mm^2]$$ for bending stresses

$$\tau = \frac{80}{k} \quad [N/mm^2]$$ for shear stresses

k : material factor according to Section 2, A.2, but k is not to be taken less than 0.72 unless a direct strength analysis with regard to relevant modes of failures (including fatigue analysis according to Section 20) is carried out.

(IACS UR S8.2.1a and IACS UR S.9.2.1a)

G.2.1.2 The buckling strength of primary members is to be verified according to Section 3, D..

(IACS UR S8.2.1b and IACS UR S.9.2.1b)

G.2.1.3 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 $0.8 \cdot R_{eH}$, where R_{eH} is the yield strength of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

(IACS UR S8.2.1c and IACS UR S.9.2.1c)

G.2.1.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension stress in way of threads of bolts not carrying support forces is not to exceed $125 / k$ $[N/mm^2]$ with k according to G.2.1.1.

(IACS UR S8.2.1d and IACS UR S.9.2.1d)

G.3 Load on bow doors and inner doors

G.3.1 Load on bow doors

G.3.1.1 The design external pressure p_e to be considered for the scantlings of primary members, securing and supporting devices of bow doors is not to be less than determined by the following formula:

$$p_e = 2.75 \cdot \frac{1 + c_{RW}}{2} \cdot c_H \cdot (0.22 + 0.15 \cdot \tan\alpha) \cdot \left(0.4 \cdot v_o \cdot \sin\beta + 0.6 \cdot \sqrt{\mathbf{L}_{200}}\right)^2 \quad [kN/m^2]$$ with $p_e \geq p_E$

c_H : coefficient, defined as:

$c_H = 0.0125 \cdot \mathbf{L}$ for $\mathbf{L} < 80$ m

$c_H = 1.0$ for $\mathbf{L} \geq 80$ m

α : flare angle [°] at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, see also Fig. 6.3

β : entry angle [°] at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, see also Fig. 6.3

(IACS UR S8.3.1a)

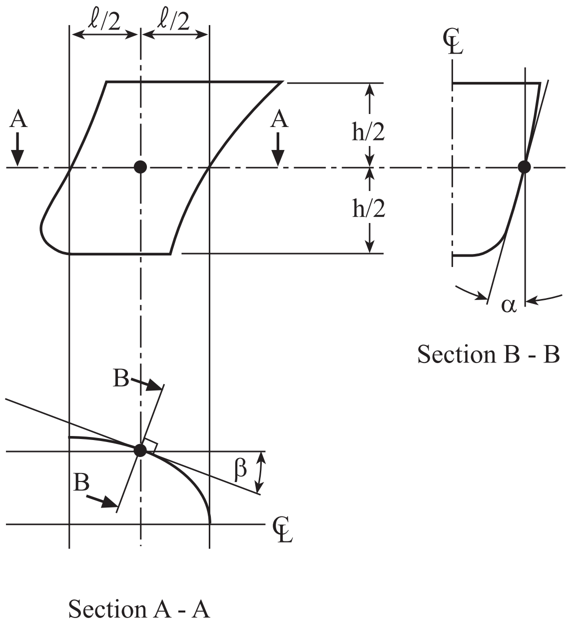


Fig. 6.3 Definition angles α and β

G.3.1.2 The design external forces F_x, F_y and F_z for determining scantlings of securing and supporting devices of bow doors are not to be less than determined by the following formula:

$$F_x = p_e \cdot A_x \quad [kN]$$

$$F_y = p_e \cdot A_y \quad [kN]$$

$$F_z = p_e \cdot A_z \quad [kN]$$

p_e : external design pressure $[kN/m^2]$ according to G.3.1.1 with angles α and β defined as follows:

α is the 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 Fig. 6.3.

β is the entry angle measured at the same point as α

ℓ : length $[m]$ of the door at a height $h / 2$ above the bottom of the door

h : height $[m]$ 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

A_x : area $[m^2]$ of the transverse vertical projection 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, see also Fig. 6.4

A_y : area $[m^2]$ of the longitudinal vertical projection 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, see also Fig. 6.4

A_z : area $[m^2]$ of the horizontal projection 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, see also Fig. 6.4

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.

(IACS UR S8.3.1b)

G.3.1.3 For visor doors the closing moment M_y under external loads is to be determined by the following formula:

$$M_y = F_x \cdot a + 10 \cdot W \cdot c - F_z \cdot b \quad [kNm]$$

F_x, F_z : design external forces according to G.3.1.2

W : mass $[t]$ of the visor door

a : vertical distance $[m]$ from visor pivot to the centroid of the transverse vertical projected area A_x of the visor door, as shown in Fig. 6.4

b : horizontal distance $[m]$ from visor pivot to the centroid of the horizontal projected area A_z of the visor door, as shown in Fig. 6.4

A_x, A_z : areas according to G.3.1.2

c : horizontal distance $[m]$ from visor pivot to the centre of gravity of visor mass, as shown in Fig. 6.4

(IACS UR S8.3.1c)

G.3.1.4 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 $1.5\ kN/m^2$ is to be taken into account.

(IACS UR S8.3.1d)

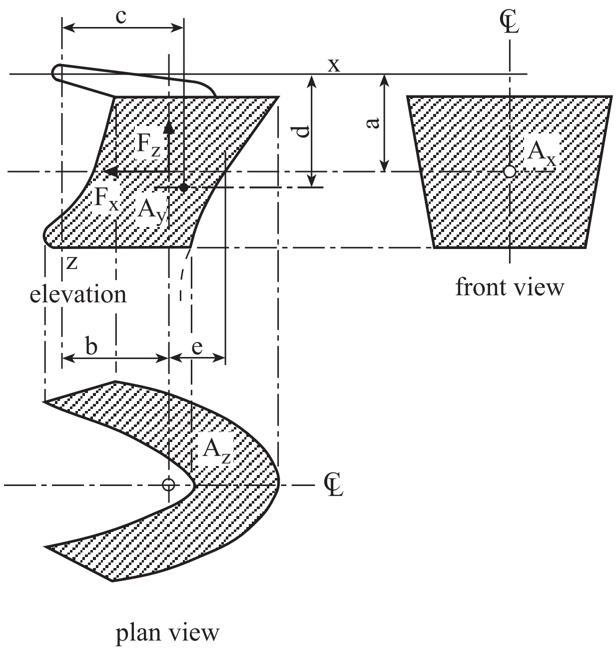


Fig. 6.4 Bow door of visor type

G.3.2 Load on inner doors

G.3.2.1 The design external pressure p_e, considered for the scantlings of primary members, securing and supporting devices and surrounding structure of inner doors is to be determined by the following formula:

$$p_e = \max\left[0.45 \cdot \mathbf{L}_{200}\ ;\ 10 \cdot h\right] \quad [kN/m^2]$$

h : distance $[m]$ from the load point to the top of the cargo space

(IACS UR S8.3.2a)

G.3.2.2 The design internal pressure p_i considered for the scantlings of securing devices of inner doors is not to be less than determined by the following formula:

$$p_i = 25 \text{ kN} / \text{m}^2$$

(IACS UR S8.3.2b)

G.4 Scantlings of bow doors

G.4.1 General

G.4.1.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

(IACS UR S8.4.1a)

G.4.1.2 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.

(IACS UR S8.4.1b)

G.4.2 Plating and secondary stiffeners

G.4.2.1 The thickness t of the bow door plating is to be determined by the following formula:

$$t = t_{S2} \qquad \text{with } t \geq t_{min}$$

t_{S2} : shell thickness according to C.1, using bow door stiffener spacing and $\sigma_{p\ell} = 230 / k$

t_{min} : minimum shell thickness according to C.2

(IACS UR S8.4.2a)

G.4.2.2 The section modulus of horizontal or vertical stiffeners is not to be less than that required for framing at the position of the door according to Section 9. Consideration is to be given, where necessary, to differences in fixity between ship's frames and bow doors stiffeners.

(IACS UR S8.4.2b)

G.4.2.3 The stiffener webs are to have a net sectional area A_w not less than determined by the following formula:

$$A_w = \frac{Q \cdot k}{10} \quad [\text{cm}^2]$$

Q : shear force $[\text{kN}]$ in the stiffener calculated by using p_e

p_e : load on bow doors according to G.3.1.1

(IACS UR S8.4.2c)

G.4.3 Primary structure

G.4.3.1 The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

(IACS UR S8.4.3a)

G.4.3.2 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.

(IACS UR S8.4.3b)

G.4.3.3 Scantlings of the primary members are generally to be verified by direct calculations in association with the external design pressure given in G.3.1.1 and permissible stresses given in G.2.1.1. 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

(IACS UR S8.4.3c)

G.5 Scantlings of inner doors

G.5.1 General

G.5.1.1 Scantlings of the primary members are generally to be verified by direct calculations in association with the external design pressure given in G.4.3.3 and permissible stresses given in G.2.1.1. Normally, formulae for simple beam theory may be applied.

(IACS UR S8.5.1a)

G.5.1.2 Where inner doors also serve as vehicle ramps, the scantlings are not to be less than those required for vehicle decks according to Section 7, C.2.1.

(IACS UR S8.5.1b)

G.5.1.3 The distribution of the forces acting on the securing and supporting devices is generally to be verified by direct calculations taking into account the flexibility of the structure and the actual position and stiffness of the supports.

(IACS UR S8.5.1c)

G.6 Securing and supporting of bow doors

G.6.1 General

G.6.1.1 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. The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

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

(IACS UR S8.6.1a)

G.6.1.2 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 G.6.2.5. The number of securing and supporting devices are generally to be the minimum practical whilst taking into account the redundancy requirements given in G.6.2.6 and G.6.2.7 and the available space for adequate support in the hull structure.

(IACS UR S8.6.1b)

G.6.1.3 For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self closing under external loads, that is $M_y > 0$. Moreover, the closing moment M_y as given in G.3.1.3 is to be not less than determined by the following formula:

$$M_{yo} = 10 \cdot W \cdot c + 0.1 \cdot \sqrt{a^2 + b^2} \cdot \sqrt{F_x^2 + F_z^2} \quad [\mathrm{kNm}]$$

F_x, F_z : design external forces according to G.3.1.2

W : mass [t] of the visor door

a, b, c :distances according to G.3.1.3

A_x, A_z : areas according to G.3.1.2

(IACS UR S8.6.1c)

G.6.2 Scantlings

G.6.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in G.2.1.1.

(IACS UR S8.6.2a)

G.6.2.2 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:

- Case 1: F_x and F_z,
- Case 2: $0.7 \cdot F_y$ acting on each side separately together with $0.7 \cdot F_x$ and $0.7 \cdot F_z$

F_x, F_y, F_z : design external forces according to G.3.1.2 applied at the centroid of the projected areas

(IACS UR S8.6.2b)

G.6.2.3 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:

- Case 1: F_x, F_y and F_z acting on both doors
- Case 2: $0.7 \cdot F_x$ and $0.7 \cdot F_z$ acting on both doors and $0.7 \cdot F_y$ acting on each door separately

F_x, F_y, F_z : design external forces according to G.3.1.2 applied at the centroid of the projected areas

(IACS UR S8.6.2c)

G.6.2.4 The support forces as determined according to G.6.2.2 and G.6.2.3 have generally to result in 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.

(IACS UR S8.6.2d)

G.6.2.5 The distribution of the reaction forces acting on the securing and supporting devices may require to be verified by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports. This is, for instance, the case when the bow door is supported statically undetermined.

(IACS UR S8.6.2e)

G.6.2.6 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 of withstanding the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in G.2.1.1.

(IACS UR S8.6.2f)

G.6.2.7 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 G.2.1.1. The opening moment M_o to be balanced by this reaction force, is not to be taken less than determined by the following formula:

$$M_o = \max\left[M_{o1}\ ;\ M_{o2}\right]$$

$$M_{o1} = F_H \cdot d + 5 \cdot A_x \cdot a \quad [\mathrm{kNm}]$$

$$M_{o2} = \Delta x \cdot \sqrt{F_x^2 + F_z^2} \quad [\mathrm{kNm}]$$

F_H : horizontal design force [kN], acting forward in the centre of gravity, defined as:

$$F_H = 10 \cdot W$$

W : mass [t] of the visor door

d : vertical distance [m] from the hinge axis to the centre of gravity of the door mass, as shown in Fig. 6.4

A_x : area according to G.3.1.2

a : distance [m] according to G.3.1.3

Δx : lever [m], defined as:

$$\Delta x = 0.25 \cdot e$$

e : distance [m] according to Fig. 6.4

F_x, F_z : design external forces according to G.3.1.2

(IACS UR S8.6.2g)

G.6.2.8 For visor doors, the securing and supporting devices excluding the hinges are to be capable of resisting the vertical design force $F_v = F_z - 10 \cdot W$ [kN] within the permissible stresses given in G.2.1.1.

F_z : design external force according to G.3.1.2

W : mass [t] of the visor door

(IACS UR S8.6.2h)

G.6.2.9 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 of the same strength standard as required for the securing and supporting devices.

(IACS UR S8.6.2i)

G.6.2.10 For side-opening doors, thrust bearings are 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. An example for a thrust bearing is shown in Fig. 6.5. Securing devices are to be provided so that each part of the thrust bearing can be kept secured on the other part. Any other arrangement serving the same purpose may be accepted.

(IACS UR S8.6.2j)

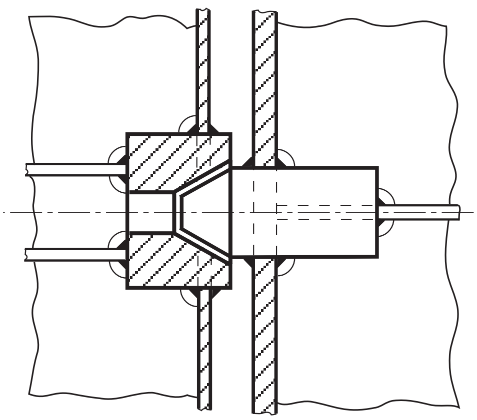


Fig. 6.5 Thrust bearing

G.7 Arrangement of securing and locking devices

G.7.1 Systems for operation

G.7.1.1 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.

(IACS UR S8.7.1a)

G.7.1.2 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 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.

(IACS UR S8.7.1b)

G.7.1.3 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.

(IACS UR S8.7.1c)

G.7.2 Systems for indication / monitoring

The requirements according to G.7.2.3 – G.7.2.6 are only for ships – with or without passengers – with Ro-Ro spaces as defined in Chapter II-2, Regulation 3 of **SOLAS 74**.

G.7.2.1 Indicator lights are to be provided on the bridge and at the operating console for indication that the bow door and the inner door are closed and the locking and securing devices are in their correct positions. Deviations from the correct closed, locked and secured condition are to be indicated by optical and audible alarms.

The indicator panel is to be provided with:

- a power failure alarm
- an earth failure alarm
- a lamp test and
- separate indication for door closed, door locked, door not closed and door not locked

Switching the indicating lights off is not permitted.

(IACS UR S8.7.2a)

G.7.2.2 The indicator system is to be designed on the self-monitoring principle and is to be alarmed by visual and audible means if the door is not fully closed and not fully locked or 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 doors. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages. Degree of protection: at least IP 56.

(IACS UR S8.7.2b)

G.7.2.3 The indication panel on the navigation bridge is to be equipped with a selector switch "harbour/sea voyage", so arranged that alarm is given if vessel leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

(IACS UR S8.7.2c)

G.7.2.4 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 room of leakage through the inner door.

(IACS UR S8.7.2d)

G.7.2.5 For the space 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 has to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

(IACS UR S8.7.2e)

G.7.2.6 A drainage system is to be arranged in the area between bow door and ramp, as well as in the area between the ramp and inner door where fitted. The system is to be equipped with an acustic alarm function to the navigation bridge for water level in these areas exceeding 0.5 m above the car deck level.

(IACS UR S8.7.2f)

G.7.2.7 For indication and monitoring systems see also the GL Rules for Electrical Installations (I-1-3), Section 16, E.

G.8 Operating and maintenance manual

G.8.1 An operating and maintenance manual according to IACS unified requirement S8 for the bow door and inner door has to be provided on board and contain necessary information on:

- description of the door system and design drawings
- service conditions, service area restrictions and acceptable clearances for supports
- maintenance and function testing
- register of inspections and repairs

The manual has to be submitted for approval.

Note

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

(IACS UR S8.8.1)

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

(IACS UR S8.8.2)

H Side Shell Doors and Stern Doors

H.1 General

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

(IACS UR S9.1.1a)

H.2 Arrangement

H.2.1 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.

(IACS UR S9.1.2a)

H.2.2 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.

(IACS UR S9.1.2b)

H.2.3 Where the sill of any side shell door is below the uppermost load line, the arrangement is to be specially considered.

(IACS UR S9.1.2c)

H.2.4 Doors should preferably open outwards.

(IACS UR S9.1.2d)

H.2.5 In case of ice strengthening see Section 15.

H.3 Strength criteria

The requirements of G.2 apply.

(IACS UR S9.2)

H.4 Loads on side shell doors and stern doors

The design forces p_e considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are to be not less than the greater of the values determined by the following formulae:

- Design forces for securing or supporting devices of doors opening inwards:

$$F_E = A \cdot p_e + F_P \quad [\mathrm{kN}] \qquad \text{as external force}$$

$$F_I = F_o + 10 \cdot W \quad [\mathrm{kN}] \qquad \text{as internal force}$$

- Design forces for securing or supporting devices of doors opening outwards:

$$F_E = A \cdot p_e \quad [\mathrm{kN}] \qquad \text{as external force}$$

$$F_I = F_o + 10 \cdot W + F_P \quad [\mathrm{kN}] \qquad \text{as internal force}$$

- Design forces for primary members:

$$F_E = A \cdot p_e \quad [\mathrm{kN}] \qquad \text{as external force}$$

$$F_I = F_o + 10 \cdot W \quad [\mathrm{kN}] \qquad \text{as internal force}$$

A : area $[\mathrm{m}^2]$ of the door opening

p_e : external design pressure $[\mathrm{kN/m}^2]$ determined at the centre of gravity of the door opening; defined as:

$$p_e = p_S \qquad p_e \ge p_{e,min}$$

$p_{e,min}$: minimum load $[\mathrm{kN/m}^2]$ on ship's side; defined as:

$$p_{e,min} = 10 \cdot (\mathbf{T} - z_G) + 25 \qquad \text{for } z_G < \mathbf{T}$$

$$p_{e,min} = 25 \qquad \text{for } z_G \ge \mathbf{T}$$

Moreover, for stern doors of ships fitted also with bow doors, $p_{e,min}$ is to be determined by the following formula:

$$p_{e,min} = 0.6 \cdot \left(\frac{1 + c_{RW}}{2}\right) \cdot c_H \cdot \left(0.8 + 0.6 \cdot \sqrt{\mathbf{L}}\right)^2 \quad [\mathrm{kN/m}^2]$$

z_G : height $[\mathrm{m}]$ of centre of area of door above base line

c_H : coefficient according to G.3.1.1

F_P : total packing force $[\mathrm{kN}]$, where the packing line pressure is normally not to be taken less than $5\ \mathrm{N/mm}$

F_o : force $[kN]$, defined as:

$$F_o = \max\left[F_C \; ; \; 5 \cdot A\right]$$

F_C : accidental force $[kN]$ due to loose of cargo etc., to be uniformly distributed over the area A and not to be taken less than 300 kN. 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.

W : mass $[t]$ of the door

(IACS UR S9.3.1)

H.5 Scantlings

H.5.1 General

The requirements of G.4.1 apply analogously with the following additions:

- Where doors also serve as vehicle ramps, the design of the hinges shall take into account the ship's angle of trim and heel which may result in uneven loading on the hinges.
- 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.

(IACS UR S9.4.1)

H.5.2 Plating and secondary stiffeners

The requirements of G.4.2.1 and G.4.2.2 apply analoguously with the following additions:

Where doors serve as vehicle ramps, plate thickness and stiffener scantlings are to comply with the requirements of Section 7, C.2.

(IACS UR S9.4.2)

H.5.3 Primary structure

The requirements of G.4.3 apply analoguously taking into account the design loads specified in H.4.

Where doors serve as vehicle ramps, plate thickness and stiffener scantlings are to comply with the requirements of Section 7, C.2.

(IACS UR S9.4.3)

H.6 Securing and supporting of side shell and stern doors

H.6.1 General

The requirements of G.6.1.1 and G.6.1.2 apply analogously.

(IACS UR S9.5.1)

H.6.2 Scantlings

The requirements of G.6.2.1, G.6.2.5, G.6.2.6 and G.6.2.9 apply analogously taking into account the design loads specified in H.4.

(IACS UR S9.5.2)

H.7 Arrangement of securing and locking devices

H.7.1 Systems for operation

H.7.1.1 The requirements of G.7.1.1 apply.

(IACS UR S9.6.1a)

H.7.1.2 Doors which are located partly or totally below the freeboard deck with a clear opening area greater than $6\ m^2$ are to be provided with an arrangement for remote control, from a position above the freeboard deck according to G.7.1.2.

(IACS UR S9.6.1b)

H.7.1.3 The requirements of G.7.1.3 apply.

(IACS UR S9.6.1c)

H.7.2 Systems for indication/monitoring

(IACS UR S9.6.2)

H.7.2.1 The requirements of G.7.2.1, G.7.2.2 and G.7.2.3 apply analoguously to doors leading directly to special category spaces or Ro-Ro spaces, as defined in **SOLAS 1974**, Chapter II-2, Reg. 3, through which such spaces may be flooded.

H.7.2.2 For Ro-Ro 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 Ro-Ro cargo ships, a water leakage detection system with audible alarm is to be arranged to provide an indication to the navigation bridge.

H.8 Operating and maintenance manual

The requirements of G.8 apply analoguously as well as the IACS unified requirement S9.

(IACS UR S9.7)

I Bulwark

I.1 The thickness t of bulwark plating is not to be less than determined by the following formulae:

$$t = \left(0.75 - \frac{\mathbf{L}}{1000}\right) \cdot \sqrt{\mathbf{L}} \quad [\text{mm}] \qquad \text{for } \mathbf{L} \le 100\ \text{m}$$

$$t = 0.65 \cdot \sqrt{\mathbf{L}_{200}} \quad [\text{mm}] \qquad \text{for } \mathbf{L} > 100\ \text{m}$$

The thickness of bulwark plating forward particularly exposed to wash of sea is to be equal to the thickness of the forecastle side plating according to Section 16, D.2.1.1.

In way of superstructures above the freeboard deck abaft $0.25\ \mathbf{L}$ from **F.P.** the thickness of the bulwark plating may be reduced by 0.5 mm.

I.2 The vertical bulwark height or height of guard rail is not to be less than 1.0 m.

I.3 Plate bulwarks are to be stiffened at the upper edge by a bulwark rail section.

I.4 The bulwark is to be supported by bulwark stays fitted at every alternate frame. Where the stays are designed according to Fig. 6.6, the section modulus W of their cross section effectively attached to the deck is not to be less than determined by the following formula:

$$W = 4 \cdot p \cdot e \cdot \ell^2 \quad [\text{cm}^3]$$

p : design pressure $[\text{kN/m}^2]$, defined as:

$p = p_s$ or p_e as the case may be with $p \ge p_{min}$

p_{min} : minimum design pressure $[kN / m^2]$, defined as:

$$p_{min} = 15$$

e : spacing $[m]$ of stays

ℓ : length $[m]$ of stay

The required section modulus W is to be fulfilled at following cross sections:

- If the flange of the bulwark stay is connected to the deck:
  - W is to be fulfilled at cross section A – A (including the flange)
- if the flange of the bulwark stay is not connected to the deck:
  - W is to be fulfilled at cross section A – A (including the flange)
  - W is to be fulfilled at cross section B – B (excluding the flange)

The effective breath is to be considered analogously to cantilevers according to Section 3, C.2.3.

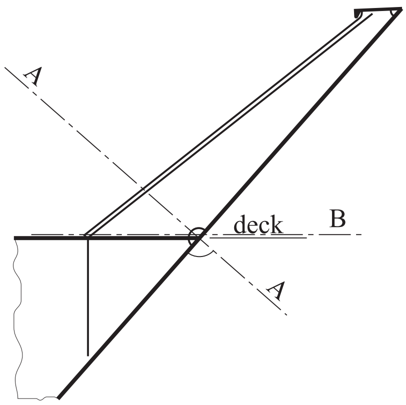


Fig. 6.6 Bulwark stay

I.5 The stays are to be fitted above deck beams, beam knees or carlings. It is recommended to provide flat bars in the lower part which are to be effectively connected to the deck plating. Particularly in ships the strength deck of which is made of higher tensile steel, smooth transitions are to be provided at the end connection of the flat bar faces to deck.

I.6 On ships carrying deck cargo, the bulwark stays are to be effectively connected to the bulwark and the deck. The stays are to be designed for a load at an angle of heel of $30°$. Under such loads the following stresses are not to be exceeded:

$$\sigma_b = \frac{120}{k} \quad [N / mm^2]$$ for bending stresses

$$\tau = \frac{80}{k} \quad [N / mm^2]$$ for shear stresses

For loads caused by containers and by stow and lashing arrangements, see also Section 21, H.

I.7 An adequate number of expansion joints is to be provided in the bulwark. In longitudinal direction the stays adjacent to the expansion joints are to be as flexible as practicable.

The number n of expansion joints for ships exceeding 60 m in length should be:

$$\frac{\mathbf{L}}{40} \le n \le 5$$

I.8 Openings in the bulwarks are to have sufficient distance from the end bulkheads of superstructures. For avoiding cracks the connection of bulwarks to deckhouse supports is to be carefully designed.

I.9 For the connection of bulwarks with the sheer strake C.3.4 is to be observed.

I.10 Bulwarks are to be provided with freeing ports of sufficient size. See also Section 21, E.2 and **ICLL**.

Section 7 Decks

A General

A.1 Definitions

Helideck

Helideck is a purpose-built helicopter landing platform or other deck area including all structure, fire-fighting appliances and other equipment necessary for the safe operation of helicopters, as referred to in SOLAS regulations II-2/3.26 and 18.5 and the 2009 MODU Code (chapter 1, paragraph 1.3.27).

Helicopter landing area

Helicopter landing area is an area on a ship designated for occasional or emergency landing of helicopters, for example as referred to in SOLAS regulation II-2/18.2.2 and not designed for routine helicopter operations.

Symbols

k : material factor according to Section 2, A.2

$\mathbf{L}_{200}$: corresponds to the length of the ship as $\mathbf{L}$, but $\mathbf{L}_{200}$ is not to be taken greater than $200\ \mathrm{m}$

p_{AD}, p_{MD} : loads on accommodation and machinery decks according to Section 4, C.3

p_D : external load on weather decks $[\mathrm{kN/m^2}]$ according to Section 4, B.1

p_L : 'tween deck load $[\mathrm{kN/m^2}]$ according to Section 4, C.1.1

t_K : corrosion addition according to Section 3, G.

B Strength Deck

B.1 Corrosion addition

If the strength deck is protected by sheathing a smaller corrosion addition t_k than required by Section 3, G may be permitted. Where a sheathing other than wood is used, attention is to be paid that the sheathing does not affect the steel. The sheathing is to be effectively fitted to the deck.

B.2 Connection between strength deck and sheerstrake

B.2.1 The welded connection between strength deck and sheerstrake may be performed by fillet welds according to Section 19, Table 19.3. Where the plate thickness exceeds approximately $25\ \mathrm{mm}$, a double bevel weld connection according to Section 19, B.3.2, is to be provided for instead of fillet welds. Bevelling of the deck stringer to 0.65 times of its thickness in way of the welded connection is admissible.

In special cases a double bevel weld connection may also be required, where the plate thickness is less than $25\ \mathrm{mm}$.

B.2.2 Where the connection of deck stringer to sheerstrake is rounded, the requirements of Section 6, C.3.4 are to be observed.

B.3 Openings in the strength deck

B.3.1 General

B.3.1.1 All openings in the strength deck are to have well rounded corners. Circular openings are to be edge-reinforced. The sectional area A of the face bar is not to be less than determined by the following formula:

$$A_f = 0.25 \cdot d \cdot t \quad [cm^2]$$

d : diameter $[cm]$ of openings

t : deck thickness $[cm]$

The reinforcing face bar may be dispensed with, where the diameter is less than $300\ mm$ and the smallest distance from another opening is not less than 5 times the diameter of the smaller opening. The distance between the outer edge of openings for pipes etc. and the ship's side is not to be less than the opening diameter.

B.3.1.2 The hatchway corners are to be surrounded by strengthened plates which are to extend over at least one frame spacing fore-and-aft and athwartships. Within $0.5 \cdot \mathbf{L}$ amidships, the thickness of the strengthened plate is not to be less than the deck thickness abreast the hatchway plus the deck thickness between the hatchways. Outside $0.5 \cdot \mathbf{L}$ amidships the thickness of the strengthened plate is not to exceed 1.6 times the thickness of the deck plating abreast the hatchway.

The reinforcement may be dispensed with in case of proof by a fatigue analysis.

B.3.1.3 The hatchway corner radius r is not to be less than determined by the following formula:

$$r = n \cdot b \cdot \left(1 - \frac{b}{\mathbf{B}}\right) \quad [m] \qquad \text{with } r \geq r_{min}$$

The term $b / \mathbf{B}$ need not be taken smaller than 0.4.

r_{min} : minimum hatchway corner radius $[m]$, defined as:

$$r_{min} = 0.1$$

n : factor, defined as:

$$n = \frac{\ell}{200} \qquad \text{with } 0.10 \leq n \leq 0.25$$

ℓ : length $[m]$ of hatchway

b : breadth $[m]$, of hatchway or total breadth of hatchways in case of more than one hatchway

B.3.1.4 Where the hatchway corners are elliptic or parabolic, strengthening according to B.3.1.2 is not required. The dimensions a and b of the elliptical and parabolical corners as shown in Fig. 7.1 are to be complied with the following formulae:

$$a \geq 2 \cdot c$$

$c = r$ according to B.3.1.3

Where smaller values are taken for a and c, reinforced insert plates are required which will be considered in each individual case.

B.3.1.5 At the corners of the engine room casings, strengthenings according to B.3.1.2 may also be required, depending on the position and the dimensions of the casing.

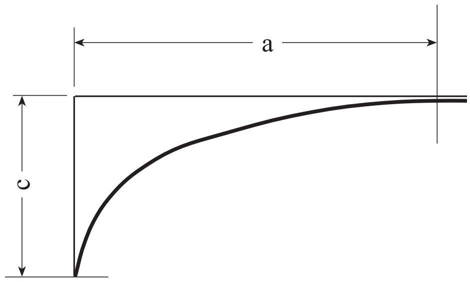


Fig. 7.1 Elliptic or parabolic hatch corner

B.3.2 Ships with large deck openings

B.3.2.1 For ships with large deck openings according to Section 5, E.8 the design of the hatch corners will be specially considered on the basis of the stresses due to longitudinal hull girder bending, torsion and transverse loads.

Approximately the following formulae can be used to determine the radii of the hatchway corners:

$$r \geq c_1 \cdot c_2$$ with $r \geq r_{min}$

r_{min} : minimum radius $[m]$ of the hatchway corner, defined as:

$r_{min} = 0.15$ for hatchway corners in the strength deck

$r_{min} = 0.10$ in all other locations

c_1 : coefficient, defined as:

$$c_1 = \left(f_D + \frac{\ell}{750}\right) \cdot b_L$$ for hatchway corners between longitudinal deck strips and a closed deck area, see HC1 in Fig. 7.2

$$c_1 = 0.4 \cdot b_Q$$ for hatchway corners between transverse deck strips and a closed deck area, see HC2 in Fig. 7.2

$$c_1 = \left(f_D + \frac{\ell}{750}\right) \cdot \sqrt{\frac{b_L^2 \cdot b_Q^2}{b_L^2 + b_Q^2}}$$ or hatchway corners between two deck strips, see HC3 in Fig. 7.2

f_D : coefficient for deck configuration, defined as:

$$f_D = 0.25 + \frac{\mathbf{L}}{2\,000}$$ for hatchway corners of the strength deck and for decks and coamings above the strength deck

$$f_D = 0.2 + \frac{\mathbf{L}}{1\,800}$$ for the strength deck, decks and coamings above the strength deck and for decks within the distance of maximum b_L below the strength deck, if a further deck with the same hatchway corner radius is arranged in a distance of less than b_L below the strength deck.

$$f_D = 0.1$$ for lower decks where the distance from the strength deck exceeds b_L

ℓ : relevant length $[m]$ of large deck openings forward and/or aft of the superstructure

b_L : breadth $[m]$ of deck girder alongside the hatchway

b_Q : breadth $[m]$ of cross deck strip between hatchways

For hatchway corners above or below the strength deck b_L and b_Q are to be taken as the breadths of the longitudinal or transverse structural members adjacent to the hatchway corners.

$\mathbf{L}$: length of the ship $\mathbf{L}$, but not to be taken less than 100 m and not greater than 300 m

c_2 : coefficient, defined as:

$$c_2 = \frac{\left|M_T \cdot \left(z_D - z_o\right)\right|}{I_y \cdot 175 \cdot 10^3 \cdot c_s} \cdot \frac{t_D}{t_i} \cdot \sqrt[4]{k_i}$$

M_T : total longitudinal bending moment $[kNm]$, according to Section 5, A.3 at the forward or aft edge of the relevant cross deck strip or the relevant closed deck area

z_D : distance $[m]$ of the relevant hatchway corner from the baseline

z_0 : distance $[m]$ of neutral axis of the hull section from the baseline

t_D : plate thickness $[mm]$ of the longitudinal structural member

t_i : thickness $[mm]$ of the hatchway corner plate, with:

$$1.0 \ge \frac{t_D}{t_i} \ge 0.625$$

I_y : moment of inertia $[m^4]$ of the section according to Section 5, A.3 in the hatchway corner without inserted strengthened plate

c_s : distribution factor, defined as:

$c_s =$ according to Section 5, E.1.2.1 — for the strength deck

$c_s = 1.0$ — for the lower decks

k_i : material factor according to Section 2, A.2 of the relevant hatchway corner

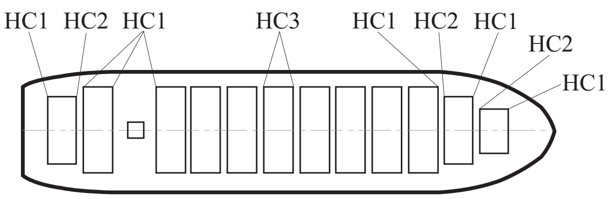


Fig. 7.2 Positions of hatch corners

B.3.2.2 Where required by above calculation or on the basis of direct fatigue assessment hatchway corners are to be surrounded by strengthened plates, i.e. insert plates, which extend minimum distances a and b from hatch edges (see Fig. 7.3), where

$$a = 3 \cdot \left(t_i - t\right) + 300 \quad [mm]$$ with $a \ge a_{min}$

$$b = r + 3 \cdot \left(t_i - t\right) + 125 \quad [mm]$$

a_{min} : minimum distance $[mm]$, defined as:

$$a_{min} = 350$$

B.3.2.3 Openings in way of hatchway corners are not to be located within the following minimum distances (see Fig. 7.3).

Opening outside of insert plate:

c : distance $[mm]$ of opening from butt seam, defined as:

$c = 2 \cdot t + h + 50$ for strength deck

$c = 2 \cdot t + h / 2 + 50$ for lower decks

Opening inside of insert plate:

e : distance $[mm]$ of opening from longitudinal bulkhead, defined as:

$e = 2.0 \cdot r + h / 2$ for strength deck

$e = 1.5 \cdot r + h / 2$ for lower decks

t_i : thickness of the hatchway corner plate according to B.3.2.1

t : thickness $[mm]$ of the deck plate

r : radius of the hatchway corner according to B.3.2.1

h : diameter $[mm]$ of opening

On the basis of direct calculations, other minimum distances for specific cases may be accepted.

Outside 0.5 $\mathbf{L}$ midships the thickness of the strengthened plate is not to exceed 1.6 times the thickness of the deck plating abreast the hatchway.

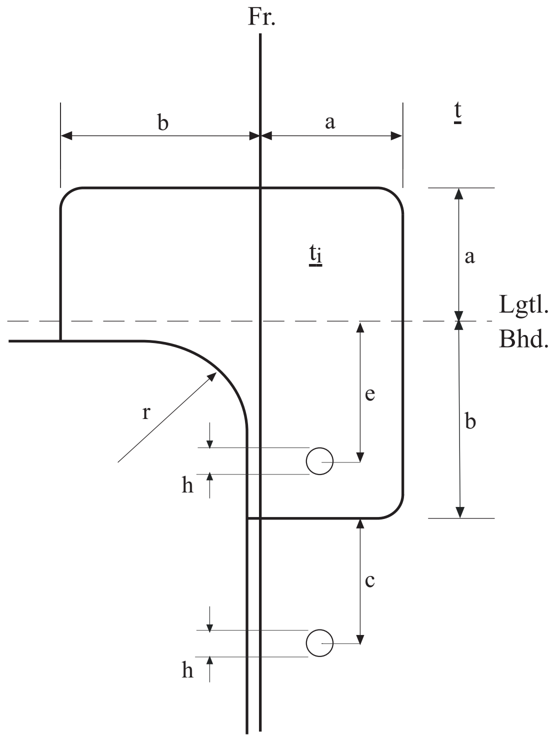


Fig. 7.3 Strengthening of hatchway corners

B.4 Scantlings

B.4.1 Ships without proven longitudinal strength

The scantlings of the strength deck for ships, for which proof of longitudinal strength accordant to Section 5 is not required, are to be determined such, that the requirements for the minimum midship section modulus according to Section 5, E.1.2.2 are complied with.

B.4.2 Ships with proven longitudinal strength

B.4.2.1 Deck sectional area

The deck sectional area abreast the hatchways, if any, is to be so determined such, that the section moduli of the cross sections are in accordance with the requirements of Section 5, E.1.

B.4.2.2 Deck stringer

If the thickness of the strength deck plating is less than that of the side shell plating, a stringer plate is to be fitted having the width of the sheerstrake and the thickness of the side shell plating.

B.4.3 Minimum thickness

B.4.3.1 Within 0.4 L amidships outside line of hatchways

B.4.3.1.1 The thickness t of the strength deck within $0.4\,\mathbf{L}$ amidships outside line of hatchways is not to be less than determined by the following formulae:

$$t = t_E \qquad \text{with } t \ge t_{min}$$

t_E : thickness according to B.4.3.2

t_{min} : minimum thickness $[mm]$, defined as:

$$t_{min} = (4.5 + 0.05 \cdot \mathbf{L}_{200}) \cdot \sqrt{k}$$

B.4.3.1.2 When the deck is located above a level of $\mathbf{T} + c_0$ above basis a smaller thickness than t_{min} may be accepted if the stress level permits such reduction.

c_0 : wave coefficient according to Section 4, A.3.

B.4.3.2 Thickness at ship's ends and between hatchways

The thickness of strength deck plating t_E for $0.1\,\mathbf{L}$ from the ends and between hatchways is not to be less than determined by the following formula:

$$t_E = \max\left[t_{E1}\ ;\ t_{E2}\right] \qquad \text{with } t_E \ge t_{E,min}$$

$$t_{E1} = 1.21 \cdot \mathbf{a} \cdot \sqrt{p_D \cdot k} + t_K \quad [mm]$$

$$t_{E2} = 1.10 \cdot \mathbf{a} \cdot \sqrt{p_L \cdot k} + t_K \quad [mm]$$

$t_{E,min}$: minimum thickness $[mm]$, defined as:

$$t_{E,min} = \left(5.5 + 0.02 \cdot \mathbf{L}_{200}\right) \cdot \sqrt{k}$$

C Lower Decks

C.1 Decks for cargo loads

The plate thickness t is not to be less than determined by the following formula:

$$t = 1.1 \cdot \mathbf{a} \cdot \sqrt{p_L \cdot k} + t_K \quad [mm] \qquad \text{with } t \ge t_{min}$$

t_{min} : minimum thickness $[mm]$, defined as:

$$t_{min} = \left(5.5 + 0.02 \cdot \mathbf{L}_{200}\right) \cdot \sqrt{k} \qquad \text{for the } 2^{nd} \text{ deck}$$

$$t_{min} = 6.0 \qquad \text{for other lower decks}$$

C.2 Decks for wheel loading

C.2.1 Plate thickness

The thickness t of deck plating for wheel loading is to be determined by the following formula:

$$t = c \cdot \sqrt{P \cdot k} + t_K \quad [mm]$$

P : load $[kN]$ of one wheel or group of wheels on a plate panel $a \cdot b$ considering the acceleration factor a_v, defined as:

$$P = \frac{Q}{n} \cdot (1 + a_v)$$

If the footprint of wheel overlaps the plate panel, the load P can be scaled by: area of foot-print inside plate panel divided by area of footprint f.

Q : axle load $[kN]$. For fork lift trucks Q is generally to be taken as the total weight of the fork lift truck.

n : number of wheels or group of wheels per axle

a_v : acceleration addition, defined as:

a_v = according to Section 4, A.3 — in general

$a_v = 0$ — for harbour conditions

c : coefficient according to Table 7.1

f : print area of wheel or group of wheels. In case of narrowly spaced wheels these may be grouped together to one wheel print area.

Where the wheel print area is not known, it may approximately be determined as follows:

$$f = \frac{P}{p} \cdot 10^2 \quad [cm^2]$$

p : specific wheel pressure according to Table 7.2

F : area of plate panel, defined as:

$F = a \cdot b$ — with $F \le 2.5 \cdot a$

a : width of smaller side of plate panel (in general beam spacing) according to Fig. 7.4

b : width of larger side of plate panel according to Fig. 7.4

Table 7.1 Coefficient c

Ratio of area of wheel print and area of plate panel	$b / a = 1$	$b / a \ge 2.5$
$0 < \frac{f}{F} < 0.3$	$c = 1.87 - \sqrt{\frac{f}{F} \cdot \left(3.4 - 4.4 \cdot \frac{f}{F}\right)}$	$c = 2.00 - \sqrt{\frac{f}{F}\left(5.2 - 7.2 \cdot \frac{f}{F}\right)}$
$0.3 \le \frac{f}{F} \le 1.0$	$c = 1.20 - 0.40 \cdot \frac{f}{F}$	$c = 1.20 - 0.517 \cdot \frac{f}{F}$
for intermediate values of b / a the factor c is to be obtained by direct interpolation		

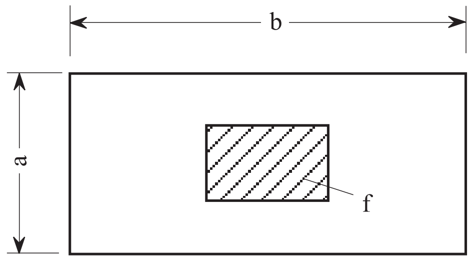


Fig. 7.4 Footprint of wheel

Table 7.2 Specific wheel pressure

Type of vehicle	Specific wheel pressure p [bar]	
	Pneumatic tyres	Solid rubber tyres
cars	2	–
trucks	8	–
trailers	8	15
fork lift trucks	6	15

C.2.2 Deck beams and girdres

In deck beams and girders, the stress is not to exceed $165 / k$ [N / mm²].

C.3 Machinery decks and accommodation decks

C.3.1 The thickness t of the plates is not to be less than determined by the following formula:

$$t = 1.1 \cdot \mathbf{a} \cdot \sqrt{p \cdot k} + t_K \quad [\mathrm{mm}] \qquad \text{with } t \geq t_{min}$$

t_{min} : minimum thickness [mm], defined as:

$$t_{min} = 5$$

p : design load [N / mm²], defined as:

$p = p_{AD}$ or p_{MD} as the case may be

C.3.2 At the corners of the engine room casings, strengthenings according to B.1.1 may also be required depending on the position and the dimensions of the casing.

D Decks in way of superstructures

D.1 Strength deck

In way of superstructures the thicknesses of strength deck plating according to B.4 are to be extended into the superstructure for a distance equal to the width of the deck plating abreast the hatchway.

For strengthening of the stringer plate in the breaks, see Section 16, B.

D.2 Lower decks

In way of a superstructure deck which is to be considered as a strength deck, the deck below the superstructure deck is to have the same scantlings as a 2^{nd} deck, and the deck below this deck the same scantlings as a 3^{rd} deck.

E Helidecks and helicopter landing areas

E.1 General

E.1.1 Helidecks are to comply with all requirements of this Section and helicopter landing areas are to comply with the scantling requirements of this Section.

E.1.2 The starting / landing zone is to be dimensioned for the largest helicopter type expected to use the helideck.

The maximum permissible take-off weight is to be indicated in the drawing and will be entered in the technical file of the Class Certificate.

E.1.3 For scantling purposes, other loads (cargo, snow / ice, etc.) are to be considered simultaneously or separately, depending on the conditions of operation to be expected. Where these conditions are not known, the data contained in E.2 are to be used as a basis.

E.1.4 Requirements regarding structural fire protection see Section 22.

E.1.5 Depending of the flag state relevant national or international standards and regulations have to be fulfilled besides of these GL Rules. The following examples are given as reference:

- Guide to Helicopter / Ship Operations, published by the International Chamber of Shipping (ICS)
- Offshore Helicopter Landing Areas – Guidance to Standards CAP 437 (Civil Aviation Authority)
- IMO Res. A.855(20): Standards for on board Helicopter facilities
- Offshore Helideck Design Guidelines, Health and Safety Executive
- Guidelines for the Management of Offshore Helideck Operations, UK Offshore Operators Association

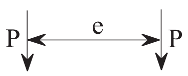
E.2 Design loads

E.2.1 LC 1

Helicopter lashed on deck, with the following vertical forces acting simultaneously:

- wheel and/or skid force P acting at the points resulting from the lashing position and distribution of the wheels and/or supports according to helicopter construction.

$$P = 0.5 \cdot G \cdot (1 + a_v) \quad [\text{kN}]$$



G : maximum permissible take-off weight $[\text{kN}]$

a_v : acceleration addition accordant to Section 4, A.3

P : evenly distributed force over the contact area $f = 30 \text{ x } 30 \text{ cm}$ for single wheel or according to data supplied by helicopter manufacturers; for dual wheels or skids to be determined individually in accordance with given dimensions.

e : wheel or skid distance according to helicopter types to be expected

- force due to weight of helicopter deck M_e as follows:

$$M_e \cdot (1 + a_v) \quad [\text{kN}]$$

- load $p = 2.0 \text{ kN} / \text{m}^2$ evenly distributed over the entire landing deck for taking into account snow or other environmental loads

E.2.2 LC 2

Helicopter lashed on deck, with the following horizontal and vertical forces acting simultaneously:

- wheel and/or skid force P acting vertically at the points resulting from the lashing position and distribution of the wheels and/or supports according to helicopter construction, see LC 1

$$P = 0.5 \cdot G \quad [kN]$$

- vertical force on supports of the deck due to weight of helicopter deck:

$$M_e \quad [kN]$$

- load $p = 2.0 \text{ kN/m}^2$ evenly distributed over the entire landing deck for taking into account snow or other environmental loads
- horizontal forces on the lashing points of the helicopter:

$$H = 0.6 \cdot G + W_{He} \quad [kN]$$

W_{He} : wind load $[kN]$ on the helicopter at the lashing points related to a wind velocity of $v_W = 50$ m / s

- horizontal force on supports of the deck due to weight and structure of helicopter deck:

$$H = 0.6 \cdot G + W_{St} \quad [kN]$$

W_{St} : wind load $[kN]$ on the structure of the helicopter deck related to a wind velocity of $v_W = 50 \text{ m/s}$

E.2.3 LC 3

Normal landing impact, with the following forces acting simultaneously:

- wheel and/or skid load P at two points simultaneously, at an arbitrary (most unfavourable) point of the helicopter deck (landing zone + safety zone)

$$P = 0.75 \cdot G \quad [kN]$$

- load $p = 0.5 \text{ kN/m}^2$ evenly distributed over the entire landing deck for taking into account snow or other environmental loads
- force due to weight of helicopter deck M_e as follows:

$$M_e \quad [kN]$$

- wind load on structure in accordance with the wind velocity admitted for helicopter operation (v_w). Where no data are available, $v_W = 25 \text{ m/s}$ may be used.

$$W_{St} \quad [kN]$$

E.2.4 LC 4

Emergency / crash landing impact with following vertical forces:

- wheel and / or skid load P at two points simultaneously, at an arbitrary (most unfavourable) point of the helicopter deck (entire area), see LC 1.

$$P = 1.25 \cdot G \quad [kN]$$

- forces due to weight of helicopter deck, evenly distributed loads and wind loads according to LC 3 are to be considered.

E.2.5 Wind loads

As first approximation the wind loads on the helicopter (W_{He}) or on the structure of the helicopter deck (W_{St}) may be determined by the following formula:

$$W = 0.5 \cdot \rho \cdot v_W^2 \cdot A \cdot 10^{-3} \quad [kN]$$

ρ : air density $[kg / m^3]$, defined as:

$\rho = 1.2$ for an air temperature of $20\ °C$

v_W : wind velocity $[m / s]$

A : area $[m^2]$ exposed to wind

E.3 Scantlings of structural members

E.3.1 Stresses and forces in the supporting structure are to be evaluated by means of direct calculations.

E.3.2 Permissible stresses for stiffeners, girders and substructure:

$$\sigma_{perm} = \frac{235}{k \cdot \gamma_f} \quad [N / mm^2]$$

γ_f : safety factor according to Table 7.3

Table 7.3 Safety factor γ_f

Structural element	γ_f	
	LC 1, LC 2	**LC 3**
stiffeners (deck beams)	1.25	1.10
main girders (deck girders)	1.45	1.45
load-bearing structure (pillar system)	1.70	2.00

E.3.3 The thickness of the plating is to be determined according to C.2 where the coefficient c may be reduced by $5\ \%$.

E.3.4 Proof of sufficient buckling strength is to be carried out in accordance with Section 3, D for structures subjected to compressive stresses.

E.4 Helicopter deck equipment

E.4.1 Deck sheathing

The landing deck sheathing has to comply with the following requirements:

- resistant against increased mechanical impact at starting and landing procedure
- resistant against aircraft fuel, hydraulic and lubricating oils
- resistant against dry fire extinguishing powder and foams
- resistant against defrosting expedient and salt
- friction coefficient $\mu = 0.65$ at minimum, to be checked periodically

No flights shall be undertaken to helicopter decks where essential visual aids for landing are insufficient. Adequate cleaning operations or preventive measures have to be executed regularly on the deck.

E.4.2 Rope netting

Tautly-stretched rope netting should be provided to aid the landing of helicopters with wheeled undercarriages in adverse weather conditions. The intersections should be knotted or otherwise secured to prevent distortion of the mesh. It is preferable that the rope be $20\ mm$ diameter sisal, with a maximum mesh size of $200\ mm$. The rope should be secured every $1.5\ m$ round the landing area perimeter and tensioned to at least $2\ 225\ N$.

The location of the net should ensure coverage of the area of the aiming circle but should not cover helicopter deck markings.

Helicopter deck netting may not be applied if only helicopters with skids are used.

E.4.3 Helicopter lashing points

Sufficient flush fitting (when not in use) or removable semi-recessed lashing points shall be provided for fastening the maximum sized helicopter for which the helicopter deck is designed. They shall be so located and be of such strength and construction to secure the helicopter when subjected to weather conditions pertinent to the design considerations of the offshore service vessel. They shall also take into account the inertial forces resulting from the movement of the service vessel.

E.4.4 Marking

The marking of the helicopter deck shall be done according to international or national regulations and standards, see E.1.5.

E.4.5 Wind direction indicator

A wind direction indicator shall be located on the ship which, in so far as is practicable, indicates the actual wind conditions over the helicopter deck. Units on which night helicopter operations take place shall have provisions to illuminate the wind direction indicator, see Offshore Helicopter Landing Areas – Guidance to Standards CAP 437 (Civil Aviation Authority).

E.5 Personnel safety measures

E.5.1 Means of escape

At least two means of escape have to be provided from the helicopter deck. They shall be situated at the maximum possible distance from each other.

E.5.2 Safety net and railings

Safety nets for personnel protection shall be installed around the landing area except where adequate structural protection against falls exists. The netting used shall be of a flexible nature, with the inboard edge fastened level with, or just below, the edge of the helicopter landing deck. The net itself shall extend 1.5 m in the horizontal plane and be arranged so that the outboard edge is slightly above the level of the landing area, but by not more than 0.25 m, so that it has an upward and outward slope of at least $10°$. The net shall be strong enough to withstand and contain, without damage a 75 kg weight being dropped from a height of 1 m.

If handrails are used, they shall be retractable, collapsible and removable and painted in a contrasting colour scheme. Procedures shall be in place to retract, collapse or remove them prior to helicopter arrival. Once the helicopter has landed and the crew have indicated that passenger movement may commence, the hand rails may be raised and locked in position. The hand rails shall be retracted, collapsed or removed again prior to the helicopter take-off.

E.6 Drainage

Every helicopter deck shall have a drainage system which will direct any rainwater and fuel spills within its boundary to a safe place. Any distortion of the deck's surface due to, for example, loads from a helicopter at rest shall not modify the landing area drainage system to the extent of allowing spilled fuel to remain on deck. A system of guttering or a slightly raised kerb shall be provided around the perimeter to prevent spilled fuel falling on to other parts of the service vessel and to conduct the spillage to an appropriate drainage system.

The capacity of the drainage system shall be sufficient to accept a maximum spillage of fuel on the deck. The calculation of the amount of spillage to be contained shall be based on an analysis of the helicopter type, fuel capacity, typical fuel loads and uplifts. The design of the drainage system shall preclude blockage by debris. The helicopter deck area shall be properly sealed so that spillage will only route into the drainage system.

Section 8 Bottom Structures

A General

A.1 References

A.1.1 For strengthening in the range of grabs, see Section 23, J.

A.1.2 For bottom strengthening forward see Section 6, D

A.2 Definitions

a : spacing $[m]$ of stiffeners

k : material factor according to Section 2, A.2

t_K : corrosion addition according to Section 3, G

p_0 : basic external dynamic load for wave directions with or against the ship's heading according to Section 4, A.3

p_{01} : basic external dynamic load for wave directions transverse to the ship's heading according to Section 4, A.3

p_B : load on the ship's bottom according to Section 4, B.5

p_I : load on the inner bottom according to Section 4, C.2.1

p_{T1}, p_{T2} : loads on fillet tanks according to Section 4, D.1

$p_{f\ell}$: load $[kN/m^2]$ on inner bottom in flooded condition according to Section 4, C.2.2

P_L : load on cargo decks due to bulk cargoes according to Section 4, C.1

σ_ℓ : bending stress $[N/mm^2]$ in longitudinal girders

σ_L : design hull girder bending stress according to Section 5, D.2.2 (hogging or sagging, whichever condition is examined).

σ_q : bending stress $[N/mm^2]$ in transverse girders

τ : shear stress $[N/mm^2]$

B Single Bottom

B.1 Floor plates

B.1.1 General

B.1.1.1 Floor plates are to be fitted at every frame. For the connection with the frames, see Section 19, B.4.2.

B.1.1.2 Deep floors, particularly in the after peak, are to be provided with buckling stiffeners.

B.1.1.3 The floor plates are to be provided with limbers to permit the water to reach the pump suctions.

B.1.2 Scantlings

B.1.2.1 Floor plates in the cargo hold area

The scantlings of floor plates between afterpeak bulkhead and collision bulkhead on ships without double bottom or outside of the double bottom are to be determined by the following formulae.

The section modulus W is not to be less than determined by the following formula:

$$\mathrm{W} = \mathrm{c} \cdot \mathbf{T} \cdot \mathrm{e} \cdot \ell^2 \quad [\mathrm{cm}^3]$$

c : coefficient, defined as:

$\mathrm{c} = 7.5$	for spaces which may be empty at full draught, e.g. machinery spaces, store-rooms, etc.
$\mathrm{c} = 4.5$	elsewhere

e : spacing $[\mathrm{m}]$ of plate floors

ℓ : unsupported span $[\mathrm{m}]$, generally measured on upper edge of floor from side shell to side shell, with:

$\ell \geq 0.7 \cdot \mathbf{B}$	if the floors are not supported at longitudinal bulkheads

The depth h of the floor plates is not to be less than determined by the following formula:

$$\mathrm{h} = 55 \cdot \mathbf{B} - 45 \quad [\mathrm{mm}] \qquad \text{with } \mathrm{h} \geq \mathrm{h}_{\mathrm{min}}$$

$\mathrm{h}_{\mathrm{min}}$: minimum depth $[\mathrm{mm}]$, defined as:

$$\mathrm{h}_{\mathrm{min}} = 180$$

In ships having rise of floor, at $0.1\,\ell$ from the ends of the length ℓ where possible, the depth of the floor plate webs is not to be less than half the required depth.

In ships having a considerable rise of floor, the depth of the floor plate webs at the beginning of the turn of bilge is not to be less than the depth of the frame.

The web thickness t is not to be less than determined by the following formula:

$$\mathrm{t} = \frac{\mathrm{h}}{100} + 3 \quad [\mathrm{mm}]$$

The web sectional area is to be determined according to C.5.2.2 analogously.

B.1.2.2 Floor plates in the peaks

The thickness t of the floor plates in the peaks is not to be less than determined by the following formula:

$$t = 0.035 \cdot \mathbf{L} + 5.0 \quad [\text{mm}]$$

The thickness, however, need not be greater than required by C.5.2.1.

The floor plate height in the fore peak above top of keel or stem shoe is not to be less than determined by the following formula:

$$h = 0.06 \cdot \mathbf{H} + 0.7 \quad [\text{m}]$$

The floor plates in the afterpeak are to extend over the stern tube (see also Section 13, C.1.4).

Particularly in case of flat bottoms additional longitudinal stiffeners are to be fitted above or forward of the propeller.

B.1.2.3 Face plates of floor plates

The face plates of the floor plates are to be continuous over the span ℓ. If they are interrupted at the centre keelson, they are to be connected to the centre keelson by means of full penetration welding.

B.2 Longitudinal girders

B.2.1 General

B.2.1.1 All single bottom ships are to have a centre girder. Where the breadth measured on top of floors does not exceed 9 m one additional side girder is to be fitted, and two side girders where the breadth exceeds 9 m. Side girders are not required where the breadth does not exceed 6 m.

B.2.1.2 For the spacing of side girders from each other and from the centre girder in way of bottom strengthening forward see Section 6, D.1.

B.2.1.3 The centre and side girders are to extend as far forward and aft as practicable. They are to be connected to the girders of a non-continuous double bottom or are to be scarphed into the double bottom by two frame spacings.

B.2.2 Scantlings

B.2.2.1 Centre girder

The web thickness t_w and the sectional area A_f of the face plate within $0.7\,\mathbf{L}$ amidships are not to be less than determined by the following formulae:

$$t_w = 0.07 \cdot \mathbf{L} + 5.5 \quad [\text{mm}]$$

$$A_f = 0.7 \cdot \mathbf{L} + 12 \quad [\text{cm}^2]$$

Towards the ends the thickness of the web plate as well as the sectional area of the top plate may be reduced by 10 %. Lightening holes are to be avoided.

B.2.2.2 Side girder

The web thickness t_w and the sectional area of the face plate A_f within $0.7\,\mathbf{L}$ amidships are not to be less than determined by the following formulae:

$$t_w = 0.04 \cdot \mathbf{L} + 5 \quad [\text{mm}]$$

$$A_f = 0.2 \cdot \mathbf{L} + 6 \quad [\text{cm}^2]$$

Towards the ends, the web thickness and the sectional area of the face plate may be reduced by 10 %.

C Double Bottom

C.1 References

C.1.1 For the arrangement of double bottom see Section 27, C.2.

C.1.2 For the double bottom structure of bulk carriers, see Section 23, C.3.

C.1.3 Ships touching ground whilst loading and discharging

On request of the owner, the bottom structures of a ship which is expected to frequently touch ground whilst loading and discharging will be examined particularly.

To fulfil this requirement, where the transverse framing system is adopted, plate floors are to be fitted at every frame and the spacing of the side girders is to be reduced to half the spacing as required according to C.3.1.

When the longitudinal framing system is adopted, the longitudinal girder system according to C.6.4 is to be applied.

The thickness of bottom plating is to be increased by $10\,\%$, compared to the plate thickness according to Section 6, B.

C.2 Centre girder

C.2.1 Openings

Openings in the centre girder are generally permitted only outside $0.75\,\mathbf{L}$ amidships. Their depth is not to exceed half the depth of the centre girder and their lengths are not to exceed half the frame spacing.

In general openings in the centre girder are to be reduced to a minimum.

C.2.2 Scantlings

C.2.2.1 The depth h of the centre girder is not to be less than determined by the following formula:

$$h = 350 + 45 \cdot \ell \quad [\mathrm{mm}] \qquad \text{with } h \geq h_{min}$$

h_{min} : minimum depth $[\mathrm{mm}]$, defined as:

$$h_{min} = 600$$

ℓ : unsupported span $[\mathrm{m}]$ of the floor plates, defined as:

$\ell = \mathbf{B}$	in general
$\ell = 0.8 \cdot \mathbf{B}$	in case of longitudinal side bulkheads, the distance between the bulkheads can be used as unsupported span
$\ell = \mathrm{B}'$	in case of double bottoms with hopper tanks (e.g. on bulk carriers) the fictitious breadth B' (see also Fig. 8.1) can be used as unsupported span

However, $\ell \geq 0.8 \cdot \mathbf{B}$

In case of additional longitudinal bulkheads, the unsupported span can be shortened accordingly.

B' : fictitious breadth $[\mathrm{m}]$, defined as:

$\mathrm{B}' = \frac{1}{3} \cdot (2 \cdot \mathbf{B} + \mathrm{b})$	for $\alpha \geq 35°$
$\mathrm{B}' = \mathbf{B}$	for $\alpha < 35°$

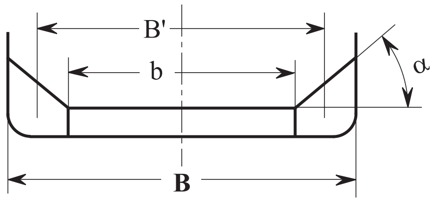


Fig. 8.1 Fictitious breadth B'

C.2.2.2 The thickness t_m of the centre girder is not to be less than determined by the following formulae:

$$t_m = \frac{h}{h_a} \cdot \left(\frac{h}{100} + 1.0\right) \cdot \sqrt{k} \quad [mm] \qquad \text{for } h \le 1\,200 \text{ mm}$$

$$t_m = \frac{h}{h_a} \cdot \left(\frac{h}{120} + 3.0\right) \cdot \sqrt{k} \quad [mm] \qquad \text{for } h > 1\,200 \text{ mm}$$

However, $t_m \ge t$

h : depth of the centre girder according to C.2.2.1

h_a : depth $[mm]$ of centre girder as built

t : plate thickness of the longitudinal girders according to C.6.4

C.3 Side girders

C.3.1 Arrangement

At least one side girder is to be fitted in the engine room and in way of $0.25\,\mathbf{L}$ aft of F.P. In the other parts of the double bottom, one side girder is to be fitted where the horizontal distance between ship's side and centre girder exceeds 4.5 m. Two side girders are to be fitted where the distance exceeds 8 m, and three side girders where it exceeds 10.5 m. The distance of the side girders from each other and from centre girder and ship's side respectively is not to be greater than:

1.8 m	in the engine room within the engine seatings
4.5 m	where one side girder is fitted in the other parts of double bottom
4.0 m	where two side girders are fitted in the other parts of double bottom
3.5 m	where three side girders are fitted in the other parts of double bottom

C.3.2 Scantlings

The thickness t_m of the side girders is not to be less than determined by the following formula:

$$t_m = \frac{h^2}{120 \cdot h_a} \cdot \sqrt{k} \quad [mm] \qquad \text{with } t_m \ge t$$

h : depth of the centre girder according to C.2.2.1

h_a : as built depth $[mm]$ of side girders. h_a need not be taken less than h to calculate t.

t : plate thickness of the longitudinal girders according to C.6.4

For strengthenings under the engine seating see D.3.2.

C.4 Inner bottom

C.4.1 The thickness t of the inner bottom plating is not to be less than determined by the following formula:

$$t = 1.1 \cdot \mathbf{a} \cdot \sqrt{p \cdot k} + t_K \quad [mm]$$

p : design pressure $[kN/m2]$, defined as:

$$p = \max\left[p_I \ ; p_{T1} \ ; p_{T2} \ ; p_{f\ell}\right]$$ as applicable

C.4.2 If no ceiling according to Section 21, C.1 is fitted on the inner bottom, the thickness determined in accordance with C.4.1 for p_{T1} or p_{T2} is to be increased by 2 mm. This increase is required for ships with the notations **GENERAL CARGO SHIP** and **MULTI-PURPOSE DRY CARGO SHIP**.

C.4.3 For strengthening of inner bottom in machinery spaces, see D.3.3.

C.5 Double bottom, transverse framing system

C.5.1 Plate floors

C.5.1.1 It is recommended to fit plate floors at every frame in the double bottom if transverse framing is adopted.

C.5.1.2 Plate floors are to be fitted at every frame:

- in way of strengthening of the bottom forward according to Section 6, D
- in the engine room
- under boiler seatings

C.5.1.3 Plate floors are to be fitted:

- below bulkheads
- below corrugated bulkheads, see also Section 3, B.4.1 and Section 23, C.3.3

C.5.1.4 For the remaining part of the double bottom, the spacing of plate floors is not to exceed approximately 3 m.

C.5.2 Scantlings

C.5.2.1 The thickness t_{pf} of plate floors is not to be less than determined by the following formula:

$$t_{pf} = t_m - 2.0 \cdot \sqrt{k} \quad [mm]$$ with $t_{pf} \le 16$ mm

t_m : thickness of centre girder according to C.2.2.2

C.5.2.2 The web sectional area A of the plate floors is not to be less than determined by the following formula:

$$A_w = \varepsilon \cdot \mathbf{T} \cdot \ell \cdot e \cdot \left(1 - \frac{2 \cdot y}{\ell}\right) \cdot k \quad [cm^2]$$

ε : coefficient, defined as:

$\varepsilon = 0.5$ for spaces which may be empty at full draught, e.g. machinery spaces, storerooms, etc.

$\varepsilon = 0.3$ elsewhere

ℓ : unsupported span $[m]$, defined as:

ℓ = spacing of longitudinal bulkheads if any fitted

$\ell = \mathbf{B}$ if longitudinal bulkheads are not fitted

e : spacing [m] of plate floors

y : distance [m] between supporting point of the plate floor (ship's side, longitudinal bulkhead) and the section considered. The distance y is not to be taken greater than $0.4 \cdot \ell$.

C.5.2.3 Where in small ships side girders are not required (see C.3.1) at least one vertical stiffener is to be fitted at every plate floor; its thickness is to be equal to that of the floors and its depth of web at least $1/15$ of the height of centre girder.

C.5.2.4 In way of strengthening of bottom forward according to Section 6, D, the plate floors are to be connected to the shell plating and inner bottom by continuous fillet welding.

C.5.2.5 For strengthening of floors in machinery spaces, D.3.1.

C.5.3 Bracket floors

C.5.3.1 Where plate floors are not required according to C.5.1 bracket floors may be fitted.

C.5.3.2 Bracket floors consist of bottom frames at the shell plating and reversed frames at the inner bottom, attached to centre girder, side girders and ship's side by means of brackets.

C.5.3.3 The section modulus of bottom and inner bottom frames is not to be less than determined by the following formula::

$$W = n \cdot c \cdot \mathbf{a} \cdot \ell^2 \cdot p \cdot k \quad [cm^3]$$

n : factor, defined as:

$n = 0.44$ for $p = p_{T2}$

$n = 0.55$ for $p = p_I$ or p_{T1}

$n = 0.70$ for $p = p_B$

c : factor, defined as:

$c = 0.60$ where struts according to C.8 are provided at $\ell / 2$

$c = 1.00$ otherwise

ℓ : unsupported span [m] disregarding struts, if any

p : design pressure [kN/m2], as applicable:

$p = p_B$ for bottom frames

$p = \max\left[p_I\ ;\ p_{T1}\ ;\ p_{T2}\ ;\ p_{f\ell}\right]$ for inner bottom frames

C.5.4 Brackets

C.5.4.1 The brackets are, in general, to be of same thickness as the plate floors. Their breadth is to be 0.75 of the depth of the centre girder according to C.2.2.1. The brackets are to be flanged at their free edges, where the unsupported span of bottom frames exceeds 1 m or where the depth of floors exceeds 750 mm.

C.5.4.2 At the side girders, bottom frames and inner bottom frames are to be supported by flat bars having the same depth as the inner bottom frames.

C.6 Double bottom, longitudinal framing system

C.6.1 Bottom and inner bottom longitudinals

C.6.1.1 The scantlings are to be calculated according to Section 9, C.

C.6.1.2 Where bottom and inner bottom longitudinals are coupled by struts in the centre of their unsupported span ℓ their section moduli may be reduced to $60\ \%$ of the values required by Section 9, C. The scantlings of the struts are to be determined in accordance with C.8.

C.6.2 Plate floors

C.6.2.1 The floor spacing should, in general, not exceed 5 times the mean longitudinal frame spacing.

C.6.2.2 Floors are to be fitted at every frame as defined in C.5.1.3 as well as in the machinery space under the main engine. In the remaining part of the machinery space, floors are to be fitted at every alternate frame.

C.6.2.3 Regarding floors in way of the strengthening of the bottom forward, Section 6, D is to be observed. For ships intended for carrying heavy cargo, see Section 23.

C.6.2.4 The scantlings of floors are to be determined according to C.5.2.

C.6.2.5 The plate floors are to be stiffened in general at every longitudinal by a vertical stiffener having scantlings which fulfil the requirements in Section 9, C.4.

C.6.3 Brackets

C.6.3.1 Where the ship's sides are framed transversely flanged brackets having a thickness of the floors are to be fitted between the plate floors at every transverse frame, extending to the outer longitudinals at the bottom and inner bottom.

C.6.3.2 One bracket is to be fitted at each side of the centre girder between the plate floors where the plate floors are spaced not more than $2.5\ \mathrm{m}$ apart. Where the floor spacing is greater, two brackets should be fitted.

C.6.4 Longitudinal girder system

C.6.4.1 Where longitudinal girders are fitted instead of bottom longitudinals, the spacing of floors may be greater than permitted by C.6.2.1, proven that adequate strength of the structure is proved.

C.6.4.2 The plate thickness t of the longitudinal girders is not to be less than determined by the following formula:

$$t = (5.0 + 0.03 \cdot \mathbf{L}) \cdot \sqrt{k} \quad [\mathrm{mm}] \qquad \text{with } t \geq t_{min}$$

t_{min} : minimum plate thickness $[\mathrm{mm}]$, defined as:

$$t_{min} = 6.0 \cdot \sqrt{k}$$

C.7 Direct calculation of bottom structures

C.7.1 General

C.7.1.1 In general a direct calculation of the bottom structure is to be carried out.

Where it is intended to load the cargo holds unevenly (alternately loaded holds), this direct calculation is to be carried out.

C.7.1.2 For two or more holds arranged one behind the other, the calculation is to be carried out for the hogging as well as for the sagging condition.

C.7.2 Design loads

$p = p_i - p_a^{'} \quad [kN/m^2]$ for loaded holds

$p = p_a^{'} \quad [kN/m^2]$ for empty holds

p_i : load $[kN/m^2]$ on inner bottom, defined as:

$p_i = p_I$ for distributed loads

$p_i = P_L$ for single loads

Where high density ore cargo is intended to be carried in the holds in a conical shape, in agreement with GL a corresponding load distribution p_i on the inner bottom is to be used for the calculation.

$p_a^{'}$: external load $[kN/m^2]$, defined as:

$p_a^{'} = 10 \cdot \mathbf{T} + p_0 \cdot c_F$ for hogging condition

$p_a^{'} = 10 \cdot \mathbf{T} - p_0 \cdot c_F$ for sagging condition

c_F : distribution factor according to Section 4, A.3

C.7.3 Permissible stresses

C.7.3.1 Permissible equivalent stress σ_v

The equivalent stress is not to exceed the following value:

$$\sigma_v = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \cdot \sigma_y + 3 \cdot \tau^2} \le \frac{230}{k} \quad [N/mm^2]$$

σ_x : stress $[N/mm^2]$ in the ship's longitudinal direction, defined as:

$\sigma_x = \sigma_L + \sigma_\ell$ in general

$\sigma_x = 0$ for webs of transverse girders

σ_y : stress $[N/mm^2]$ in the ship's transverse direction, defined as:

$\sigma_y = \sigma_q$ in general

$\sigma_y = 0$ for webs of longitudinal girders

C.7.3.2 Permissible maximum values for σ_ℓ, σ_q and τ

The bending stress σ_ℓ in longitudinal girders, the bending stress σ_q in transverse girders and the shear stress τ in both longitudinal and transverse girders are not to exceed the following values:

$$\sigma_\ell, \sigma_q = \frac{150}{k} \quad [N/mm^2]$$

$$\tau = \frac{100}{k} \quad [N/mm^2]$$

C.8 Struts

The cross sectional area of the struts in double bottom is to be determined according to Section 10, C.2 analogously. The design force P is to be determined by the following formula:

$P = 0.5 \cdot p \cdot \mathbf{a} \cdot \ell \quad [kN]$

p : load according to C.5.3.3

ℓ : unsupported span according to C.5.3.3

D Bottom Structure in Machinery Spaces in Way of the Main Propulsion Plant

D.1 General

D.1.1 Openings in way of the engine foundation are to be kept as small as possible with due regard, however, to accessibility. Where necessary, the edges of openings are to be strengthened by means of face bars or the plate panels are to be stiffened.

D.1.2 Local strengthenings are to be provided beside the following minimum requirements, according to the construction, the local conditions and the main engine maker requirements.

D.2 Single bottom

D.2.1 The scantlings of floors are to be determined according to B.1.2.1 for the greatest unsupported span measured in the engine room.

D.2.2 The web depth of the plate floors in way of the engine foundation is to be as large as possible. The depth of plate floors connected to web frames is to be similar to the depth of the longitudinal foundation girders. In way of the crank case, the depth is not to be less than $0.5 \cdot h$.

The web thickness t is not to be less than determined by the following formula:

$$t = \frac{h}{100} + 4 \quad [\text{mm}]$$

h : depth of the floor plate according to B.1.2.1

D.2.3 The thickness of the longitudinal foundation girders is to be determined according to D.4.2.1.

D.2.4 No centre girder needs to be fitted in way of longitudinal foundation girders. Intercostal docking profiles are to be fitted instead. The sectional area A_w of the docking profiles is not to be less than determined by the following formula:

$$A_w = 10 + 0.2 \cdot \mathbf{L} \quad [\text{cm}^2]$$

Docking profiles are not required where a bar keel is fitted. Brackets connecting the plate floors to the bar keel are to be fitted on either side of the floors.

D.3 Double bottom

D.3.1 Plate floors

Plate floors are to be fitted at every frame. The floor thickness t is to be determined by the following formula:

$$t = c \cdot t_{pf} \quad [\text{mm}]$$

c : coefficient, defined as:

$$c = 1.0 + \left(3.6 + \frac{P}{500}\right) \cdot 10^{-3} \qquad \text{with } 1.05 \le c \le 1.15$$

P : single engine output $[\text{kW}]$

t_{pf} : thickness of floor plates according to B.5.2.1

The thickness of the plate floors below web frames may have to be increased in addition to the above provisions. In this case the thickness of the plate floors is not to be taken less than the web thickness according to Section 9, B.6.2.1.

D.3.2 Side girders

D.3.2.1 The thickness of side girders under an engine foundation top plate inserted into the inner bottom is to be equal to the thickness of side girders above the inner bottom according to D.4.2.1.

D.3.2.2 Side girders with the thickness of longitudinal girders according to D.4.2.1 are to be fitted under the foundation girders in full height of the double bottom. Where two side girders are fitted on either side of the engine, one may be a half-height girder under the inner bottom for engines up to 3 000 kW.

D.3.2.3 Side girders under foundation girders are to be extended into the adjacent spaces and to be connected to the bottom structure. This extension abaft and forward of the engine room bulkheads is to be two to four frame spacings, if practicable.

D.3.2.4 No centre girder is required in way of the engine seating (see D.2.4).

D.3.3 Inner bottom

Between the foundation girders, the thickness of the inner bottom plating required according to C.4.1 is to be increased by 2 mm. The strengthened plate is to be extended beyond the engine seating by three to five frame spacings.

D.4 Engine seating

D.4.1 General

D.4.1.1 The following rules apply to low speed engines. Seating for medium and high speed engines as well as for turbines will be specially considered.

D.4.1.2 The rigidity of the engine seating and the surrounding bottom structure is to be adequate to keep the deformations of the system due to the loads within the permissible limits. In special cases, proof of deformations and stresses may be required.

Note

If in special cases a direct calculation of motor seatings may become necessary, the following is to be observed:

- *For seatings of slow speed two-stroke diesel engines and elastically mounted medium speed four-stroke diesel engines the total deformation $\Delta f = f_u + f_o$ is not to be greater than:*

$$\Delta f = 0.2 \cdot \ell_M \quad [mm]$$

ℓ_M : *length of motor $[m]$*

f_u : *maximum vertical deformation of the seating downwards within the length ℓ_M $[mm]$*

f_o : *maximum vertical deformation of the seating upwards within the length ℓ_M $[mm]$*

The individual deformations f_u and f_o is not to be greater than:

$$f_{u,max}, f_{o,max} = 0.7 \cdot \Delta f \quad [mm]$$

For the calculation of the deformations the maximum static and wave induced dynamic internal and external differential loads due to local loads and the longitudinal hull girder bending moments as well as the rigidity of the motor are to be considered.

- *For seatings of non-elastically mounted medium speed four-stroke diesel engines the deformation values are not to exceed 50 % of the above values.*

D.4.1.3 Due regard is to be paid, at the initial design stage, to a good transmission of forces in transverse and longitudinal direction, see also Section 12, H.2 (A.7).

D.4.1.4 The foundation bolts for fastening the engine at the seating are to be spaced no more than 3 x d apart from the longitudinal foundation girder. Where the distance of the foundation bolts from the longitudinal foundation girder is greater, proof of equivalence is to be provided.

d : diameter of the foundation bolts

D.4.1.5 In the whole speed range of main propulsion installations for continuous service resonance vibrations with inadmissible vibration amplitudes are not to occur; if necessary structural variations have to be provided for avoiding resonance frequencies. Otherwise, a barred speed range has to be fixed. Within a range of -10 % to + 5 % related to the rated speed no barred speed range is permitted. GL may require a vibration analysis and, if deemed necessary, vibration measurement.

D.4.2 Longitudinal girders

D.4.2.1 The thickness t of the longitudinal girders above the inner bottom is not to be less than determined by the following formula:

$$t = \sqrt{\frac{P}{15}} + 6 \quad [\text{mm}] \qquad \text{for } P < 1\,500 \text{ kW}$$

$$t = \frac{P}{750} + 14 \quad [\text{mm}] \qquad \text{for } 1\,500 \le P < 7\,500 \text{ kW}$$

$$t = \frac{P}{1\,875} + 20 \quad [\text{mm}] \qquad \text{for } 7\,500 \text{ kW} \le P$$

P : single engine output [kW]

D.4.2.2 Where two longitudinal girders are fitted on either side of the engine, their thickness required according to D.4.2.1 may be reduced by 4 mm.

D.4.2.3 The sizes of the top plate (width and thickness) are to be sufficient to attain efficient attachment and seating of the engine and - depending on seating height and type of engine - adequate transverse rigidity.

The thickness of the top plate is approximately to be equal to the diameter of the fitted-in bolts. The cross sectional area A_T of the top plate is not to be less than determined by the following formulae:

$$A_T = \frac{P}{15} + 30 \quad [\text{cm}^2] \qquad \text{for } P \le 750 \text{ kW}$$

$$A_T = \frac{P}{75} + 70 \quad [\text{cm}^2] \qquad \text{for } P > 750 \text{ kW}$$

Where twin engines are fitted, a continuous top plate is to be arranged in general if the engines are coupled to one propeller shaft.

For elastically mounted engines the sectional area A_T may be adequately reduced.

D.4.2.4 The longitudinal girders of the engine seating are to be supported transversely by means of web frames or wing bulkheads. The scantlings of web frames are to be determined according to Section 9, B.6.

D.4.2.5 Top plates are to be connected to longitudinal and transverse girders thicker than approx. 15 mm by means of a double bevel butt joint (K butt joint), (see also Section 19, B.3.2).

E Sea chests

E.1 Plate thickness

The plate thickness t of sea chests is not to be less than determined by the following formula:

$$t = 12 \cdot a \cdot \sqrt{p \cdot k} + t_K \quad [\text{mm}]$$

p : blow out pressure [bar] at the safety valve, with:

$p \geq 2$

see also the GL Rules for Machinery Installations (I-1-2), Section 11

E.2 Stiffeners

The section modulus W of sea chest stiffeners is not to be less than determined by the following formula:

$$W = 56 \cdot a \cdot p \cdot \ell^2 \cdot k \quad [cm^3]$$

p : blow out pressure according to E.1

ℓ : unsupported span $[m]$ of stiffeners

E.3 Gratings

The sea-water inlet openings in the shell are to be protected by gratings.

F Transverse Thrusters

F.1 General

In the context of this Section, transverse thrusters refer to manoeuvring aids, which are integrated in the ship structure and which are able to produce transverse thrust at very slow ship speeds. Retractable rudder propellers are not transverse thrusters in the context of this Section.

In case of transverse thrusters which are used beyond that of short-term manoeuvring aids in harbours or estuaries, e.g. Dynamic Positioning Systems (class notation "**DP x**") or use during canal passage, additional requirements may be defined by GL.

F.2 Structural principles

F.2.1 Transverse thruster tunnels are to be completely integrated in the ship structure and welded to it.

The thickness t of the tunnel is not be less than determined by the following formula:

$$t = \sqrt{\mathbf{L} \cdot k} + 5 \quad [mm]$$

F.2.2 Thrust element housing structures as holding fixtures for propulsion units are to be effectively connected to the tunnel structure.

F.2.3 If a propulsion engine is as well directly supported by the ship structure, it is to be ensured that the engine housing and the supporting elements are able to withstand the loading by the propulsion excitation without taking damage.

F.2.4 All welding of structural elements which are part of the watertight integrity of the ship hull are generally to be carried out as welds with full root penetration, according to Section 19, B (see also Section 19, Fig. 19.8). In certain circumstances HV- or DHV-welds with defined incomplete root penetration according to Section 19, B (see also Section 19, Fig. 19.9) may be used for lightly loaded structural elements for which the risk of damage is low.

F.2.5 If the gear housing is supported in the vicinity of the propeller hub, the support bracket is to be connected to the tunnel by HV- or DHV-welds with full root penetration. The transition is to be carried out according Fig. 8.2 and be grinded notch-free. The radius R is not to be less than determined by the following formula:

$$R = 3 + 0.7 \cdot t_s \cdot \cos(AW - 45°) \quad [mm]$$

t_s : thickness $[mm]$ of the gear housing support bracket

AW : angle $[°]$ between tunnel and gear housing support bracket

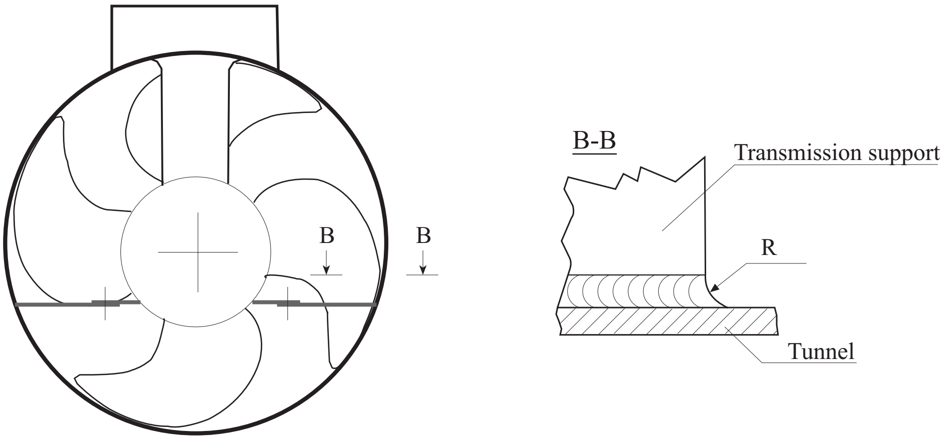


Fig. 8.2 Connection between gear housing support bracket and thruster tunnel

F.3 Special designs

If suction or draining ducts are arranged in the ship's bottom the design bottom slamming pressure p_{SL} according to Section 4, B.6 is to be considered.

F.4 Thruster grids

For ships with ice class notation see also Section 15, B.8 and for ships with class notation **IW** see also Section 34, B.7.

F.5 *Note for Vibration design*

From a vibration point of view it is recommended that shell and tank structures in the vicinity of transverse thrusters should be designed such that the following design criteria are fulfilled:

$$f_{plate} > 1.2 \cdot f_{blade}$$

$$f_{stiff} < 0.8 \cdot f_{blade} \quad \textit{or} \quad f_{stiff} > 1.2 \cdot f_{blade}$$

f_{plate} : *lowest natural frequency $[Hz]$ of isotropic plate field under consideration of additional outfitting and hydrodynamic masses*

f_{stiff} : *lowest natural frequency $[Hz]$ of stiffener under consideration of additional outfitting and hydrodynamic masses*

f_{blade} : *propeller blade passage excitation frequency $[Hz]$ at n*

$$f_{blade} = \frac{1}{60} \cdot n \cdot z$$

The natural frequencies of plate fields and stiffeners can be estimated by POSEIDON or by means of the software tool GL LocVibs which can be downloaded from the GL homepage http://www.gl-group.com/en/gltools/GL-Tools.php.

n : *maximum revolution speed $[1/min]$ of transverse thruster*

z : *number of propeller blades*

G Docking Calculation

G.1 General

For ships exceeding 120 m in length, for ships of special design, particularly in the aft body and for ships with a docking load of more than 700 kN/m a special calculation of the docking forces is required. The maximum permissible cargo load to remain onboard during docking and the load distribution are to be specified. The proof of sufficient strength can be performed either by a simplified docking calculation or by a direct docking calculation. The number and arrangement of the keel blocks are to agree with the submitted docking plan. Direct calculations are required for ships with unusual overhangs at the ends or with inhomogeneous distribution of cargo.

Note

The arrangement of the keel blocks and their contact areas are to be defined under consideration of the ship size.

G.2 Simplified docking calculation

The local forces of the keel blocks acting on the bottom structures can be calculated in a simplified manner using the nominal keel block load q_0. Based on these forces sufficient strength is to be shown for all structural bottom elements which may be influenced by the keel block forces.

The nominal keel block load q_0 is to be determined by the following formula, see also Fig. 8.3:

$$q_0 = \frac{G_S \cdot C}{L_{KB}} \quad [\text{kN/m}]$$

G_S : total ship weight $[\text{kN}]$ during docking including cargo, ballast and consumables

L_{KB} : length of the keel block range $[\text{m}]$; i.e. in general the length of the horizontal flat keel

C : weighting factor, defined as:

$C = 1.25$	in general
$C = 2.00$	in the following areas:
	within $0.075 \cdot L_{KB}$ from both ends of the length L_{KB}, and
	below the main engine, and
	in way of the transverse bulkheads along a distance of $2 \cdot e$, and
	in way of gas tank supports of gas tankers

e : distance of plate floors adjacent to the transverse bulkheads $[\text{m}]$; for e no value larger than 1 m needs to be taken.

If a longitudinal framing system is used in the double bottom in combination with a centre line girder in accordance with C.2, it may be assumed that the centre line girder carries $50\ \%$ of the force and the two adjacent (see Section 6, B.4.2) keel block longitudinals $25\ \%$ each.

G.3 Direct docking calculation

If the docking block forces are determined by direct calculation, e.g. by a finite element calculation, considering the stiffness of the ship's body and the weight distribution, the ship has to be assumed as elastically bedded at the keel blocks. The stiffness of the keel blocks has to be determined including the wood layers.

If a floating dock is used, the stiffness of the floating dock is to be taken into consideration.

Transitory docking conditions need also to be considered.

G.4 Permissible stresses

The permissible equivalent stress σ_v is:

$$\sigma_v = \frac{R_{eH}}{1.05}$$

G.5 Buckling strength

The bottom structures are to be examined according to Section 3, D. For this purpose a safety factor $S = 1.05$ has to be applied.

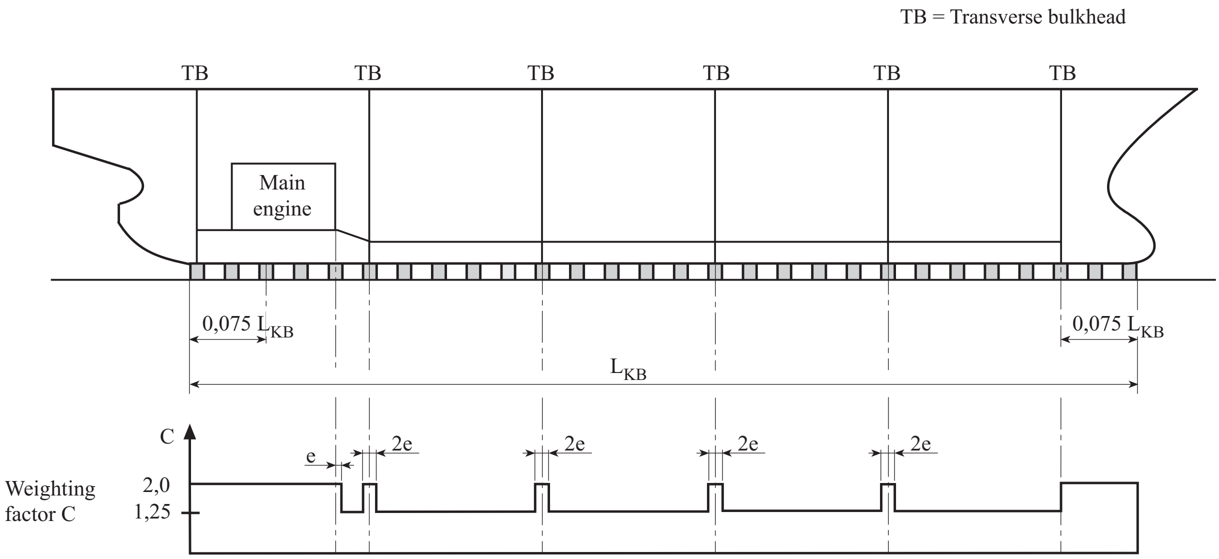


Fig. 8.3 Load on keel blocks

Section 9 Framing System

A General

A.1 Definitions

c_0 : wave coefficient according to Section 4, A.3

c_F : distribution factor according to Section 4, A.3

c_R : factor to take curved plates (e.g. in the bilge area) in way of longitudinals and longitudinal beams into account, according to Section 3, B.3.6

H_u : depth up to the lowest deck [m]

k : material factor according to Section 2, A.2

ℓ : unsupported span [m], according to Section 3, B.3.3, with:

$\ell \geq 2.0$ for main frames

m_a : factor to take the load distribution into account according to Section 3, B.3.2

m_{k1}, m_{k3} : factors to take a shortened unsupported span into account according to Section 3, B.3.3

m_c : factor to take curved frames into account according to Section 3, B.3.4

n : factor, defined as:

$n = 0.9 - 0.0035 \cdot \mathbf{L}$ for $\mathbf{L} < 100$ m

$n = 0.55$ for $\mathbf{L} \geq 100$ m

e : spacing of web frames [m]

p_0 : basic external dynamic load according to Section 4, A.3

p_B : load on ship's bottom according to Section 4, B.5

p_D : load on weather decks according to Section 4, B.1

p_{DA} : load on superstructure end bulkheads, deckhouse walls, transverse hatch coamings and hatch cover skirt plates according to Section 4, B.8

p_E : load on bow structures according to Section 4, B.3 or on stern structures according to Section 4, B.4

$p_{f\ell}$: load on inner bottom in flooded condition according to Section 4, C.2.2

p_I : load on inner bottom according to Section 4, C.2.1

p_L : load on cargo decks according to Section 4, C.1

p_S, p_{S1} : load on ship's sides according to Section 4, B.2

p_{T1}, p_{T2} : loads for filled tanks according to Section 4, D.1

p_{T3} : load for partially filled tanks according to Section 4, D.2

T_{min} : smallest ballast draught [m]

z : distance $[m]$ of structure considered above base line

σ_L : design stress according to Section 5, D.2

B Transverse Framing

B.1 General

B.1.1 Frame spacing

Forward of the collision bulkhead and aft of the after peak bulkhead, the frame spacing is in general not to exceed $600\ mm$.

B.2 Main frames

B.2.1 Scantlings

B.2.1.1 The section modulus W_R and shear area A_R of the main frames including end attachments are not to be less than determined by the following formulae:

$$W_R = n \cdot m_{k3} \cdot \left(1 - m_a^2\right) \cdot m_c \cdot \mathbf{a} \cdot \ell^2 \cdot p \cdot k \quad [cm^3]$$

$$A_{RO} = 0.04 \cdot \left(1 - 0.817 \cdot m_a\right) \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \quad [cm^2]$$ for the upper end shear area

$$A_{RU} = 0.07 \cdot \left(1 - 0.817 \cdot m_a\right) \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \quad [cm^2]$$ for the lower end shear area

m_{k3} : factor to take curved frames into account, defined as:

m_{k3} = according to Section 3, B.3.4 — in general

$m_{k3} = 1.0$ — within the lower bracket connection

p : design pressure $[kN/m^2]$, defined as

$p = p_S$ or p_E — as the case may be

B.2.1.2 In areas of ships with more than 3 decks the main frames are to extend at least to the deck above the lowest deck.

B.2.1.3 The scantlings of the main frames are not to be less than those of the 'tween deck frames above.

B.2.1.4 Where the scantlings of the main frames are determined by direct strength calculations, the following permissible stresses are to be exceeded:

$$\sigma_b = \frac{150}{k} \quad [N/mm^2]$$ for bending stresses

$$\tau = \frac{100}{k} \quad [N/mm^2]$$ for shear stresses

$$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} = \frac{180}{k} \quad [N/mm^2]$$ for equivalent stresses

B.2.1.5 Forces due to lashing arrangements acting on frames are to be considered when determining the scantlings of the frames (see also Section 21, I).

B.2.1.6 For main frames in holds of bulk carriers see also Section 23, C.4.2.

B.2.2 End attachment

B.2.2.1 The lower bracket attachment to the bottom structure is to be determined according to Section 3, B.3.5.2 on the basis of the main frame section modulus.

B.2.2.2 The upper bracket attachment to the deck structure and / or to the 'tween deck frames is to be determined according to Section 3, B.3.5.2 on the basis of the section modulus of the deck beams or 'tween deck frames whichever is the greater.

B.2.2.3 Where frames are supported by a longitudinally framed deck, the frames fitted between web frames are to be connected to the adjacent longitudinals by brackets. The scantlings of the brackets are to be determined in accordance with Section 3, B.3.5.2 on the basis of the section modulus of the frames.

B.3 'Tween deck and superstructure frames

B.3.1 General

In ships having a speed exceeding $v_0 = 1.6 \cdot \sqrt{\mathbf{L}}\ \ [\mathrm{kn}]$ the forecastle frames forward of $0.1\ \mathbf{L}$ from **F.P.** are to have at least the same scantlings as the frames located between the first and the second deck.

Where further superstructures, or big deckhouses are arranged on the superstructures strengthening of the frames of the space below may be required.

For 'tween deck frames in tanks, the requirements for the section moduli W_1 and W_2 according to Section 12, B.3 are to be observed.

B.3.2 Scantlings

The section modulus W_t and shear area A_t of the 'tween deck and superstructure frames are not to be less than determined by the following formulae:

$$W_t = 0.55 \cdot \left(m_{k1}^2 - m_a^2\right) \cdot m_c \cdot \mathbf{a} \cdot \ell^2 \cdot p \cdot k \quad [\mathrm{cm}^3] \qquad \text{with } \left(m_{k1}^2 - m_a^2\right) \geq \frac{m_{k1}^2}{2}$$

$$A_t = 0.05 \cdot \left(1 - 0.817 \cdot m_a\right) \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \quad [\mathrm{cm}^2]$$

p : design pressure $[\mathrm{kN/m}^2]$, defined as:

$p = p_S$ or p_E as the case may be, however $p \geq p_{min}$

p_{min} : minimum design pressure $[\mathrm{kN/m}^2]$, defined as:

$$p_{min} = 0.4 \cdot f_1 \cdot p_L \cdot \left(\frac{b}{\ell}\right)^2$$

f_1 : factor, defined as:

$f_1 = 1.0$ in general

$f_1 = 0.75 + 0.2 \cdot \dfrac{e}{\mathbf{a}} \leq 1.0$ for 'tween deck frames connected at their lower ends to the deck transverses

b : unsupported span $[\mathrm{m}]$ of the deck beam below the respective 'tween deck frame

B.3.3 End attachment

'Tween deck and superstructure frames are to be connected to the main frames below, or to the deck. The end attachment may be carried out in accordance with Fig. 9.1.

For 'tween deck and superstructure frames B.2.2.3 is to be observed, where applicable.

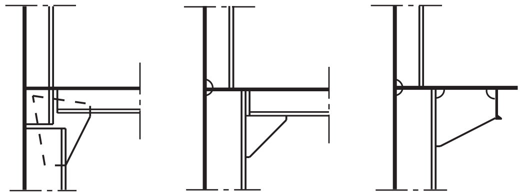


Fig. 9.1 Typical end attachments of 'tween deck and superstructure frames

B.4 Peak frames and frames in way of the stern

B.4.1 Peak frames

B.4.1.1 Section modulus W_P and shear area A_P of the peak frames are not to be less than determined by the following formulae:

$$W_p = 0.55 \cdot \left(m_{k1}^2 - m_a^2\right) \cdot m_c \cdot \mathbf{a} \cdot \ell^2 \cdot p \cdot k \quad [\mathrm{cm}^3]$$ with $\left(m_{k1}^2 - m_a^2\right) \geq \frac{m_{k1}^2}{2}$

$$A_p = 0.05 \cdot \left(1 - 0.817 \cdot m_a\right) \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \quad [\mathrm{cm}^2]$$

p : design pressure $[\mathrm{kN/m^2}]$, defined as:

$p = p_S$ or p_E as the case may be

B.4.1.2 The peak frames are to be connected to the stringer plates to ensure sufficient transmission of shear forces.

B.4.2 Frames in way of the stern

An additional stringer may be required in the aft body outside the after peak where frames are inclined considerably and not fitted vertically to the shell.

B.5 Strengthenings in fore- and aft body

B.5.1 General

In the fore body, i.e. from the forward end to $0.15\ \mathbf{L}$ behind **F.P.**, flanged brackets have to be used in principle.

As far as practicable and possible, web frames and stringers are to be fitted in the fore- and after peak.

B.5.2 Tiers of beams

B.5.2.1 Forward of the collision bulkhead, tiers of beams (beams at every other frame) generally spaced no more than 2.6 m apart, measured vertically, are to be arranged below the lowest deck within the forepeak. Stringer plates are to be fitted on the tiers of beams which are to be connected by continuous welding to the shell plating and by a bracket to each frame. The width b and thickness t of the stringer plates are to be determined from the following formulae:

$$b = 75 \cdot \sqrt{\mathbf{L}} \quad [\mathrm{mm}]$$

$$t = 6.0 + \frac{\mathbf{L}}{40} \quad [\mathrm{mm}]$$

B.5.2.2 The cross sectional area of each beam is to be determined according to Section 10, C.2 for a load

$$P = A \cdot p \quad [\mathrm{kN}]$$

A : load area [m2] of a beam

B.5.2.3 In the after peak, tiers of beams with stringer plates generally spaced 2.6 m apart, measured vertically, are to be arranged as required under B.5.2.1, as far as practicable with regard to the ship's shape.

B.5.2.4 Intermittent welding at the stringers in the after peak is to be avoided. Any scalloping at the shell plating is to be restricted to holes required for welding and for limbers.

B.5.2.5 Where peaks are used as tanks, stringer plates are to be flanged or face bars are to be fitted at their inner edges. Stringers are to be effectively fitted to the collision bulkhead so that the forces can be properly transmitted.

B.5.2.6 Where perforated decks are fitted instead of tiers of beams, their scantlings are to be determined as for wash bulkheads according to Section 12, G. The requirements regarding cross sectional area stipulated in B.5.2.2 are, however, to be complied with.

B.5.3 Web frames and stringers

B.5.3.1 Where web frames and supporting stringers are fitted instead of tiers of beams, their section modulus W and web shear area at the supports A_W are to be determined by the following formulae:

$$W = 0.55 \cdot e \cdot \ell^2 \cdot p \cdot n_c \cdot k \quad [cm^3]$$

$$A_W = 0.05 \cdot e \cdot \ell_1 \cdot p \cdot k \quad [cm^2]$$

ℓ : unsupported span $[m]$, without consideration of cross ties, if any

ℓ_1 : similar to ℓ, however, considering cross ties, if any

p : design pressure $[kN/m^2]$, defined as:

$p = p_S$ or p_E as the case may be

n_c : coefficient according to the following Table 9.1

Table 9.1 Reduction coefficient n_c

Number of cross ties	n_c
0	1.0
1	0.5
3	0.3
≥ 3	0.2

B.5.3.2 Vertical transverses are to be interconnected by cross ties and their cross sectional area is to be determined according to B.5.2.2.

B.5.3.3 If web frames and stringers in the fore body are dimensioned by strength calculations the stresses are not to exceed the permissible stresses in B.2.1.4.

Note

Where a large and long bulbous bow is arranged a dynamic pressure p_{sdyn} is to be applied unilaterally. The unilateral pressure can be calculated approximately as follows:

$$p_{sdyn} = p_o \cdot c_F \cdot \left(1 + \frac{z}{T}\right) \quad [kN/m^2]$$

p_o : *basic external dynamic load according to Section 4, A.3 with $f = 0.75$*

c_F : *distribution factor as defined* in Section 4, A.3

For the effective area of p_{sdyn}, the projected area of the z-x-plane from forward to the collision bulkhead may be assumed.

B.5.4 Web frames and stringers in 'tween decks and superstructure decks

Where the speed of the ship exceeds $v_0 = 1.6 \cdot \sqrt{\mathbf{L}}$ $[\mathrm{kn}]$ or in ships with a considerable bow flare respectively, stringers and transverses according to B.5.3 are to be fitted within $0.1\ \mathbf{L}$ from forward perpendicular in 'tween deck spaces and superstructures.

The spacing of the stringers and transverses is to be less than $2.8\ \mathrm{m}$. A considerable bow flare exists, if the flare angel exceeds $40\ °$, measured in the ship's transverse direction and related to the vertical plane.

B.5.5 Tripping brackets

B.5.5.1 Between the point of greatest breadth of the ship at maximum draft and the collision bulkhead tripping brackets spaced not more than $2.6\ \mathrm{m}$, measured vertically, according to Fig. 9.2 are to be fitted. The thickness of the brackets is to be determined according to B.5.2.1. Where proof of safety against tripping is provided tripping brackets may partly or completely be dispensed with.

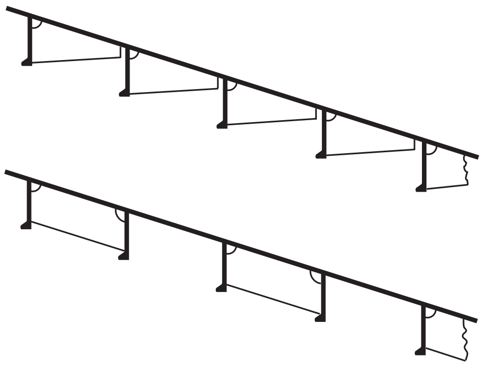


Fig. 9.2 Tripping brackets

B.5.5.2 In the same range, in 'tween deck spaces and superstructures of $3\ \mathrm{m}$ and more in height, tripping brackets according to B.5.5.1 are to be fitted.

B.5.5.3 Where peaks or other spaces forward of the collision bulkhead are intended to be used as tanks, tripping brackets according to B.5.5.1 are to be fitted between tiers of beams or stringers.

B.5.5.4 For ice strengthening, see Section 15.

B.6 Web frames in machinery spaces

B.6.1 Arrangement

B.6.1.1 In the engine room, web frames are to be fitted. Generally, they should extend up to the uppermost continuous deck. They are to be spaced not more than 5 times the frame spacing in the engine room.

B.6.1.2 For combustion engines, web frames are generally to be fitted at the forward and aft ends of the engine. The web frames are to be evenly distributed along the length of the engine.

B.6.1.3 Where combustion engines are fitted aft, stringers spaced $2.6\ \mathrm{m}$ apart are to be fitted in the engine room, in alignment with the stringers in the after peak, if any. Otherwise the main frames are to be adequately strengthened. The scantlings of the stringers are to be similar to those of the web frames. At least one stringer is required where the depth up to the lowest deck is less than $4\ \mathrm{m}$.

B.6.2 Scantlings

B.6.2.1 The section modulus W and moment of inertia I of web frames are not to be less than determined by the following formulae:

$$W = 0.8 \cdot e \cdot \ell^2 \cdot p_S \cdot k \quad [cm^3]$$

$$I = \mathbf{H} \cdot (4.5 \cdot \mathbf{H} - 3.5) \cdot c_i \cdot 10^2 \quad [cm^4]$$ for $3\ m \le \mathbf{H} \le 10\ m$

$$I = \mathbf{H} \cdot (7.25 \cdot \mathbf{H} - 31) \cdot c_i \cdot 10^2 \quad [cm^4]$$ for $\mathbf{H} > 10\ m$

$\mathbf{H}$: depth of the ship, but $\mathbf{H}$ is not to be taken less than $3\ m$

c_i : coefficient, defined as:

$$c_i = 1 + \left(H_u - 4\right) \cdot 0.07$$

The depth h and thickness t of the webs are to be determined by the following formulae:

$$h = 50 \cdot \mathbf{H} \quad [mm]$$ with $h \ge h_{min}$

$$t = \frac{h}{32 + 0.03 \cdot h} \quad [mm]$$ with $t \ge t_{min}$

h_{min} : minimum depth $[mm]$, defined as:

$$h_{min} = 250$$

t_{min} : minimum thickness $[mm]$, defined as:

$$t_{min} = 8$$

B.6.2.2 In very wide engine rooms it is recommended to provide side longitudinal bulkheads.

C Bottom-, Side- and Deck Longitudinals, Side Transverses

C.1 General

C.1.1 Longitudinals are to be continuous through floor plates and transverses.

For longitudinal frames and beams sufficient fatigue strength according to Section 20 is to be demonstrated.

Ahead of $0.1\ \mathbf{L}$ from **F.P.** webs of longitudinals are to be connected effectively at both sides. If the flare angle is more than $40\ °$ additional heel stiffeners or brackets are to be arranged.

C.1.2 Where longitudinals abut at transverse bulkheads or webs, they are to be attached to these by brackets with the thickness of the stiffeners web thickness, and with a length of weld at the longitudinals equal to 2 x depth of the longitudinals.

C.1.3 Where longitudinals are sniped at watertight floors and bulkheads, they are to be attached to the floors by brackets of the thickness of plate floors, and with a length of weld at the longitudinals equal to 2 x depth of the bottom longitudinals.

C.2 Design pressure

The design pressure p for longitudinals is defined as:

$p = p_B$ for bottom longitudinals

$p = p_S$ or p_E as the case may be for longitudinals at ship's sides

$p = p_{T1}$ for longitudinals in way of tanks except bottom longitudinals and longitudinals at ship's side below T_{min}

$p = p_{T1} - 10 \cdot T_{min} + p_0 \cdot c_F$ for bottom longitudinals in way of tanks

$p = p_{T1} - 10\left(T_{min} - z\right) + p_0 \cdot c_F \left(1 + \frac{z}{T_{min}}\right) \le p_{T1}$ for longitudinals in way of tanks at ship's side below T_{min}

$p = p_{T3}$ for longitudinals in way of tanks intended to be partially filled at ship's sides and at longitudinal bulkheads

$p = p_D$ for longitudinals of the weather deck

$p = p_{DA}$. for longitudinals of exposed decks which are not to be treated as weather deck

$p = \max\left[p_I \; ; \; p_L \; ; \; p_{f\ell}\right]$ for inner bottom longitudinals

$p = p_L$ for longitudinals of cargo decks

C.3 Scantlings of longitudinals and longitudinal beams

C.3.1 Reference is made to additional requirements regarding scantlings of longitudinals and longitudinal beams:

- for longitudinals and longitudinal beams in way of tank structures see Section 12, B.2
- for deck longitudinal outside the upper and lower hull flange see Section 10, B.1.1
- for scantlings of side longitudinals in way of those areas which are to be strengthened against loads due to harbour and tug manoeuvres see Section 6, C.4.

C.3.2 Section modulus W_ℓ and shear area A_ℓ of longitudinals and longitudinal beams of the strength deck are not to be less than determined by the following formulae:

$$W_\ell = \frac{83}{\sigma_{pr}} \cdot \left(m_{k1}^2 - m_a^2\right) \cdot \mathbf{a} \cdot \ell^2 \cdot p \quad [cm^3] \qquad \text{with } \left(m_{k1}^2 - m_a^2\right) \ge \frac{m_{k1}^2}{2}$$

$$A_\ell = 0.05 \cdot \left(1 - 0.817 \cdot m_a\right) \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \quad [cm^2]$$

σ_{pr} : permissible local stress $[N/mm^2]$, defined as:

$$\sigma_{pr} = \sigma_{perm} - \left|\sigma_L\right| \qquad \text{with } \sigma_{pr} \le \frac{150}{k}$$

σ_{perm} : total permissible stress $[N/mm^2]$, defined as:

$$\sigma_{perm} = \left(0.8 + \frac{\mathbf{L}}{450}\right) \cdot \frac{230}{k} \qquad \text{with } \sigma_{perm} \le \frac{230}{k}$$

p : design pressure according to C.2

C.3.3 In addition to C.3.2 the section modulus W_ℓ and shear area A_ℓ of side longitudinals are not be less than determined by the following formulae:

$$W_{\ell,min} = \frac{83}{\sigma_{perm,max} - \left|\sigma_L\right|} \cdot \left(m_{k1}^2 - m_a^2\right) \cdot c_R \cdot \mathbf{a} \cdot \ell^2 \cdot p_{S1} \quad [cm^3]$$

$$A_{\ell,min} = 0.037 \cdot \left(1 - 0.817 \cdot m_a\right) \cdot c_R \cdot \mathbf{a} \cdot \ell \cdot p_{S1} \cdot k \quad [cm^2]$$

C.3.4 In tanks, the section modulus is not to be less than W_2 according to Section 12, B.2.1.1.

C.3.5 Where the scantlings of longitudinals are determined by strength calculations, the total stress comprising local bending and normal stresses due to longitudinal hull girder bending is not to exceed the total stress value σ_{perm} and $\sigma_{perm,max}$ respectively as defined in C.3.2.

C.3.6 If asymmetrical sections are used the required section moduli are to be multiplied with the factor k_{sp} according to Section 3, Table 3.1

C.3.7 Fatigue strength analysis are to be carried out for longitudinals and longitudinal beams according to Section 20 considering additional stresses for asymmetrical sections according to Section 3, B.3.7.1 and for local bending according to Section 3, B.3.8.1

C.3.8 Where necessary, for longitudinals between transverse bulkheads and side transverses additional stresses according to Section 3, B.3.8.2, which are resulting from the deformation of the side transverses are to be taken into account.

C.3.9 In the fore body where the flare angle α is more than $40\,°$ and in the aft body where the flare angle α is more than $75\,°$ the unsupported span of the longitudinals located above $T_{min} - c_0$ is not to be larger than $2.6\ m$. Otherwise tripping brackets according to B.5.5 are to be arranged.

C.3.10 The side shell longitudinals within the range from $0.5\ m$ below the minimum draught up to $2.0\ m$ above the maximum draught and a waterline breadth exceeding $0.9 \cdot \mathbf{B}$ are to be examined for sufficient strength against berthing impacts. The force P_f induced by a fender into the side shell may be determined by the following formulae:

$$P_f = 0.08 \cdot D \quad [kN] \qquad \text{for } 0 < D \le 2\,100\ t$$

$$P_f = 170 \quad [kN] \qquad \text{for } 2\,100\ t < D \le 17\,000\ t$$

$$P_f = D/100 \quad [kN] \qquad \text{for } 17\,000\ t < D$$

D : displacement [t] of the ship at scantling draught, with:

$D \le 100\,000$

C.3.11 In order to withstand the load P_f induced by a fender the section modulus W_ℓ of side shell longitudinals are not to be less than determined by the following formula:

$$W_\ell = \frac{k \cdot M_f}{235} \cdot 10^3 \quad [cm^3]$$

M_f : bending moment [kNm] induced by fender, defined as:

$$M_f = \frac{P_f}{16} \cdot (\ell - 0.5)$$

C.4 Connections between transverse support member and intersecting longitudinal

C.4.1 At the intersection of a longitudinal with a transverse support member (e.g., web), the shear connections and attached heel stiffener are to be designed within the limit of the permissible stresses according to C.4.7. At intersections of longitudinals with transverse tank boundaries the local bending of tank plating is to be prevented by effective stiffening.

C.4.2 The total force P transmitted from the longitudinal to the transverse support member is given by:

$$P = (1 - 0.817 \cdot m_a) \cdot \mathbf{a} \cdot \ell \cdot p \quad [kN]$$

p : design load according to C.2

In case of different conditions at both sides of the transverse support member the average unsupported length ℓ and the average load p are to be used.

C.4.3 The stiffness of the connections between the longitudinal and transverse support member are accounted for by considering S_h, S_s and S_c. If no heel stiffener or lug plate are fitted, the respective values are to be taken as S_h, $S_c = 0$.

$$S_h = \frac{E \cdot \ell_h \cdot t_h \cdot \left(1 + \frac{450}{\ell_h}\right)}{380} \quad [\mathrm{N/mm}]$$ for heel stiffener

$$S_s = \frac{G \cdot h_s \cdot t_s}{b_s} \quad [\mathrm{N/mm}]$$ for web

$$S_c = \frac{G \cdot h_c \cdot t_c}{b_c} \quad [\mathrm{N/mm}]$$ for lug plate

G : shear modulus $[\mathrm{N/mm^2}]$

ℓ_{hc} : connection length $[\mathrm{mm}]$ of heel stiffener

ℓ_h : length $[\mathrm{mm}]$ of the minimum heel stiffener cross-sectional area according to Fig. 9.3

t_h : thickness $[\mathrm{mm}]$ of the heel stiffener according to Fig. 9.3

b_s, h_s, t_s : dimensions [mm] of the connection of the stiffener to the web according to Fig. 9.3

b_c, h_c, t_c : dimensions [mm] of the connection of the stiffener to the lug plate according to Fig. 9.3

ℓ_k : effective supporting length $[\mathrm{mm}]$ due to heel stiffeners and brackets according Section 3, B.3.3.1

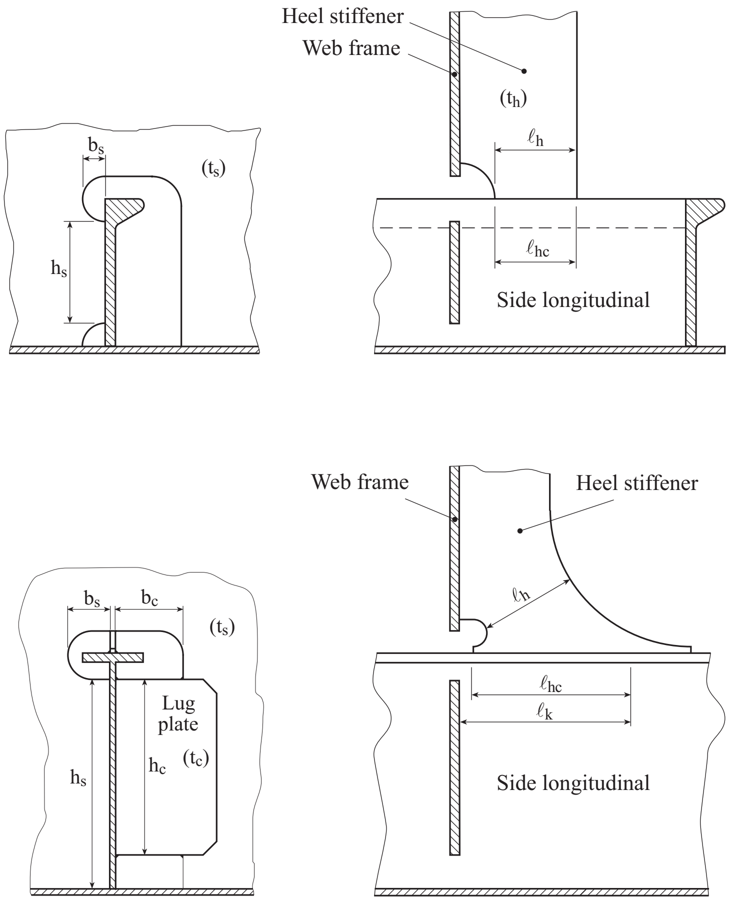


Fig. 9.3 Typical intersections of longitudinals and transverse support members

C.4.4 The force P_h transmitted from the longitudinal to the transverse member by the heel stiffener is to be determined by the following formula:

$$P_h = \varepsilon_h \cdot P \quad [kN]$$

ε_h : factor, defined as:

$$\varepsilon_h = \frac{S_h}{S_h + S_s + S_c} \quad [kN]$$

P : force according to C.4.2

C.4.5 The forces P_s and P_c transmitted through the shear connections to the transverse support member are to be determined by the following formulae:

$$P_s = \varepsilon_s \cdot P \quad [kN]$$

$$P_c = \varepsilon_c \cdot P \quad [kN]$$

ε_s, ε_s : factors, defined as:

$$\varepsilon_s = \frac{S_s}{S_h + S_s + S_c}$$

$$\varepsilon_c = \frac{S_c}{S_h + S_s + S_c}$$

P : force according to C.4.2

C.4.6 The cross-sectional areas of a heel stiffener are to be such that the calculated stresses do not exceed the permissible stresses.

- normal stress at minimum heel stiffener cross-sectional area:

$$\sigma_{axial} = \frac{P_h}{\ell_h \cdot t_h} \cdot 10^3 \quad [N/mm^2] \qquad \text{with } \sigma_{axial} \le \frac{150}{k} \quad [N/mm^2]$$

- normal stress in the fillet weld connection of heel stiffener:

$$\sigma_{weld} = \frac{P_h}{2 \cdot a \cdot (\ell_{hc} + t_h + a)} \cdot 10^3 \quad [N/mm^2] \qquad \text{with } \sigma_{weld} \le \sigma_{vp}$$

a : throat thickness of fillet weld according to Section 19, B.3.3

σ_{vp} : permissible equivalent stress in the fillet weld according to Section 19, Table 19.2

C.4.7 The cross-sectional areas of the shear connections are to be such that the calculated stresses do not exceed the permissible stresses.

- shear stress in the shear connections to the transverse support member:

$$\tau_i = \frac{P_i}{h_i \cdot t_i} \cdot 10^3 \le \frac{100}{k} \quad [N/mm^2] \qquad \text{with } \tau_i \le \frac{100}{k} \quad [N/mm^2]$$

- shear stress in the shear connections in way of fillet welds:

$$\tau_{weld,i} = \frac{P_i}{2 \cdot a \cdot h_i} \cdot 10^3 \le \tau_p \quad [N/mm^2] \qquad \text{with } \tau_{weld,i} \le \tau_p$$

τ_p : permissible shear stress in the fillet weld according to Section 19, Table 19.2

i : index, defined as:

$i = s$	for the shear connection of longitudinal and transverse support member
$i = c$	for the shear connection of longitudinal and lug plate

C.4.8 The cross-sectional area of a lug plate is to be such that the calculated bending stress does not exceed the permissible stresses.

- bending stress of lug plate:

$$\sigma_c = \frac{3 \cdot P_c \cdot b_c}{h_c^2 \cdot t_c} \cdot 10^3 \le \frac{150}{k} \quad [N/mm^2] \qquad \text{with } \sigma_c \le \frac{150}{k} \quad [N/mm^2]$$

- bending stress in the fillet weld connection of the lug plate:

$$\sigma_{weld,c} = \frac{1.5 \cdot P_c \cdot b_c}{h_c^2 \cdot a} \cdot 10^3 \le \sigma_{vp} \quad [N/mm^2] \qquad \text{with } \sigma_{weld,c} \le \sigma_{vp}$$

C.4.9 For typical heel stiffeners (Fig. 9.3, upper part) at outer shell the fatigue strength is to be approximated by a simplified approach.

C.4.9.1 The fatigue relevant pressure range Δp induced by tank pressure and outer pressure on the shell or a superposition of both is given by the pressure difference between maximum and minimum load according to Section 20, Table 20.1.

C.4.9.2 The permissible fatigue stress range is given by:

$$\Delta\sigma_p = \frac{90 \cdot f_n \cdot f_r}{\left(\frac{\ell_h}{50} + C\right) \cdot k_{sp}^2} \quad [N/mm^2]$$

f_r : mean stress factor according to Section 20

f_n : factor according to Section 20, Table 20.2 for welded joints

C : factor, defined as:

$C = 1$ if a lug plate is fitted

$C = 2$ if no lug plate is fitted

k_{sp} : factor for additional stresses in non-symmetrical longitudinal sections according to Section 3, Table 3.1

C.4.9.3 A comprehensive fatigue strength analysis according to Section 20, C may substitute the simplified approach for the typical heel stiffener and is requested if more complex designs with soft heel and/or toe or additional brackets are necessary.

C.5 Side transverses

C.5.1 Section modulus W and shear area A_W of side transverses supporting side longitudinals are not to be less than determined by the following formulae:

$$W = 0.55 \cdot e \cdot \ell^2 \cdot p \cdot k \quad [cm^3]$$

$$A_W = 0.05 \cdot e \cdot \ell \cdot p \cdot k \quad [cm^2]$$

C.5.2 Where the side transverses are designed on the basis of strength calculations the following stresses are not to be exceeded:

$$\sigma_b = \frac{150}{k} \quad [N/mm^2] \qquad \text{for bending stresses}$$

$$\tau = \frac{100}{k} \quad [N/mm^2] \qquad \text{for shear stresses}$$

$$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} \le \frac{180}{k} \quad [N/mm^2] \qquad \text{for equivalent stresses}$$

Note

The web thickness can be dimensioned depending on the size of the unstiffened web field as follows:

$$t_s = \frac{f \cdot b}{1 + \frac{b^2}{a^2}} \cdot \sqrt{\frac{200}{k} \cdot \left(2 + \frac{b^2}{a^2}\right)}$$

a, b : *lengths of side of the unstiffened web plate field with* $a \geq b$

f : *factor, defined as:*

$f = 0.75$	*in general*
$f = 0.90$	*in the aft body with extreme flare and in the fore body with flare angles* α *are less or equal* $40\,°$
$f = 1.00$	*in the fore body where flare angles* α *are greater than* $40\,°$

In the fore body where flare angles α are larger than $40\,°$ the web in way of the deck beam is to be stiffened.

C.5.3 In tanks the web thickness is not to be less than the minimum thickness according to Section 12, B.1.3, and the section modulus and the cross sectional area are not to be less than W_2 and A_{w2} according to Section 12, B.2.2.1.

C.5.4 The webs of side transverses within the range from 0.5 m below the minimum draught up to 2.0 m above the maximum draught and a waterline breadth exceeding $0.9 \cdot \mathbf{B}$ are to be examined for sufficient buckling strength against berthing impacts. The force induced by a fender into the web frame may be determined as in C.3.10.

C.5.5 In order to withstand the load P_f on the web frames, the following condition has to be met:

$$P_f \leq P_{fu}$$

P_f : force induced by a fender according to C.3.10

P_{fu} : capacity [kN] of the web of side transverses, defined as:

$$P_{fu} = t_s^2 \cdot \sqrt{R_{eH}} \cdot [C + 0.17]$$

C : factor, defined as:

$C = 0.27$	in general
$C = 0.20$	for web frame cutouts with free edges in way of continuous longitudinals

t_s : web thickness [mm] of the side transverses

C.6 Strengthenings in the fore and aft body

In the fore and aft peak web frames and stringers or tiers of beams respectively are to be arranged according to B.5.

Section 10 Deck Beams and Supporting Deck Structures

A General

A.1 Definitions

e : width $[m]$ of plating supported, measured from centre to centre of the adjacent unsupported fields

k : material factor according to Section 2, A.2

ℓ : unsupported span according to Section 3, B.3.3

p_D : load on weather decks according to Section 4, B.1

p_{DA} : load on exposed decks of superstructures and deckhouses according to Section 4, B.7

p_L : load on cargo decks according to Section 4, C.1

c : factor to take boundary conditions into account, defined as:

$c = 0.55$ for beams, girders and transverses which are constraint at both ends

$c = 0.75$ for beams, girders and transverses which are simply supported at one or both ends

λ_s : degree of slenderness of the pillar, defines as:

$$\lambda_s = \frac{\ell_s}{i_s \cdot \pi} \cdot \sqrt{\frac{R_{eH}}{E}}$$ with $\lambda_s \geq 0.2$

ℓ_s : length $[cm]$ of the pillar

i_s : radius $[cm]$ of gyration of the pillar, defined as:

$$i_s = \sqrt{\frac{I_s}{A_s}}$$ in general

$$i_s = 0.25 \cdot d_s$$ for solid pillars of circular cross section

$$i_s = \sqrt{d_a^2 + d_i^2}$$ for tubular pillars

I_s : moment of inertia $[cm^4]$ of the pillar

A_s : sectional area $[cm^2]$ of the pillar

d_s : pillar diameter $[cm]$

d_a : outside diameter $[cm]$ of the pillar

d_i : inside diameter $[cm]$ of the pillar

σ_ℓ : local bending stress in $[N/mm^2]$ the ship's longitudinal direction

σ_L : design longitudinal hull girder bending stress according to Section 5, D.2.2

σ_t : stress $[N/mm^2]$ in the ship's transverse direction

A.2 Permissible stresses

Where the scantlings of girders not forming part of the longitudinal hull structure, or of transverses, deck beams, etc. are determined by means of strength calculations the following stresses are not to be exceeded:

$$\sigma_b = \frac{150}{k} \quad [N/mm^2]$$ for bending stresses

$$\tau = \frac{100}{k} \quad [N/mm^2]$$ for shear stresses

$$\sigma_v = \sqrt{\sigma^2 + 3\cdot\tau^2} = \frac{180}{k} \quad [N/mm^2]$$ for equivalent stresses

B Deck Beams and Girders

B.1 Transverse deck beams and deck longitudinals

B.1.1 Section modulus and shear area

The section modulus W_d and shear area A_d of transverse deck beams and of deck longitudinals not contributing to the longitudinal strength are to be not less than determined by the following formulae:

$$W_d = c\cdot\left(m_{k1}^2 - m_a^2\right)\cdot \mathbf{a}\cdot\ell^2\cdot p\cdot k \quad [cm^3]$$ with $\left(m_{k1}^2 - m_a^2\right) \geq \frac{m_{k1}^2}{2}$

$$A_d = 0.05\cdot\left(1 - 0.817\cdot m_a\right)\cdot \mathbf{a}\cdot\ell\cdot p\cdot k \quad [cm^2]$$

m_{k1} : factor to take a shortened unsupported span into account according to Section 3, B.3.3.1

m_a : factor to take the load distribution into account according to Section 3, B.3.2

p : design pressure $[kN/m^2]$, as applicable:

$p = p_D, p_{DA}$ or p_L as the case may be

The section modulus and shear area of deck longitudinals contributing to the longitudinal strength are to be calculated according to Section 9, C.

B.1.2 Attachment

B.1.2.1 Transverse deck beams are to be connected to the frames by brackets according to Section 3, B.3.5.2.

B.1.2.2 Continuous deck beams crossing longitudinal walls and girders may be attached to the stiffeners of longitudinal walls and the webs of girders respectively by welding without brackets.

B.1.2.3 Deck beams may be attached to hatchway coamings and girders by double fillet welds where there is a small or no constraint. The length of weld is not to be less than 0.6 x depth of the section.

B.1.2.4 Where deck beams are to be attached to hatchway coamings and girders of considerable rigidity (e.g. box girders), brackets are to be provided.

B.1.2.5 Within $0.6\,\mathbf{L}$ amidships, the arm lengths of the beam brackets in single deck ships are to be increased by $20\,\%$. The scantlings of the beam brackets need, however, not be taken greater than required for the Rule section modulus of the frames.

B.1.2.6 Regarding the connection of deck longitudinals to transverses and bulkheads, Section 9, C.1 is to be observed.

B.2 Girders and transverses

B.2.1 References

B.2.1.1 For girders in line of the deckhouse sides under the strength deck, see Section 16, B.2.

B.2.1.2 For girders forming part of the longitudinal hull structure and for hatchway girders see E.

B.2.2 Section modulus and shear area of girders and transverses

B.2.2.1 The section modulus W and the shear area A_W are not to be less than determined by the following formulae:

$$W = c \cdot e \cdot \ell^2 \cdot p \cdot k \quad [cm^3]$$

$$A_W = 0.05 \cdot p \cdot e \cdot \ell \cdot k \quad [cm^2]$$

p : design pressure $[kN/m^2]$, as applicable:

$p = p_D$, p_{DA} or p_L as the case may be

B.2.2.2 Where a girder does not have the same section modulus throughout all girder fields, the greater scantlings are to be maintained above the supports and are to be reduced gradually to the smaller scantlings.

B.2.2.3 Face plates are to be stiffened by tripping brackets according to Section 3, E.3.5. At girders of symmetrical section, they are to be arranged alternately on both sides of the web.

B.2.3 Rigidity of girders and transverses

B.2.3.1 The moment of inertia I of transverses and girders are not to be less than determined by the following formula:

$$I = c \cdot W \cdot \ell \quad [cm^4]$$

c : factor to take boundary conditions into account, defined as:

$c = 4.0$ if both ends are simply supported

$c = 2.0$ if one end is constrained

$c = 1.5$ if both ends are constrained

W : section modulus $[cm^3]$ of the structural member considered

ℓ : unsupported span $[m]$ of the structural member considered

B.2.3.2 The depth of girders is not to be less than $1/25$ of the unsupported span ℓ. The web depth of girders scalloped for continuous deck beams is to be at least 1.5 x depth of the cut out depth.

B.2.4 Attachment

End attachments of girders at bulkheads are to be so dimensioned that the bending moments and shear forces can be transferred. Bulkhead stiffeners under girders are to be sufficiently dimensioned to support the girders.

B.3 Supporting structure of windlasses and chain stoppers

B.3.1 For the supporting structure under windlasses and chain stoppers, the following permissible stresses are to be observed:

$$\sigma_b = \frac{200}{k} \quad [N/mm^2]$$ for bending stresses

$$\tau = \frac{120}{k} \quad [N/mm^2]$$ for shear stresses

$$\sigma_v = \sqrt{\sigma^2 + 3 \cdot \tau^2} = \frac{220}{k} \quad [N/mm^2]$$ for equivalent stresses

B.3.2 The acting forces are to be calculated for $80\ \%$ and $45\ \%$ respectively of the rated breaking load of the chain cable, i.e.:

- for chain stoppers $80\ \%$
- for windlasses $80\ \%$, where chain stoppers are not fitted
- for windlasses $45\ \%$, where chain stoppers are fitted

B.3.3 The GL Rules for Machinery Installations (I-1-2), Section 14, D. are to be observed. See also the Rules for Equipment (II-1-4), Section 2, Table 2.7.

C Pillars

C.1 General

C.1.1 Structural members at heads and heels of pillars as well as substructures are to be constructed according to the forces they are subjected to. The connection is to be so dimensioned that at least $1\ cm^2$ cross sectional area is available for $10\ kN$ of load.

Where pillars are affected by tension loads doublings are not permitted.

C.1.2 Pillars in tanks are to be checked for tension. Tubular pillars are not permitted in tanks for flammable liquids.

C.1.3 For structural elements of the pillars' transverse section, sufficient buckling strength according to Section 3, D has to be verified. The wall thickness of tubular pillars which may be expected to be damaged during loading and unloading operations is not to be less than determined by the following formulae:

$$t_w = 4.5 + 0.015 \cdot d_a \quad [mm]$$ for $d_a \le 300\ mm$

$$t_w = 0.03 \cdot d_a \quad [mm]$$ for $d_a > 300\ mm$

C.1.4 Pillars also loaded by bending moments have to be specially considered.

C.2 Scantlings

The sectional area $A_{s,req}$ of pillars is not to be less than determined by the following formula:

$$A_{s,req} = \frac{P_s}{\sigma_p} \cdot 10 \quad [cm^2]$$

P_s : pillar load $[kN]$, defined as:

$$P_s = p \cdot A + P_i$$

A : load area $[m^2]$ for one pillar

P_i : load [kN] from pillars located above the pillar considered

σ_p : permissible compressive stress $[N/mm^2]$, defined as:

$$\sigma_p = \frac{\kappa}{S} \cdot R_{eH}$$

κ : reduction factor, defined as:

$$\kappa = \frac{1}{\phi + \sqrt{\phi^2 - \lambda_s^2}}$$

ϕ : characteristic value, defined as:

$$\phi = 0.5 \cdot \left[1 + n_p \cdot (\lambda_s - 0.2) + \lambda_s^2\right]$$

n_p : factor, defined as:

$n_p = 0.34$ for tubular and rectangular pillars

$n_p = 0.49$ for open sections

S : safety factor, defined as:

$S = 2.00$ in general

$S = 1.66$ in accommodation area

D Cantilevers

D.1 General

D.1.1 In order to withstand the bending moment arising from loads, cantilevers for supporting girders, hatchway coamings, engine casings and unsupported parts of decks are to be connected to transverses, web frames, reinforced main frames, or walls.

D.1.2 When determining the scantlings of the cantilevers and the aforementioned structural elements, it is to be taken into consideration that the cantilever bending moment depends on the load capacity of the cantilever, the load capacity being dependent on the ratio of rigidity of the cantilever to that of the members supported by it.

D.1.3 Face plates are to be secured against tilting by tripping brackets fitted to the webs at suitable distances (see also Section 3, E.3.5).

D.1.4 Particulars of calculation, together with drawings of the cantilever construction are to be submitted for approval.

D.2 Permissible stresses

When determining the scantlings of cantilevers, the following permissible stresses are to be observed:

- where single cantilevers are fitted at greater distances:

$\sigma_b = \dfrac{125}{k} \quad [N/mm^2]$ for bending stresses

$\tau = \dfrac{80}{k} \quad [N/mm^2]$ for shear stresses

- where several cantilevers are fitted at smaller distances (e.g. at every frame):

$\sigma_b = \frac{150}{k} \quad [N/mm^2]$ for bending stresses

$\tau = \frac{100}{k} \quad [N/mm^2]$ for shear stresses

$\sigma_v = \sqrt{\sigma^2 + 3 \cdot \tau^2} = \frac{180}{k} \quad [N/mm^2]$ for equivalent stresses

Likewise, the stresses in web frames are not to exceed the values specified above.

E Hatchway Girders and Girders Forming Part of the Longitudinal Hull Structure

E.1 The scantlings of longitudinal and transverse hatchway girders are to be determined on the basis of strength calculations. The calculations are to be based upon the deck loads calculated according to Section 4, B and Section 4, C.

E.2 The hatchway girders are to be so dimensioned that the stress values given in Table 10.1 will not be exceeded.

Table 10.1 Maximum stress values σ_ℓ for hatchway girders

Longitudinal coaming and girders of the strength deck	All other hatchway girders
upper and lower flanges: $\sigma_\ell = \frac{150}{k} \quad [N/mm^2]$	$\sigma_\ell = \frac{150}{k} \quad [N/mm^2]$
deck level: $\sigma_\ell = \frac{70}{k} \quad [N/mm^2]$	

E.3 For continuous longitudinal coamings the combined stress resulting from longitudinal hull girder bending and local bending of the longitudinal coaming is not to exceed the following value:

$$\sigma_L + \sigma_\ell \le \frac{200}{k} \quad [N/mm^2]$$

E.4 When determining the scantlings of hatchway girders and girders forming part of the longitudinal hull structure, the following permissible stresses are to be observed:

$\sigma_\ell \le \frac{150}{k} \quad [N/mm^2]$ for stresses in ship's longitudinal direction

$\sigma_t \le \frac{150}{k} \quad [N/mm^2]$ for stresses in ship's transverse direction

$\tau \le \frac{90}{k} \quad [N/mm^2]$ for shear stresses

$\sigma_v = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \cdot \sigma_y + 3 \cdot \tau^2} \le \sigma_{v,perm}$ for equivalent stresses

$\sigma_{v,perm}$: permissible equivalent stress $[N/mm^2]$, defined as:

$$\sigma_{v,perm} = \left(0.8 + \frac{\mathbf{L}}{450}\right) \cdot \frac{230}{k} \qquad \text{for } \mathbf{L} < 90 \text{ m}$$

$$\sigma_{v,perm} = \frac{230}{k} \qquad \text{for } \mathbf{L} \geq 90 \text{ m}$$

σ_x, σ_y : stress component of equivalent stress, defined as:

$$\sigma_x = \sigma_L + \sigma_\ell$$

$$\sigma_y = \sigma_t$$

E.5 Weldings at the top of hatch coamings are subject to special approval.

Section 11 Watertight Bulkheads

A General

A.1 Application

A.2 References

A.1.1 Where holds are intended to be filled with ballast water, their bulkheads are to comply with the requirements of Section 12.

A.1.2 Bulkheads of holds intended to be used for carrying dry cargo in bulk with a density $\rho_c > 1.0$ are to comply with the requirements of Section 23.

A.2 Definitions

a, b : spacings $[m]$ of stiffeners

c_p, c_s : coefficients according to Table 11.1

f : material factor, defined as:

$$f = \frac{235}{R_{eH}}$$

k : material factor according Section 2, A.2

ℓ : unsupported span according to Section 3, B.3.3

p : design pressure $[kN / m^2]$, defined as:

$p = 9.81 \cdot h$ in general

$p = p_c$ if the ship is intended to carry dry cargo in bulk

h : distance $[m]$ from the load centre of the structure to a point 1 m above the bulkhead deck at the ship's side, for the collision bulkhead to a point 1 m above the upper edge of the collision bulkhead at the ship's side

For the definition of "load centre" see Section 4, A.3

p_c : pressure in the non-flooded bulk cargo loaded holds according to Section 23, F.2.3

t_K : corrosion addition according to Section 3, G

Table 11.1 Coefficients c_p and c_s

Structural element	Coefficient	Boundary Condition	Collision bulkhead	Other bulk-heads
Plating	c_p	-	$1.1 \cdot \sqrt{f}$	$0.9 \cdot \sqrt{f}$
Stiffeners and corrugated bulkhead elements	c_s	in case of constraint of both ends	$0.33 \cdot f$	$0.265 \cdot f$
		in case of simple support of one end and constraint at the other end	$0.45 \cdot f$	$0.36 \cdot f$
		both ends simply supported	$0.66 \cdot f$	$0.53 \cdot f$
For the definition of "constraint" and "simply supported", see Section 3, B.3.5.1				

B Bulkhead plating

B.1 The thickness t of the bulkhead plating is not to be less than determined by the following formula:

$$t = c_p \cdot a \cdot \sqrt{p} + t_K \quad [mm] \qquad \text{with } t \geq t_{min}$$

t_{min} : minimum plate thickness $[mm]$, defined as:

$$t_{min} = 6.0 \cdot \sqrt{f}$$

For ships with large deck openings according to Section 5, E.8.1.2, the plate thickness t of transverse bulkheads is not to be less than determined by the following formula:

$$t = c \cdot \sqrt[3]{\frac{\Delta\ell}{F_l \cdot R_{eH} \cdot \left(\frac{1}{a^2} + \frac{1}{b^2}\right)} \cdot \sqrt{\frac{\mathbf{H}}{2} \cdot \left(\frac{\mathbf{H}}{2} - \mathbf{T}\right) + \mathbf{T}^2}} + t_K \quad [mm]$$

c : coefficient, defined as:

$c = 13$ in general

$c = 15$ below $z = 0.2 \cdot \mathbf{H}$, above $0.8 \cdot \mathbf{H}$ and generally in the fore ship area before $x / \mathbf{L} = 0.8$

$\Delta\ell$: distance $[m]$ from the mid of hold before to the mid of hold aft of the considered transverse bulkhead or supporting bulkhead

F_l : correction factor according to Section 3, D.2

B.2 The stern tube bulkhead is to be provided with a strengthened plate in way of the stern tube.

B.3 In areas where concentrated loads due to ship manoeuvres at terminals may be expected, the buckling strength of bulkhead plate fields directly attached to the side shell, is to be examined according to Section 9, C.5.4.

B.4 When determining the bulkhead scantlings of tanks, connected by cross-flooding arrangements, the increase in pressure head at the immerged side that may occur at maximum heeling in the damaged condition is to be taken into account.

C Stiffeners

C.1 The section modulus W of bulkhead stiffeners is not to be less than determined by the following formula:

$$W = c_s \cdot \left(m_{k1}^2 - m_a^2\right) \cdot a \cdot \ell^2 \cdot p \quad [cm^3] \qquad \text{with} \left(m_{k1}^2 - m_a^2\right) \geq \frac{m_{k1}^2}{2}$$

m_{k1} : factor to take a shortened unsupported span into account according to Section 3, B.3.3.1

m_a : factor to take the load distribution into account according to Section 3, B.3.2

C.2 In horizontal part of bulkheads, the stiffeners are also to comply with the rules for deck beams according to Section 10.

C.3 The scantlings of the brackets are to be determined in dependence of the section modulus of the stiffeners according to Section 3, B.3.5.2. If the length of the stiffener is 3.5 m and over, the brackets are to extend to the next beam or the next floor.

C.4 Unbracketed bulkhead stiffeners are to be connected to the decks by welding. The length of weld is to be at least 0.6 x depth of the section.

C.5 If the length of stiffeners between bulkhead deck and the deck below is 3 m and less, no end attachment according to C.4 is required. In this case the stiffeners are to be extended to about 25 mm from the deck and sniped at the ends, see also Section 3, B.2.3.

C.6 Bulkhead stiffeners cut in way of watertight doors are to be supported by carlings or stiffeners.

D Primary supporting members

D.1 Dimensioning procedure

D.1.1 In general primary supporting members are to be dimensioned using linear direct calculation considering the load assumptions and strength criteria of D.2 for normal operation.

Also for dimensioning of primary supporting members plastic hinges can be taken into account. This can be done either by a non-linear calculation of the total bulkhead or by a linear girder grillage calculation of the idealised bulkhead.

When a linear girder grillage calculation is done, only those moments and shear forces according to D.3 are to be considered as boundary conditions at the supports, which can be absorbed by the relevant sections at these locations in full plastic condition.

D.1.2 If required also damage conditions according to D.2.2 are to considered.

D.1.3 In areas with cut-outs 2^{nd}-order bending moments are be taken into account.

D.2 Load assumptions and strength criteria

D.2.1 Normal operations

Loads during normal operation are the external water pressure, see Section 4, and the loads due to cargo and filled tanks, see Section 17, B.2, Section 21, H and if relevant depending on the deck opening Section 5, E.8.

In case of a linear direct calculation the following stresses are not to be exceeded:

$$\sigma_v = \sqrt{\sigma_N^2 + 3\cdot\tau^2} \le \frac{180}{k} \quad [N/mm^2]$$ for equivalent stresses

$$\sigma_N \le \frac{150}{k} \quad [N/mm^2]$$ for normal stresses

$$\tau \le \frac{100}{k} \quad [N/mm^2]$$ for shear stresses

For a non-linear or a linear girder grillage calculation the equivalent stresses σ_v are not to exceed the following value:

$$\sigma_v \le R_{eH}$$

D.2.2 Flooded condition

The loads in case of hold flooding result from p according to A.2.

The thickness t_w of webs is not to be less than determined by the following formula:

$$t_w = \frac{Q}{\tau_{perm}\cdot h_w}\cdot 10^3 + t_K \quad [mm]$$

Q : shear force $[kN]$

τ_{perm} : permissible shear stress $[N/mm^2]$, defined as:

$$\tau_{perm} = 7{,}27\cdot\sqrt{\frac{Q}{b\cdot h_w}\cdot\sqrt{R_{eH}\cdot\left(1+0{,}75\cdot\frac{b^2}{a^2}\right)}}$$ with $\tau_{perm} \le \frac{R_{eH}}{2{,}08}$

h_w : height $[mm]$ of web

a, b : lengths of edges of the unstiffened web field, with:

$h_w \ge b \le a$

D.3 Plastic moment M_p and shear force Q_p

The plastic moments M_p and shear forces Q_p as boundary conditions are to be determined by the following formulae:

For girders built up by one element (e.g. FB- and HP-sections):

$$M_p = \frac{W_p\cdot R_{eH}}{c\cdot 1\,200} \quad [kNm]$$

$$Q_p = \frac{A_s\cdot R_{eH}}{c\cdot 2\,080} \quad [kN]$$

For girders built up by several elements:

$$M_p = \frac{\sum_{i=1}^{n} A_i\cdot R_{eHi}\cdot e_{pi}}{c\cdot 1.2\cdot 10^6} \quad [kNm]$$

$$Q_p = \frac{\sum_{i=1}^{n} A_{si}\cdot R_{eHi}}{c\cdot 2\,080} \quad [kN]$$

W_p : plastic section modulus $[cm^3]$, defined as:

$$W_p = 10^{-3} \cdot \sum_{i=1}^{n} A_i \cdot e_{pi}$$

A_i : effective area $[mm^2]$ of element i considering Section 3, D.3.2. In this connection the area A_s of webs transferring shear is not to be taken into account.

e_{pi} : distance $[mm]$ of the centre of the partial area Ai from the neutral axis of the yielded section. The neutral axis is not to be taken in a position lower than the lowest point of the web.

c : coefficient, defined as:

$c = 1.1$	for the collision bulkhead
$c = 1.0$	for cargo hold bulkheads

A_s : web area transferring shear $[mm^2]$, defined as:

$$A_s = \Delta h_w \cdot t_w$$

Δh_w : minimum height $[mm]$ of the web area transferring shear, defined as:

$$\Delta h_w = h_w \cdot \frac{t_w}{t_{wa}}$$

t_w : web thickness $[mm]$

t_{wa} : as built thickness $[mm]$ of the web

A_{si} : shear area of element i

R_{eHi} : yield strength of element i

E Watertight longitudinal structures

The plating and stiffeners of watertight longitudinal structures are to be dimensioned according to Table 11.1, column "Other bulkheads".

F Corrugated bulkheads

F.1 The plate thickness of corrugated bulkheads is not to be less than required according to B.1. For the spacing a $[m]$ the greater one of the values b or s according to F.3 is to be taken.

F.2 The section modulus of a corrugated bulkhead element is to be determined according to C.1. For the spacing a $[m]$ the width of an element e, according to F.3 is to be taken. For the end attachment see Section 3, B.4.1.

F.3 The actual section modulus of a corrugated bulkhead element is to be assessed according to the following formula:

$$W = t \cdot d \cdot \left(b + \frac{s}{3}\right) \quad [cm^3]$$

e : width $[cm]$ of element

b : breadth $[cm]$ of face plate

s : breadth $[cm]$ of web plate

d : distance $[cm]$ between inner sides of face plates

t : plate thickness $[cm]$

α : angle [°] according to Fig. 11.1, with:

$$\alpha \geq 45$$

F.4 For watertight bulkheads of corrugated type on bulk carriers according to Section 5, C.2.2 see Section 23, F.

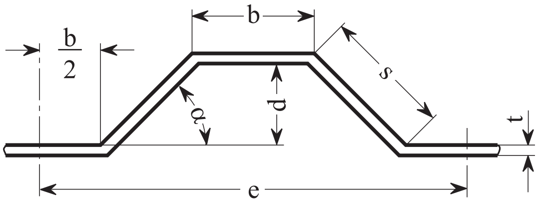


Fig. 11.1 Element of a corrugated bulkhead

G Shaft Tunnels

G.1 Scantlings

G.1.1 The plating of the shaft tunnel is to be dimensioned as for a bulkhead according to B.1.

G.1.2 The plating of the round part of tunnel tops may be 10 % less in thickness.

G.1.3 In the range of hatches, the plating of the tunnel top is to be strengthened by not less than 2 mm unless protected by a ceiling.

On containerships this strengthening can be dispensed with.

G.1.4 The section modulus of shaft tunnel stiffeners is to be determined according to C.1.

G.1.5 Horizontal parts of the tunnel are to be treated as horizontal parts of bulkheads and as cargo decks respectively.

G.1.6 Shaft tunnels in tanks are to comply with the requirements of Section 12.

Section 12 Tank Structures

A General

A.1 References

A.1.1 For the arrangement of air, overflow and sounding pipes see Section 21, F.

A.1.2 For cargo oil tanks see Section 24.

A.1.3 For dry cargo holds which are also intended to be used as ballast water tanks, see C.

A.1.4 Where tanks are provided with cross flooding arrangements the increase in pressure head at the immerged side that may occur at maximum heeling in the damaged condition is to be taken into account.

A.2 Definitions

For the terms "constraint" and "simply supported" see Section 3, B.3.5.1

Symbols

a : spacing $[m]$ of stiffeners or load width

b_t : tank breadth $[m]$

e_t : characteristic tank dimension ℓ_t or b_t $[m]$

h : filling height $[m]$ of tank

k : material factor according to Section 2, A.2

ℓ : unsupported span according to Section 3, B.3.3

ℓ_t : tank length $[m]$

n_f : factor to take the type of framing system into account, defined as:

$n_f = 1.0$ for transverse stiffening

$n_f = 0.83$ for longitudinal stiffening

p : design pressure $[N/mm^2]$, defined as:

$p = \max\left[p_{T1}\ ;\ p_{T3}\right]$ in general

$p = p_{T1} - 10\left(T_{min} - z\right) + p_0 \cdot c_F \cdot \left(1 + \frac{z}{T_{min}}\right) \le p_{T1}$ for tank structures on the shell below T_{min}

p_{T1}, p_{T2} : loads on filled tanks according to Section 4, D.1

p_{T3} : load on partial filled tanks according to Section 4, D.2

p_v : pressure according to Section 4, A.3

T_{min} : smallest design ballast draught [m]

z : distance [m] of structural member above base line

p_0 : basic external dynamic load according to Section 4, A.3

c_F : distribution factor according to Section 4, A.3

t_K : corrosion addition according to Section 3, G

$\sigma_{p\ell}$: permissible local design stress $[N/mm^2]$, defined as:

$$\sigma_{p\ell} = \sqrt{\left(\frac{235}{k}\right)^2 - 3 \cdot \tau_L^2} - 0.89 \cdot \sigma_L$$

σ_L : normal stress at the position considered according to Section 5, D.2.2

σ_{vp} : permissible equivalent stresses in the fillet weld according to Section 19, Table 19.2

τ_L : shear stress $[N/mm^2]$ at the position considered, see also Section 5, D.2.2

τ_p : permissible shear stress in the fillet weld according to Section 19, Table 19.2

B Scantlings

B.1 Plating

B.1.1 The plate thickness t is not to be less than determined by the following formulae:

$$t = \max\left[t_1 \; ; \; t_2\right]$$

$$t_1 = 1.1 \cdot a \cdot \sqrt{p \cdot k} + t_K \quad [mm]$$

$$t_2 = 0.9 \cdot a \cdot \sqrt{p_{T2} \cdot k} + t_K \quad [mm]$$

B.1.2 Above the requirements specified in B.1.1 the thickness t of tank boundaries (including deck and inner bottom) carrying also normal and shear stresses due to longitudinal hull girder bending is not to be less than determined by the following formula:

$$t = 16.8 \cdot n_f \cdot a \sqrt{\frac{p}{\sigma_{p\ell}}} + t_K \quad [mm]$$

B.1.3 The minimum plate thickness t_{min} of all structures in tanks is not to be less than determined by the following formula:

$$t_{min} = 5.5 + 0.02 \cdot \mathbf{L} \quad [mm]$$

with $t_{min} \leq 7.5$ mm for fuel oil, lubrication oil and freshwater tanks,

and $t_{min} \leq 9.0$ mm for ballast tanks of dry cargo ships

For minimum thickness of all structures in tanks of oil tankers see Section 24, G

B.2 Stiffeners and girders

B.2.1 References

For beams and girders of tank decks see also Section 10.

B.2.2 Stiffeners and girders, which are not considered as longitudinal strength members

B.2.2.1 The section modulus W of stiffeners and girders which are constrained at their ends, is not to be less than determined by the following formulae:

$$W = \max\left[W_1 \; ; \; W_2\right]$$

$$W_1 = 0.55 \cdot \left(m_{k1}^2 - m_a^2\right) \cdot a \cdot \ell^2 \cdot p \cdot k \quad [cm^3] \qquad \text{with } \left(m_{k1}^2 - m_a^2\right) \geq \frac{m_{k1}^2}{2}$$

$$W_2 = 0.44 \cdot \left(m_{k1}^2 - m_a^2\right) \cdot a \cdot \ell^2 \cdot p_{T2} \cdot k \quad [cm^3] \qquad \text{with } \left(m_{k1}^2 - m_a^2\right) \geq \frac{m_{k1}^2}{2}$$

Where one or both ends are simply supported, the section moduli are to be increased by 50 %.

The shear area A_W of the girder webs is not to be less than determined by the following formulae:

$$A_W = \max\left[A_{W1} \; ; \; A_{W2}\right]$$

$$A_{W1} = 0.05 \cdot (1 - 0.817 \cdot m_a) \cdot a \cdot \ell \cdot p \cdot k \quad [cm^2]$$

$$A_{W2} = 0.04 \cdot (1 - 0.817 \cdot m_a) \cdot a \cdot \ell \cdot p_{T2} \cdot k \quad [cm^2]$$

A_{w2} is to be increased by 50 % at the position of constraint of vertical stiffeners and vertical web frames for a length of $0.1 \cdot \ell$.

m_{k1} : factor to take a shortened unsupported span into account, defined as:

m_{k1} = according to Section 3, B.3.3.1	in general
$m_{k1} = 1$	for girders supporting longitudinal stiffeners and for heel stiffeners

m_a : factor to take the load distribution into account, defined as:

m_a = according to Section 3, B.3.2	in general
$m_a = 0$	for girders supporting longitudinal stiffeners and for heel stiffeners

B.2.2.2 Where the scantlings of stiffeners and girders are determined according to strength calculations, the following permissible stress values apply:

If the stiffeners are subjected to load p:

$$\sigma_b = \frac{150}{k} \quad [N/mm^2] \qquad \text{for bending stresses}$$

$$\tau = \frac{100}{k} \quad [N/mm^2] \qquad \text{for shear stresses}$$

$$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} = \frac{180}{k} \quad [N/mm^2] \qquad \text{for equivalent stresses}$$

If the stiffeners are subjected to load p_{T2}:

$$\sigma_b = \frac{180}{k} \quad [N/mm^2] \qquad \text{for bending stresses}$$

$$\tau = \frac{115}{k} \ [N/mm^2]$$ for shear stresses

$$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} = \frac{200}{k} \ [N/mm^2]$$ for equivalent stresses

B.2.3 Stiffeners and girders, which are to be considered as longitudinal strength members

B.2.3.1 The section moduli and shear areas of horizontal stiffeners and girders are to be determined according to Section 9, C.3.2 as for longitudinals. In this case for girders supporting transverse stiffeners the following factors are to be used:

m_{k1} : factor to take a shortened unsupported span into account, defined as:

$$m_{k1} = 1$$

m_a : factor to take the load distribution into account, defined as:

$$m_a = 0$$

B.2.3.2 The stiffeners of tank bulkheads are to be attached at their ends by brackets according to Section 3, B.3.5.2. The scantlings of the brackets are to be determined according to the section modulus of the stiffeners.

The brackets of stiffeners are to extend to the next beam, the next floor, the next frame, or are to be otherwise supported at their ends.

B.2.4 Connection between primary support members and intersecting stiffeners

At intersections of stiffeners with primary support members the shear connection and attached heel stiffeners subjected to tank loads p and p_{T2} are to be designed according to Section 9, C.4.6 – Section 9, C.4.8.

Related to the tank loads p and p_{T2} the permissible stresses according to Table 12.1 are not to be exceeded:

Table 12.1 Permissible stresses $[N/mm^2]$

Stress	Permissible stresses for load p	Permissible stresses for load p_2
σ_{axial}	$\frac{150}{k}$	$\frac{180}{k}$
σ_{weld}	σ_{vp}	$\frac{\sigma_{vp}}{0.8}$
τ_i	$\frac{100}{k}$	$\frac{115}{k}$
$\tau_{weld,i}$	τ_p	$\frac{\tau_p}{0.8}$
σ_c	$\frac{150}{k}$	$\frac{180}{k}$

B.3 Frames

The section modulus W and shear area A of frames in tanks or in hold spaces for ballast water are not to be less than determined by the following formula:

$$W = \max\left[W_1\ ;\ W_2\right]$$

$$W_1 = n \cdot m_{k3} \cdot \left(1 - m_a^2\right) \cdot m_c \cdot \mathbf{a} \cdot \ell^2 \cdot p_{T1} \cdot k \quad [cm^3]$$

$$W_2 = 0.44 \cdot m_{k3} \cdot \left(1 - m_a^2\right) \cdot m_c \cdot \mathbf{a} \cdot \ell^2 \cdot p_{T2} \cdot k \quad [cm^3]$$

$$A = \max\left[A_1\ ;\ A_2\right] \quad [cm^2]$$

$$A_1 = 0.05 \cdot \left(1 - 0.817 \cdot m_a\right) \cdot \mathbf{a} \cdot \ell \cdot p_{T1} \cdot k \quad [cm^2]$$

$$A_2 = 0.04 \cdot \left(1 - 0.817 \cdot m_a\right) \cdot \mathbf{a} \cdot \ell \cdot p_{T2} \cdot k \quad [cm^2]$$

n : factor according to Section 9, A.1

m_{k3} : factor to take a shortened unsupported span into account according to Section 3, B.3.3.3

m_a : factor to take the load distribution into account according to Section 3, B.3.2

m_c : factor to take curved frames into account according to Section 3, B.3.4

B.4 Corrugated bulkheads

B.4.1 The plate thicknesses t of corrugated bulkheads as well as the required section moduli of corrugated bulkhead elements are to be determined according to B.1 and B.2, proceeding analogously to Section 11, F.

However, the plate thickness t is not to be less than determined by the following formulae:

$$t = \frac{b}{c_p}\sqrt{\sigma_D} + t_k \quad [mm] \qquad \text{with } t \ge t_{min}$$

t_{min} : minimum thickness according to B.1.3

b : breadth $[mm]$ of face plate strip

c_p : load depending coefficient, defined as:

$c_p = 905$ if the bulkhead is subjected to load p

$c_p = 960$ if the bulkhead is subjected to load p_{T2}

σ_D : compressive stress $[N/mm^2]$

B.4.2 For the end attachment Section 3, B.4.1 is to be observed.

B.5 Thickness of clad plating

B.5.1 Where the yield strength of the cladding is not less than that of the base material the plate thickness is to be determined according to B.1.1.

B.5.2 Where the yield strength of the cladding is less than that of the base material the plate thickness is not to be less than:

$$t = \max\left[t_1\ ;\ t_2\right]$$

$$t_1 = 0.55 \cdot \mathbf{a} \cdot \sqrt{p \cdot \frac{k}{A}} + t_k \quad [mm]$$

$$t_2 = 0.45 \cdot \mathbf{a} \cdot \sqrt{p_{T2} \cdot \frac{k}{A}} + t_k \quad [mm]$$

A : factor, defined as:

$$A = 0.25 - \frac{t_p}{2 \cdot t_{ic}}\left(1 - r - \frac{t_p}{2 \cdot t_{ic}} \cdot \left(1 - r^2\right)\right)$$ for one side clad steel

$$A = 0.25 - \frac{t_p}{t}\left(1 - \frac{t_p}{t}\right) \cdot (1 - r)$$ for both side clad steel

t_{ic} : plate thickness $[mm]$ including cladding

t_p : thickness $[mm]$ of the cladding

r : ratio, defined as

$$r = \frac{R_{eH,c}}{R_{eH,b}}$$

$R_{eH,c}$: yield strength $[N / mm^2]$ of the cladding at service temperature

$R_{eH,b}$: yield strength $[N / mm^2]$ of the base material

B.5.3 The plate thicknesses determined in accordance with B.5.1 and B.5.2 respectively may be reduced by 0.5 mm. For chemical tankers however the reductions as per Chemical Tankers (I-1-7), Section 4, 4-0.1.3 apply.

B.6 *Recommendations for plating and stiffeners in the propeller area and in the engine room*

B.6.1 *General*

From a vibration point of view tank structures in the vicinity of the propeller(s) and the main engine should be designed such that the design criteria defined in B.6.3 to B.6.4 are fulfilled (see also Section 6, E.1).

B.6.2 *Definitions*

d_p : *propeller diameter $[m]$*

d_r : *ratio , defined as:*

$$d_r = \frac{r}{d_p}$$

f_{blade} : *propeller blade passage excitation frequency at n, defined as:*

$$f_{blade} = \frac{1}{60} \cdot n \cdot z \quad [Hz]$$

n : *maximum propeller shaft revolution rate $[1 / min]$*

z : *number of propeller blades*

f_{plate} : *lowest natural frequency of isotropic plate field under consideration of additional outfitting and hydrodynamic masses $[Hz]$*

f_{stiff} : *lowest natural frequency of stiffener under consideration of additional outfitting and hydrodynamic masses $[Hz]$*

The natural frequencies of plate fields and stiffeners can be estimated by POSEIDON or by means of the software tool GL LocVibs which can be downloaded from the GL homepage www.gl-group.com/en/gltools/GL-Tools.php.

$f_{ignition}$: *main engine ignition frequency at ne, defined as:*

$$f_{ignition} = \frac{1}{60} \cdot k_{stroke} \cdot n_c \cdot n_e \quad [Hz]$$

k_{stroke} : *number indicating the type of main engine*

$$k_{stroke} = 1.0$$ *for 2-stroke (slow-running) main engines*

$$k_{stroke} = 0.5$$ *for 4-stroke (medium speed) main engines*

The number for 4-stroke engines is valid for in-line engines. The ignition frequency for V-engines depends on the V-angle of the cylinder banks and can be obtained from the engine manufacturer.

n_c : *number of cylinders of main engine*

n_e : *maximum main engine revolution rate* $[1/min]$

r : *distance of plate field or stiffener to 12 o'clock propeller blade tip position* $[m]$

α : *ratio, defined as:*

$$\alpha = \frac{P}{\Delta}$$

P : *nominal main engines output* $[kW]$

Δ : *ship's design displacement* $[ton]$

B.6.3 *Tank structures in propeller area*

For vessels with a single propeller, plate fields and stiffeners of tank structures should fulfil the frequency criteria in Table 12.2. To fulfil the criteria the lowest natural frequencies of plate fields and stiffeners are to be higher than the denoted propeller blade passage excitation frequencies.

Table 12.2 Frequency criteria

$\alpha \geq 0.3$				$\alpha < 0.3$	
$0 < d_r \leq 1$	$1 < d_r \leq 2$	$2 < d_r \leq 4$	$4 < d_r \leq 6$	$0 < d_r \leq 2$	$2 < d_r \leq 4$
$4.40 \cdot f_{blade}$	$3.45 \cdot f_{blade}$	$2.40 \cdot f_{blade}$	$1.20 \cdot f_{blade}$	$2.40 \cdot f_{blade}$	$1.20 \cdot f_{blade}$

B.6.4 *Tank structures in main engine area*

For vessels with a single propeller, plate fields and stiffeners of tanks located in the engine room should at all filling states fulfil the frequency criteria as summarised in Table 12.3.

Generally, direct connections between transverse engine top bracings and tank structures shall be avoided. Pipe fittings at tank walls etc. shall be designed in such a way that the same frequency criteria as given for plates are fulfilled.

Table 12.3 Frequency criteria

Engine type	*Mounting type*	*Application area*	*Frequency criteria*
Slow-speed	*Rigid*	*Tanks within engine room*	$1.2 \cdot f_{ignition} < f_{plate} < 1.8 \cdot f_{ignition}$, *or*
			$f_{plate} > 2.2 \cdot f_{ignition}$
			$f_{stiff} > 1.2 \cdot f_{ignition}$
Medium speed	*Rigid or semi-resilient*	*Tanks within engine room*	$f_{plate} < 0.8 \cdot f_{ignition}$, *or*
			$f_{plate} > 1.2 \cdot f_{ignition}$

			$f_{stiff} < 0.8 \cdot f_{ignition}$, *or*
			$f_{stiff} > 1.2 \cdot f_{ignition}$
	Resilient	*Tanks within engine length up to next platform deck above inner bottom*	$f_{plate} < 0.9 \cdot f_{ignition}$
			$f_{stiff} > 1.1 \cdot f_{ignition}$

C Tanks with Large Lengths or Breadths

C.1 General

Tanks with lengths $\ell_t > 0.1\,\mathbf{L}$ or breadths $b_t > 0.6\,\mathbf{B}$ (e.g. hold spaces for ballast water) which are intended to be partially filled, are to be investigated to avoid resonance between the liquid motion and the pitch or roll motion of the ship. If necessary, critical tank filling ratios are to be avoided. The ship's periods of pitch and roll motion as well as the natural periods of the liquid in the tank may be determined by the following formulae:

$$T_{\ell,b} = 1.132 \cdot \sqrt{\frac{e_t}{f}} \quad [s]$$ as natural period of liquid in tank

$$T_s = \frac{\mathbf{L}}{1.17 \cdot \sqrt{\mathbf{L} + 0.15 \cdot v_0}} \quad [s]$$ as period of wave excited pitch motion

$$T_r = \frac{c_r \cdot \mathbf{B}}{\sqrt{\overline{GM}}} \quad [s]$$ as period of roll motion

f : hyperbolic function, defined as:

$$f = \tanh\left(\frac{\pi \cdot h}{e_t}\right)$$

c_r : coefficient, defined as:

$c_r = 0.78$ in general

$c_r = 0.70$ for tankers in ballast condition

$\overline{GM}$: metacentric height $[m]$, defined as:

$\overline{GM} \approx 0.07 \cdot \mathbf{B}$ in general

$\overline{GM} \approx 0.12 \cdot \mathbf{B}$ for tankers and bulk carriers

C.2 Hold spaces for ballast water

In addition to the requirements specified under C.1 above for hold spaces of dry cargo ships and bulk carriers, which are intended to be filled with ballast water, the following is to be observed:

- For hold spaces only permitted to be completely filled, a relevant notice will be entered into the Certificate.
- Adequate venting of the hold spaces and of the hatchway trunks is to be provided.
- For frames also B.3 is to be observed.

D Vegetable Oil Tanks

D.1 Further to the regulations stipulated under A and B for vegetable oil tanks, the following requirements are to be observed.

D.2 Tanks carrying vegetable oil or similar liquids, the scantlings of which are determined according to B, are to be either fully loaded or empty. A corresponding note will be entered into the Certificate.

These tanks may be partially filled provided they are subdivided according to Section 27, B.7.2. Filling ratios between 70 and $90\ \%$ should be avoided.

D.3 In tanks carrying vegetable oil or similar liquids sufficient air pipes are to be fitted for pressure equalizing. Expansion trunks of about $1\ \%$ of the tank volume are to be provided. Where the tank is subdivided by at least one centre line bulkhead, $3\ \%$ of the tank may remain empty and be used as expansion space.

E Detached Tanks

E.1 General

E.1.1 Detached tanks are to be adequately secured against forces due to the ship's motions.

E.1.2 Detached tanks in hold spaces are also to be provided with antifloatation devices. It is to be assumed that the hold spaces are flooded to the load water line. The stresses in the antifloatation devices caused by the floatation forces are not to exceed the material's yield strength.

E.1.3 Detached oil fuel tanks should not be installed in cargo holds. Where such an arrangement cannot be avoided, provision is to be made to ensure that the cargo cannot be damaged by leakage oil.

E.1.4 Fittings and pipings on detached tanks are to be protected by battens, and gutter ways are to be fitted on the outside of tanks for draining any leakage oil.

E.2 Scantlings

E.2.1 The thickness of plating of detached tanks is to be determined according to B.1.1 using the formula for t1 and the pressure p according to E.2.2.

E.2.2 The section modulus W of stiffeners of detached tanks is not to be less than determined by the following:

$$W = c \cdot a \cdot \ell^2 \cdot p \cdot k \quad [cm^3]$$

c : coefficient to take boundary conditions into account, defined as:

$c = 0.36$ if stiffeners are constrained at both ends

$c = 0.54$ if one or both ends are simply supported

p : design pressure $[kN/m^2]$, defined as:

$p = 9.81 \cdot h$

h : distance $[m]$ from load centre of plate panel or stiffener respectively to top of overflow or to a point $2.5\ m$ above tank top, whichever is the greater.

For tanks intended to carry liquids of a density greater than $1\ t/m^3$, the head h is at least to be measured to a level at the following distance h_p above tank top:

$h_p = 2.5 \cdot \rho$

ρ : density $[t / m^3]$ of liquid to carry

E.2.3 For minimum thickness the requirements of B.1.3 apply in general.

F Potable Water Tanks

F.1 Potable water tanks shall be separated from tanks containing liquids other than potable water, ballast water, distillate or feed water.

F.2 In no case sanitary arrangement or corresponding piping are to be fitted directly above the potable water tanks.

F.3 Manholes arranged in the tank top are to have sills.

F.4 If pipes carrying liquids other than potable water are to be led through potable water tanks, they are to be fitted in a pipe tunnel.

F.5 Air and overflow pipes of potable water tanks are to be separated from pipes of other tanks.

G Swash Bulkheads

G.1 The total area of perforation shall not be less than $5\ \%$ and should not exceed 10% of the total bulkhead area.

G.2 The plate thickness is, in general, to be equal to the minimum thickness according to B.1.3 Strengthenings may be required for load bearing structural parts.

The free lower edge of a swash bulkhead is to be adequately stiffened.

G.3 The section modulus of the stiffeners and girders is not to be less than W_1 according to B.2.2, however, in lieu of p the load p_{T3}, , but disregarding p_v is to be taken.

G.4 For swash bulkheads in oil tankers see also Section 24, J.

H Fuel and Lubricating Oil Tanks in Double Bottom

H.1 If the tank top of the lubricating oil circulating tank is not arranged at the same level as the adjacent inner bottom, this discontinuity of the flow of forces has to be compensated by vertical and / or horizontal brackets.

The brackets are to be designed with a soft taper at the end of each arm. The thickness of the vertical brackets has to correspond to the thickness of the floor plates according to Section 8, D.3.1, the thickness of the horizontal brackets has to correspond to the tank top thickness of the circulating tank.

The brackets are to be at least connected to the ship structure by double-bevel welds according to Section 19, B.2.2.3.

H.2 For minimum thickness the requirements of B.1.3 apply in general.

I Tanks for heated liquids

I.1 Where heated liquids are intended to be carried in tanks, a calculation of thermal stresses is required, if the carriage temperature of the liquid exceeds the following values:

$T = 65$ °C	in case of longitudinal framing
$T = 80$ °C	in case of transverse framing

I.2 The calculations are to be carried out for both temperatures, the actual carriage temperature and the limit temperature T according to I.1.

The calculations are to give the resultant stresses in the hull structure based on a sea water temperature of 0 °C and an air temperature of 5 °C.

Constructional measures and / or strengthenings will be required on the basis of the results of the calculation for both temperatures.

Section 13 Stem and Sternframe Structures

A General

A.1 Definitions

B_1 : support force $[N]$ according to Section 14, E.3

For determining preliminary scantlings the flexibility of the rudder horn may be ignored and the supporting force B_1 may be determined by the following formula:

$$B_1 = C_R \cdot \frac{b}{c}$$ in general

$$B_1 = C_R \cdot \frac{1}{2}$$ for rudders with two supports

C_R : rudder force according to Section 14, D.1

b, c, d : distances $[m]$ according to Fig. 13.1; b results from the position of the centre of gravity of the rudder area

$e(z), z$: distances $[m]$ according to Fig. 13.2

c_0 : wave coefficient according to Section 4, A.3

k : material factor according to Section 2, A.2, for cast steel $k = k_r$ according to Section 14, C.2

ℓ_{50} : length $[m]$ according to Fig. 13.3 and Section 14, E.2

t_K : corrosion addition according to Section 3, G

x : distance $[m]$ of the respective cross section from the rudder axis, with:

$$0.5 \cdot \ell_{50} \le x \le \ell_{50}$$

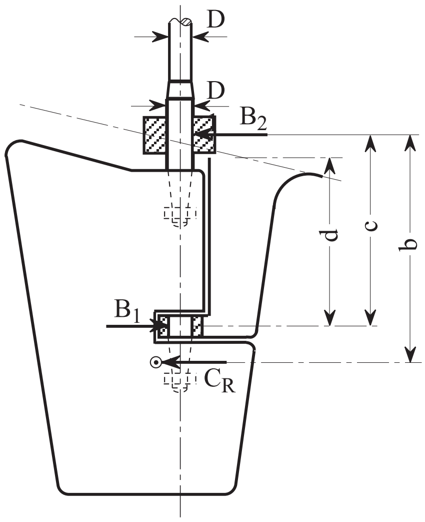


Fig. 13.1 Arrangement of bearings of a semi spade rudder

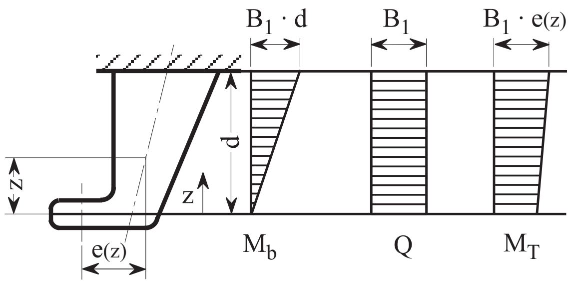


Fig. 13.2 Loads on the rudder horn

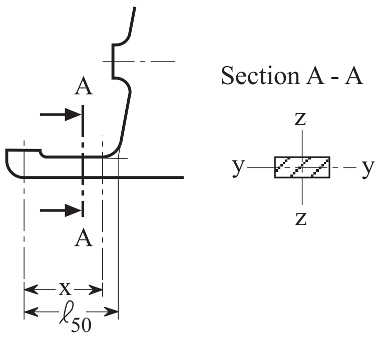


Fig. 13.3 Length ℓ_{50} of a sole piece

B Stem

B.1 Bar stem

The cross sectional area A_b of a bar stem below the load waterline is not to be less than determined by the following formula:

$$A_b = 1.25 \cdot \mathbf{L} \quad [cm^2]$$

Starting from the load waterline, the sectional area of the bar stem may be reduced towards the upper end to $0.75 \cdot A_b$.

B.2 Plate stem and bulbous bows

B.2.1 Plating

B.2.1.1 The thickness t is not to be less than determined by the following formula:

$$t = (0.6 + 0.4 \cdot a_B) \cdot (0.08 \cdot \mathbf{L} + 6) \cdot \sqrt{k} \quad [mm] \qquad \text{with } t_{min} \le t \le t_{max}$$

a_B : spacing $[m]$ of fore-hooks

t_{min} : minimum plate thickness according to Section 6, C.2

t_{max} : maximum plate thickness $[mm]$, defined as:

$$t_{max} = 25 \cdot \sqrt{k}$$

B.2.1.2 The extension ℓ of the stem plate from its trailing edge aftwards is not to be smaller than determined by the following formula:

$$\ell = 70 \cdot \sqrt{\mathbf{L}} \quad [mm]$$

B.2.1.3 Starting from 600 mm above the load waterline up to $\mathbf{T} + c_0$, the plate thickness t according to B.2.1.1 may gradually be reduced to $0.8 \cdot t$.

B.2.2 Stiffeners and girders

B.2.2.1 Dimensioning of the stiffening is to be done according to Section 9.

B.2.2.2 Plate stems and bulbous bows are to be stiffened by fore-hooks and/or cant frames. In case of large and long bulbous bows, see Section 9, B.5.5.3.

C Sternframe

C.1 General

C.1.1 Due regard is to be paid to the design of the aft body, rudder and propeller well in order to minimize the forces excited by the propeller.

C.1.2 The following value is recommended for the propeller clearance $d_{0.9}$ related to $0.9 \cdot R$ (see Fig. 13.4).

$$d_{0.9} \ge 0.004 \cdot n \cdot d_p^3 \cdot \sqrt{\frac{v_0 \cdot (1 - \sin(0.75 \cdot \gamma)) \cdot \left(0.5 + \frac{z_B}{x_F}\right)}{D}} \quad [m]$$

n : number of propeller revolutions per minute $[1/min]$

d_p : propeller diameter $[m]$

γ : skew angle $[°]$ of the propeller according to Fig. 13.5

z_B : height $[m]$ of wheelhouse deck above weather deck

x_F : distance $[m]$ of deckhouse front bulkhead from aft edge of stern according to Fig. 13.4

D : maximum displacement $[t]$ of ship

R : propeller radius

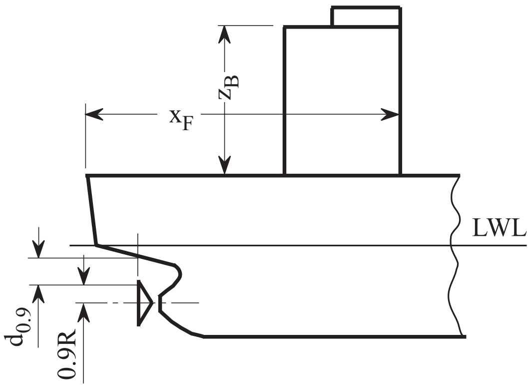


Fig. 13.4 Propeller clearance $d_{0.9}$

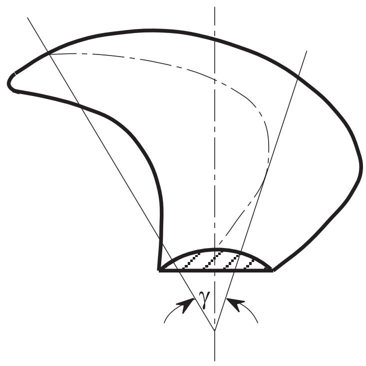


Fig. 13.5 Skew angle

C.1.3 For single screw ships, the lower part of the sternframe is to be extended forward by at least 3 times the frame spacing from fore edge of the boss, for all other ships by 2 times the frame spacing from after edge of the sternframe.

C.1.4 The stern tube is to be surrounded by the floor plates or, when the ship's shape is too narrow, to be stiffened by internal rings. Where no sole piece is fitted, the internal rings may be dispensed with.

C.1.5 The plate thickness t of sterns of welded construction for twin screw vessels is not to be less than determined by the following formula:

$$t = (0.07 \cdot \mathbf{L} + 5.0) \cdot \sqrt{k} \quad [\text{mm}] \qquad \text{with } t \le t_{max}$$

t_{max} : maximum plate thickness [mm], defined as:

$$t_{max} = 22 \cdot \sqrt{k}$$

C.2 Propeller post

C.2.1 The scantlings ℓ and b of rectangular, solid propeller posts are to be determined by the following formulae:

$$\ell = 1.4 \cdot \mathbf{L} + 90 \quad [\text{mm}]$$

$$b = 1.6 \cdot \mathbf{L} + 15 \quad [\text{mm}]$$

Where other sections than rectangular ones are used, their section modulus is not to be less than that resulting from ℓ and b.

C.2.2 The scantlings ℓ, b and t of propeller posts of welded construction are to be determined by the following formulae:

$$\ell = 50 \cdot \sqrt{\mathbf{L}} \quad [\text{mm}]$$

$$b = 36 \cdot \sqrt{\mathbf{L}} \quad [\text{mm}]$$

$$t = 2.4 \cdot \sqrt{\mathbf{L} \cdot k} \quad [\text{mm}]$$

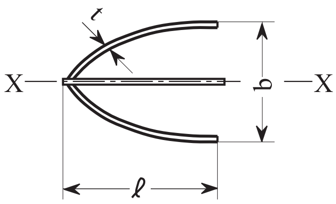


Fig. 13.6 Propeller post

Note

With single-screw ships having in the propeller region above the propeller flaring frames of more than $\alpha = 75$ the thickness of the shell should not be less than the thickness of the propeller stem. For $\alpha \le 75$ the thickness may be $0.8 \cdot t$. In no case the thickness is to be less than the thickness of the side shell according to Section 6.

This recommendation applies for that part of the shell which is bounded by an assumed sphere the centre of which is located at the top of a propeller blade in the twelve o'clock position and the radius of which is $0,75 \cdot$ propeller diameter.

Sufficient stiffening should be arranged, e.g. by floors at each frame and by longitudinal girders.

C.2.3 Where the cross sectional configuration is deviating from Fig. 13.6 and for cast steel propeller posts the section modulus W_x of the cross section related to the longitudinal axis is not to be less than determined by the following formula:

$$W_x = 1.2 \cdot \mathbf{L}^{1.5} \cdot k \quad [\text{cm}^3]$$

C.2.4 The wall thickness of the boss in the propeller post in its finished condition is to be at least $60\ \%$ of the breadth b of the propeller post according to C.2.1.

C.2.5 The wall thickness of the boss in propeller posts of welded construction according to C.2.2 is not to be less than 0.9 the wall thickness of the boss according to D.2.

C.3 Sole piece

C.3.1 The section modulus W_z of the sole piece related to the z-axis is not to be less than determined by the following formula:

$$W_z = \frac{B_1 \cdot x \cdot k}{80} \quad [\text{cm}^3]$$

The section modulus W_z may be reduced by $15\ \%$ where a rudder post is fitted.

C.3.2 The section modulus W_y related to the y-axis is not to be less than determined by the following formulae:

$$W_y = \frac{W_z}{2} \qquad \text{where no rudder post or rudder axle is fitted}$$

$$W_y = \frac{W_z}{3} \qquad \text{where a rudder post or rudder axle is fitted}$$

W_z : section moduli of the sole piece according to C.3.1

C.3.3 The sectional area A_s at the location $x = \ell_{50}$ is not to be less than determined by the following formula:

$$A_s = \frac{B_1}{48} \cdot k \quad [mm^2]$$

C.3.4 The equivalent stress σ_v at any location within the length ℓ_{50} is not to exceed:

$$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} = \frac{115}{k} \quad [N/mm^2]$$

σ_b, τ : stress components $[N / mm^2]$ of the equivalent stress, defined as:

$$\sigma_b = \frac{B_1 \cdot x}{W_z}$$

$$\tau = \frac{B_1}{A_s}$$

W_z : section moduli according to C.3.1

A_s : sectional area of the sole piece according to C.3.3

C.4 Rudder horn of semi spade rudders

C.4.1 The distribution of the bending moment M_b, shear force Q and torsional moment M_T are to be determined by the following formulae:

$$M_b = \min\left[B_1 \cdot z \; ; \; B_1 \cdot d\right] \quad [Nm]$$

$$Q = B_1 \quad [N]$$

$$M_T = B_1 \cdot e(z) \quad [Nm]$$

C.4.2 The section modulus W_x of the rudder horn in transverse direction related to the horizontal x-axis is at any location z not to be less than determined by the following formula:

$$W_x = \frac{M_b \cdot k}{67} \quad [cm^3]$$

M_b : bending at a rudders horn of semi spade rudders according to C.4.1

C.4.3 At no cross section of the rudder horn the shear stress τ due to the shear force Q is to exceed the value determined by the following formula:

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

The shear stress τ is to be determined by the following formula:

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

A_h : effective shear area $[mm^2]$ of the rudder horn in y-direction

C.4.4 The equivalent stress σ_v at any location (z) of the rudder horn are not to exceed the following value:

$$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \left(\tau^2 + \tau_T^2\right)} = \frac{120}{k} \quad [N/mm^2]$$

σ_b, τ_T : stress components $[N / mm^2]$ of the equivalent stress, defined as:

$$\sigma_b = \frac{M_b}{W_x}$$

$$\tau_T = \frac{M_T \cdot 10^3}{2 \cdot A_T \cdot t_h}$$

M_b, M_T : bending and torsional moment at a rudders horn of semi spade rudders according to C.4.1

W_x : section moduli of rudder horn of semi spade rudders according to C.4.2

A_T : sectional area $[mm^2]$ enclosed by the rudder horn at the location considered

t_h : thickness $[mm]$ of the rudder horn plating

C.4.5 When determining the thickness of the rudder horn plating the provisions of C.4.2 – C.4.5 are to be complied with. However the minimum thickness t_{min} of is not to be less than determined by the following formula:

$$t_{min} = 2.4 \cdot \sqrt{\mathbf{L} \cdot k} \quad [mm]$$

C.4.6 The rudder horn plating is to be effectively connected to the aft ship structure, e.g. by connecting the plating to longitudinal girders, in order to achieve a proper transmission of forces, see Fig. 13.7.

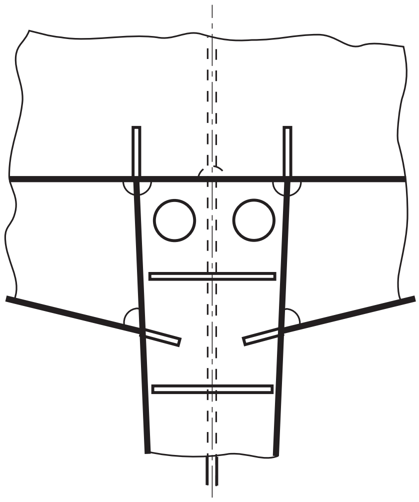


Fig. 13.7 Rudder horn integration into the aft ship structure

C.4.7 Transverse webs of the rudder horn are to be led into the hull up to the next deck in a sufficient number and are to be of adequate thickness.

C.4.8 Strengthened plate floors are to be fitted in line with the transverse webs in order to achieve a sufficient connection with the hull. The thickness of these plate floors is to be increased by $50\,\%$ above the Rule values as required by Section 8.

C.4.9 The centre line bulkhead (wash-bulkhead) in the after peak is to be connected to the rudder horn.

C.4.10 Where the transition between rudder horn and shell is curved, about $50\,\%$ of the required total section modulus of the rudder horn is to be formed by the webs in a Section $A - A$ located in the centre of the transition zone, i.e. $0.7 \cdot r$ above the beginning of the transition zone. See Fig. 13.8.

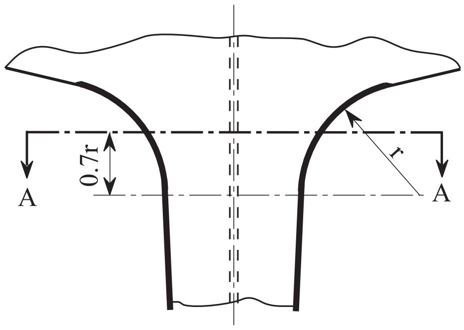


Fig. 13.8 Transition between rudder horn and shell

D Propeller Brackets

D.1 The strut axes should intersect in the axis of the propeller shaft as far as practicable. The struts are to be extended through the shell plating and are to be attached in an efficient manner to the frames and plate floors respectively. The construction in way of the shell is to be carried out with special care. In case of welded connection, the struts are to have a weld flange or a thickened part or are to be connected with the shell plating in another suitable manner. For strengthening of the shell in way of struts and shaft bossings, see Section 6, E and Section 19, B.4.3.

D.2 The scantlings of solid struts are to be determined by the following formulae:

$t = 0.44 \cdot d$ thickness

$A = 0.44 \cdot d^2$ cross-sectional area in propeller bracket

ℓ = length of boss according to the GL Rules for Machinery Installations (I-1-2), Section 4, D.5.2

$t_b = 0.25 \cdot d$ wall thickness of boss

d : shaft diameter

D.3 Propeller brackets and shaft bossings of welded construction are to have the same strength as solid ones according to D.2.

D.4 For propeller brackets consisting of one strut only a strength analysis according to E.1.2 and a vibration analysis according to E.2 are to be carried out. Due consideration is to be given to fatigue strength aspects.

E Elastic Stern Tube

E.1 Strength analysis

When determining the scantlings of the stern tube in way of the connection with the hull, the following stresses are to be proved:

E.1.1 Static load

The bending stresses σ_b caused by static weight loads are not to exceed the following value:

$$\sigma_b \le 0.35 \cdot R_{eH}$$

E.1.2 Dynamic load

The pulsating load due to loss of one propeller blade is to be determined assuming that the propeller revolutions are equal to 0.75 times the rated speed. The following permissible stresses $\sigma_{d,perm}$ are to be observed:

$\sigma_{d,perm} = 0.40 \cdot R_{eH} \quad [N/mm^2]$ for $R_{eH} = 235\ N/mm^2$

$\sigma_{d,perm} = 0.35 \cdot R_{eH} \quad [N/mm^2]$ for $R_{eH} = 355\ N/mm^2$

The aforementioned permissible stresses are approximate values. Deviations may be permitted in special cases taking into account fatigue strength aspects.

E.2 Vibration analysis

The bending natural frequency at rated speed of the system comprising stern tube, propeller shaft and propeller is not to be less than 1.5 times the rated propeller revolutions. However, it is not to exceed 0.66 times the exciting frequency of the propeller (number of propeller blades x rated propeller revolutions) and is not to coincide with service conditions, including the damage condition (loss of one propeller blade).

Section 14 Rudder and Manoeuvring Arrangement

A General

A.1 Application

A.1.1 Each ship is to be provided with a manoeuvring arrangement which will guarantee sufficient manoeuvring capability.

A.1.2 Rudder stock, rudder coupling, rudder bearings and the rudder body are dealt with in this Section.

A.2 References

A.2.1 Paragraphs of this section are based on the following international convention(s) and / or code(s):

IACS UR S10 Rev.3

At the end of each relevant paragraph, the corresponding paragraphs of the international convention(s) and / or code(s) are given in brackets.

A.2.2 For ice-strengthening see Section 15.

A.2.3 The steering gear is to comply with the GL Rules for Machinery Installation (I-1-2), Section 14.

A.3 Definitions

A : total movable area $[m^2]$ of the rudder, measured at the mid-plane of the rudder. For nozzle rudders, A is to be taken as 1.35 times the projected area of the nozzle.

A_1, A_2 : partial rudder areas $[m^2]$ according to Fig. 14.2

A_{1f}, A_{2f} : partial rudder areas $[m^2]$ according to Fig. 14.2

A_t : A + area $[m^2]$ of a rudder horn, if any

A_f : portion of rudder area $[m^2]$ located ahead of the rudder stock axis

b : mean height $[m]$ of rudder area

b_1, b_2 : mean heights $[m]$ of the partial rudder areas A_1 and A_2 according to Fig. 14.2

c_1, c_2 : mean breath $[m]$ of partial area A_1 and A_2, defined as:

$$c_1 = \frac{A_1}{b_1}$$

$$c_2 = \frac{A_2}{b_2}$$

c : mean breadth $[m]$ of rudder area, see Fig. 14.1

C_R : rudder force according to D.1.1

C_{R1}, C_{R2} : rudder forces related to partial rudder areas according to D.2.1

d_k : diameter $[mm]$ of the conical part of the rudder stock at the key

k : material factor according to Section 2, A.2

k_r : material factor according to C.2

Q_F : design yield moment $[Nm]$ of rudder stock according to H

Q_R : rudder torque according to D.1.2 or D.2.3 respectively

Q_{R1}, Q_{R2} : rudder torques related to partial rudder areas according to D.2.2

v_0 : ahead speed $[kn]$ of ship as defined in Section 1, A.3. When the speed is less than $10\ kn$, v_0 is replaced by the expression:

$$v_{min} = \frac{(v_0 + 20)}{3} \quad [kn]$$

v_a : astern speed $[kn]$ of ship; if the astern speed v_a is less than $0.4 \cdot v_0$ or $6\ kn$, whichever is less, determination of rudder force and torque for astern condition is not required. For greater astern speeds special evaluation of rudder force and torque as a function of the rudder angle may be required. If no limitations for the rudder angle at astern condition is stipulated, the factor κ_2 is not to be taken less than given in Table 14.1 for astern condition.

For ships strengthened for navigation in ice Section 15, B.7 is to be observed.

α : coefficient, defined as:

$\alpha = 0.33$ for ahead condition

$\alpha = 0.90$ for astern condition (general)

$\alpha = 0.75$ for astern condition (hollow profiles)

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

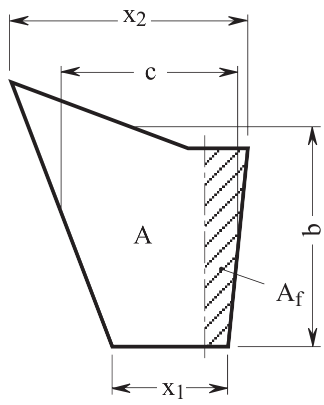
$\alpha = 0.25$ for ahead condition

$\alpha = 0.55$ for astern condition

For high lift rudders α is to be specially considered. If not known, $\alpha = 0.40$ may be used for the ahead condition

Λ : aspect ratio of rudder area A_t, defined as:

$$\Lambda = \frac{b^2}{A_t}$$



$$c = \frac{x_1 + x_2}{2} \qquad b = \frac{A}{c}$$

Fig. 14.1 Rudder area geometry

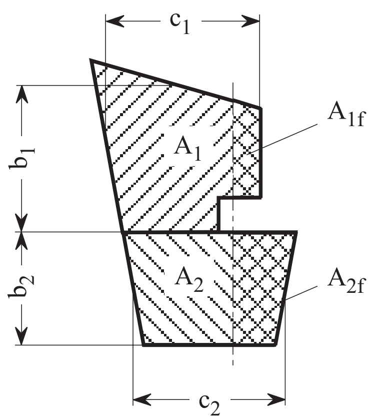


Fig. 14.2 Partial rudder areas A_1 and A_2

A.4 *Recommended size of rudder area*

In order to achieve sufficient manoeuvring capability the size of the movable rudder area A is recommended to be not less than obtained from the following formula:

$$A = c_1 \cdot c_2 \cdot c_3 \cdot c_4 \cdot \frac{1.75 \cdot \mathbf{L} \cdot \mathbf{T}}{100} \quad [m^2]$$

c_1 : *factor for the ship type, defined as:*

$c_1 = 1.0$	*in general*
$c_1 = 0.9$	*for bulk carriers and tankers having a displacement of more than 50 000 t*
$c_1 = 1.7$	*for tugs and trawlers*

c_2 : *factor for the rudder type, defined as:*

$c_2 = 1.0$	*in general*
$c_2 = 0.9$	*for semi-spade rudders*
$c_2 = 0.7$	*for high lift rudders*

c_3 : *factor for the rudder profile, defined as:*

$c_3 = 1.0$ *for NACA-profiles and plate rudder*

$c_3 = 0.8$ *for hollow profiles and mixed profiles*

c_4 : *factor for the rudder arrangement, defined as:*

$c_4 = 1.0$ *for rudders in the propeller jet*

$c_4 = 1.5$ *for rudders outside the propeller jet*

For semi-spade rudders 50 % of the projected area of the rudder horn may be included into the rudder area A.

Where more than one rudder is arranged the area of each rudder can be reduced by 20 %.

B Structural details

B.1 Effective means are to be provided for supporting the weight of the rudder body 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.

(IACS UR S10.1.2.1)

B.2 Suitable arrangements are to be provided to prevent the rudder from lifting.

(IACS UR S10.1.2.2)

B.3 The rudder stock is to be carried through the hull either enclosed in a watertight trunk, or glands are 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.

(IACS UR S10.1.2.3)

B.4 Connections of rudder blade structure with solid parts in forged or cast steel, which are used as rudder stock housing, are to be suitably designed to avoid any excessive stress concentration at these areas.

Note

The following measures are recommended in the GL Technical Publication, Paper No. 05-1 "Recommendations for Preventive Measures to Avoid or Minimize Rudder Cavitation", regarding:

- *Profile selection:*
  - *Use the appropriate profile shape and thickness.*
  - *Use profiles with a sufficiently small absolute value of pressure coefficient for moderate angles of attack (below 5 °). The pressure distribution around the profile should be possibly smooth. The maximum thickness of such profiles is usually located at more than 35 % behind the leading edge.*
  - *Use a large profile nose radius for rudders operating in propeller slips.*
  - *Computational Fluid Dynamic (CFD) analysis for rudder considering the propeller and ship wake can be used.*
- *Rudder sole cavitation:*
  - *Round out the leading edge curve at rudder sole.*
- *Propeller hub cavitation:*
  - *Fit a nacelle (body of revolution) to the rudder at the level of the propeller hub. This nacelle functions as an extension of the propeller hub.*

- *Cavitation at surface irregularities:*
  - *Grind and polish all welds.*
  - *Avoid changes of profile shape. Often rudders are built with local thickenings (bubbles) and dents to ease fitting of the rudder shaft. Maximum changes in profile shape should be kept to less than two percent of profile thickness.*
- *Gap cavitation:*
  - *Round out all edges of the part around the gap.*
  - *Gap size should be as small as possible.*
  - *Place gaps outside of the propeller slipstream.*

C Materials

C.1 For materials for rudder stock, pintles, coupling bolts etc. see Rules II – Materials and Welding, Part 1 – Metallic Materials. Special material requirements are to be observed for the ice class notations **E3** and **E4** as well as for the ice class notations **PC7** – **PC1**.

C.2 In general materials having a yield strength R_{eH} of less than $200\ N/mm^2$ and a tensile strength of less than $400\ N/mm^2$ or more than $900\ N/mm^2$ are not to be used for rudder stocks, pintles, keys and bolts.

The requirements of this Section are based on a material's yield strength R_{eH} of $235\ N/mm^2$. If material is used having a R_{eH} differing from $235\ N/mm^2$, the material factor k_r is to be determined by the following formula:

$$k_r = \left(\frac{235}{R_{eH}}\right)^{0.75} \qquad \text{for } R_{eH} > 235\ N/mm^2$$

$$k_r = \frac{235}{R_{eH}} \qquad \text{for } R_{eH} \le 235\ N/mm^2$$

R_{eH} : yield strength $[N/mm^2]$, with:

$$R_{eH} \le \min\left[0.7 \cdot R_m\ ;\ 450\right]$$

(IACS UR S10.1.3.1)

C.3 Before significant reductions in rudder stock diameter due to the application of steels with R_{eH} exceeding $235\ N/mm^2$ are accepted, GL may require the evaluation of the elastic rudder stock deflections. Large deflections should be avoided in order to avoid excessive edge pressures in way of bearings.

(IACS UR S10.1.3.2)

C.4 The permissible stresses given in G.1.3. are applicable for normal strength hull structural steel. When higher tensile steels are used, higher values may be used which will be fixed in each individual case.

(IACS UR S10.1.3.3)

D Rudder Force and Torque

D.1 Rudder force and torque for normal rudders

D.1.1 The rudder force C_R is to be determined by the following formula:

$$C_R = 132 \cdot A \cdot v^2 \cdot \kappa_1 \cdot \kappa_2 \cdot \kappa_3 \cdot \kappa_t \quad [N]$$

v : ship's speed $[kn]$, defined as:

$v = v_0$	for ahead condition
$v = v_a$	for astern condition

κ_1 : coefficient, depending on the aspect ratio Λ, defined as:

$\kappa_1 = (\Lambda + 2)/3$	where Λ need not be taken greater than 2

κ_2 : coefficient, depending on the type of the rudder and the rudder profile according to Table 14.1

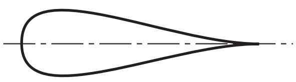
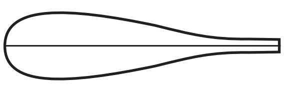
κ_3 : coefficient, depending on the location of the rudder, defined as:

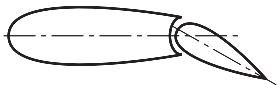
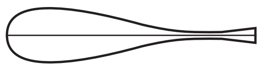
$\kappa_3 = 0.80$	for rudders outside the propeller jet
$\kappa_3 = 1.00$	elsewhere, including also rudders within the propeller jet
$\kappa_3 = 1.15$	for rudders aft of the propeller nozzle

κ_t : coefficient depending on the thrust coefficient C_{Th}; defined as:

$\kappa_t = 1.0$	normally
$\kappa_t = \dfrac{C_R(C_{Th})}{C_R(C_{Th} = 1.0)}$	in special cases for thrust coefficients $C_{Th} > 1.0$

Table 14.1 Coefficient κ_2

Profile / type of rudder	**κ_2**	
	ahead	**astern**
NACA-00 series Göttingen profiles 	1.1	0.8
flat side profiles 	1.1	0.9
mixed profiles 	1.21	0.9
hollow profiles 	1.35	0.9

high lift rudders 	1.70	to be specially considered; if not known: 1.2
fishtail profiles 	C_R : 1.35 Q_R : 1.70	1.2

(IACS UR S10.2.1.1)

D.1.2 The rudder torque Q_R is to be determined by the following formula:

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

r : lever, defined as:

$r = c \cdot (\alpha - k_b) \quad [\mathrm{m}]$ with $r \geq 0.1 \cdot c$ for ahead condition

k_b : balance factor, defined as:

$k_b = \dfrac{A_f}{A}$ for balanced rudders

$k_b = 0.08$ for unbalanced rudders

(IACS UR S10.2.1.2)

D.2 Rudder force and torque for rudder blades with cut-outs (semi-spade rudders)

D.2.1 The total rudder force C_R is to be calculated according to D.1.1. The pressure distribution over the rudder area, upon which the determination of rudder torque and rudder blade strength are 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. The resulting forces C_{R1} and C_{R2} of each part may be determined by the following formulae:

$$C_{R1} = C_R \cdot \frac{A_1}{A} \quad [\mathrm{N}]$$

$$C_{R2} = C_R \cdot \frac{A_2}{A} \quad [\mathrm{N}]$$

(IACS UR S10.2.2)

D.2.2 The resulting torques Q_{R1} and Q_{R2} related to the partial rudder area A_1 and A_2 may be determined by the following formulae:

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

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

r_1, r_2 : partial levers $[\mathrm{m}]$, defined as:

$$r_1 = c_1 \cdot (\alpha - k_{b1})$$

$$r_2 = c_2 \cdot (\alpha - k_{b2})$$

k_{b1}, k_{b2} : ratios, defined as:

$$k_{b1} = \frac{A_{1f}}{A_1}$$

$$k_{b2} = \frac{A_{2f}}{A_2}$$

(IACS UR S10.2.2)

D.2.3 The total rudder torque Q_R is to be determined by to the following formulae:

$$Q_R = Q_{R1} + Q_{R2} \quad [\mathrm{Nm}] \qquad \text{with } Q_R \geq Q_{R,min}$$

$Q_{R,min}$: minimum total rudder torque $[\mathrm{Nm}]$, defined as:

$$Q_{R,min} = C_R \cdot r_{1,2\,min}$$

$r_{1,2min}$: minimum total lever $[\mathrm{m}]$, defined as:

$$r_{1,2min} = \frac{0.1}{A} \cdot (c_1 \cdot A_1 + c_2 \cdot A_2) \qquad \text{for ahead condition}$$

(IACS UR S10.2.2)

E Scantlings of the Rudder Stock

E.1 Rudder stock diameter

E.1.1 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:

$$\tau_t = \frac{68}{k_r} \quad [\mathrm{N/mm^2}]$$

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

$$D_t = 4.2 \cdot \sqrt[3]{Q_R \cdot k_r} \quad [\mathrm{mm}]$$

(IACS UR S10.3)

E.1.2 In case of mechanical steering gear the diameter of the rudder stock in its upper part which is only intended for transmission of the torsional moment from the auxiliary steering gear may be $0.9\ D_t$. The length of the edge of the quadrangle for the auxiliary tiller is not to be less than $0.77\ D_t$ and the height not less than $0.8\ D_t$.

E.1.3 The rudder stock is to be secured against axial sliding. The degree of the permissible axial clearance depends on the construction of the steering engine and on the bearing.

E.2 Strengthening of rudder stock

E.2.1 If the rudder is so arranged that additional bending stresses occur in the rudder stock, the stock diameter has to be suitably increased. The increased diameter is, where applicable, decisive for the scantlings of the coupling.

For the increased rudder stock diameter the equivalent stress of bending and torsion is not to exceed the following value:

$$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} \leq \frac{118}{k_r} \quad [\mathrm{N/mm^2}]$$

σ_b : bending stress $[\mathrm{N/mm^2}]$, defined as:

$$\sigma_b = \frac{10.2 \cdot M_b}{D_l^3}$$

M_b : bending moment $[Nm]$ at the neck bearing

D_l : increased rudder stock diameter $[cm]$. The increased rudder stock diameter may be determined by the following formula:

$$D_l = 0.1 \cdot D_t \cdot \sqrt[6]{1 + \frac{4}{3} \cdot \left(\frac{M_b}{Q_R}\right)^2}$$

D_t : diameter of the rudder stock according to E.1.1

τ : torsional stress $[N / mm^2]$, defined as:

$$\tau = \frac{5.1 \cdot Q_R}{D_l^3}$$

(IACS UR S10.4.3)

Note

Where a double-piston steering gear is fitted, additional bending moments may be transmitted from the steering gear into the rudder stock. These additional bending moments are to be taken into account for determining the rudder stock diameter.

E.3 Analysis

E.3.1 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. 14.3 – Fig. 14.5 as outlined in E.3.2 – E.3.3.

(IACS UR S10 Annex 1.)

E.3.2 Data for the analysis

The load p_R on rudder body in general is to be determined by the following formula:

$$p_R = \frac{C_R}{\ell_{10} \cdot 10^3} \quad [kN / m]$$

For semi-spade rudders the loads p_{R10} and p_{R20}on rudder body are to be determined by the following formulae:

$$p_{R10} = \frac{C_{R2}}{\ell_{10} \cdot 10^3} \quad [kN / m]$$

$$p_{R20} = \frac{C_{R1}}{\ell_{20} \cdot 10^3} \quad [kN / m]$$

$\ell_{10} - \ell_{50}$: lengths $[m]$ of the individual girders of the system. 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.

$I_{10} - I_{50}$: moments of inertia $[cm^4]$ of the individual girders of the system. For rudders supported by a sole piece, I_{20} is the moment of inertia of the pintle in the sole piece.

Z : spring constant $[kN / m]$ of support in the sole piece or rudder horn respectively, defined as:

$$Z = \frac{6.18 \cdot I_{50}}{\ell_{50}^3}$$ for the support in the sole piece (Fig. 14.3)

$$Z=\frac{1}{f_b+f_t}$$ for the support in the rudder horn (Fig. 14.4)

f_b : unit displacement $[m/kN]$ of rudder horn due to a unit force of $1\ kN$ acting in the centre of support, defined as:

$$f_b=0.21\cdot\frac{d^3}{I_n}$$ as guidance value for steel

e, d : distances $[m]$ according to Fig. 14.4

I_n : moment of inertia $[cm^4]$ of rudder horn around the x-axis at $d/2$, (see also Fig. 14.4)

f_t : unit displacement $[m/kN]$ due to a torsional moment of the amount $1\cdot e$, defined as:

$$f_t=\frac{d\cdot e^2}{G\cdot J_t}$$ in general

$$f_t=\frac{d\cdot e^2\cdot\Sigma u_i/t_i}{3.17\cdot10^8\cdot F_T^2}$$ for steel

G : modulus of rigity $[kN/m^2]$, defined as:

$$G=7.92\cdot10^7$$ for steel

J_t : torsional moment of inertia $[m^4]$

u_i : breadth $[mm]$ of the individual plates forming the mean horn sectional area

t_i : plate thickness $[mm]$ within the individual breadth u_i

F_T : mean sectional area $[m^2]$ of rudder horn

(IACS UR S10 Annex 2.)

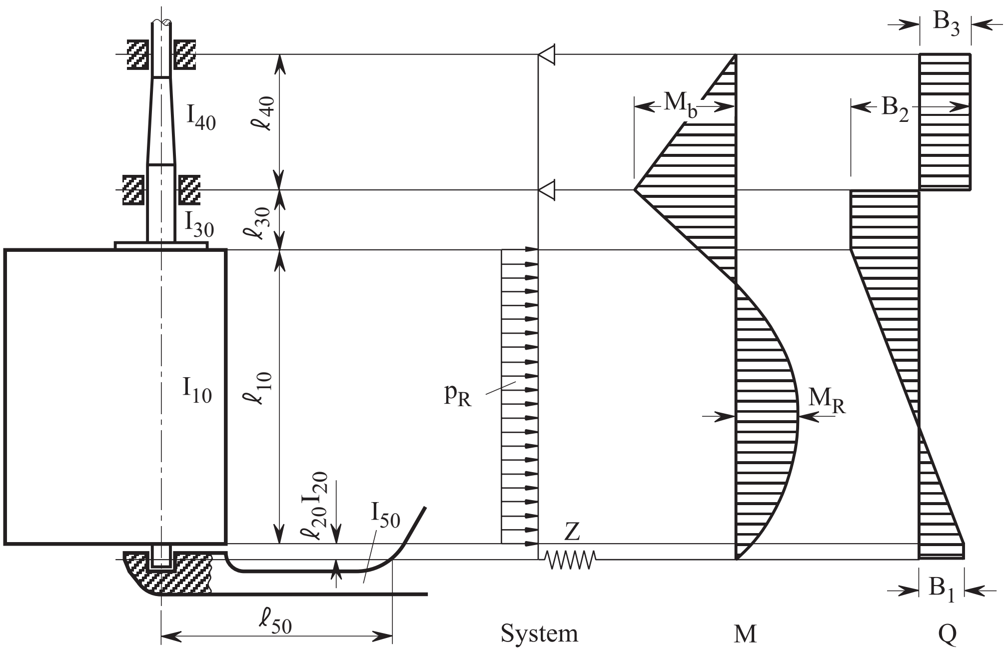


Fig. 14.3 Rudder supported by sole piece

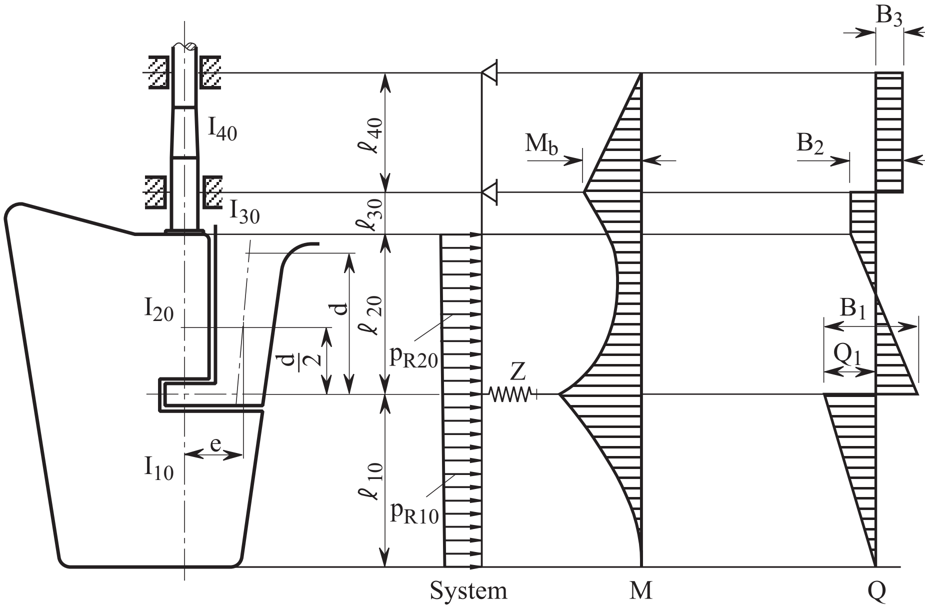


Fig. 14.4 Semi-spade rudder

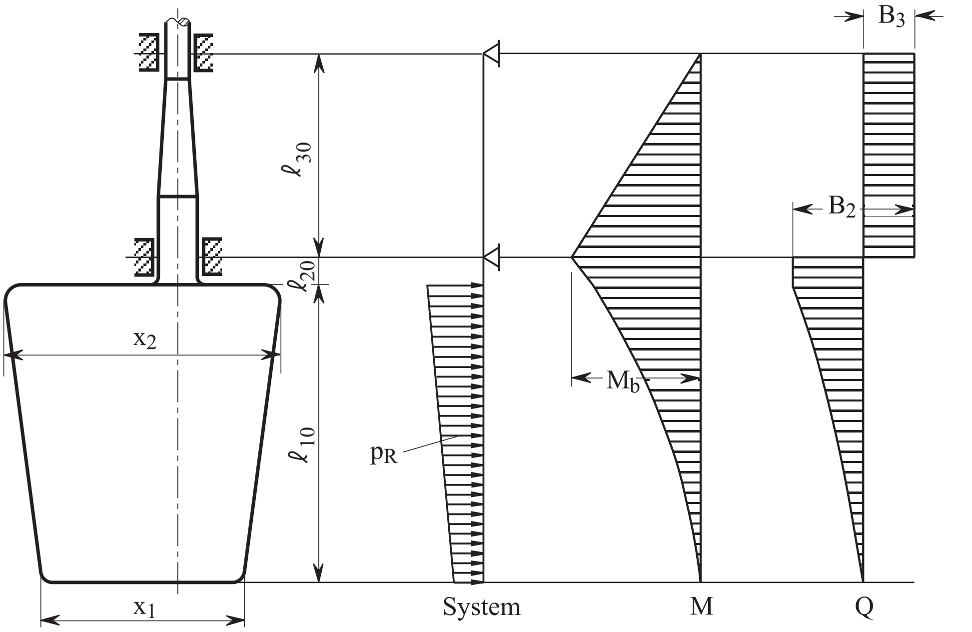


Fig. 14.5 Spade rudder

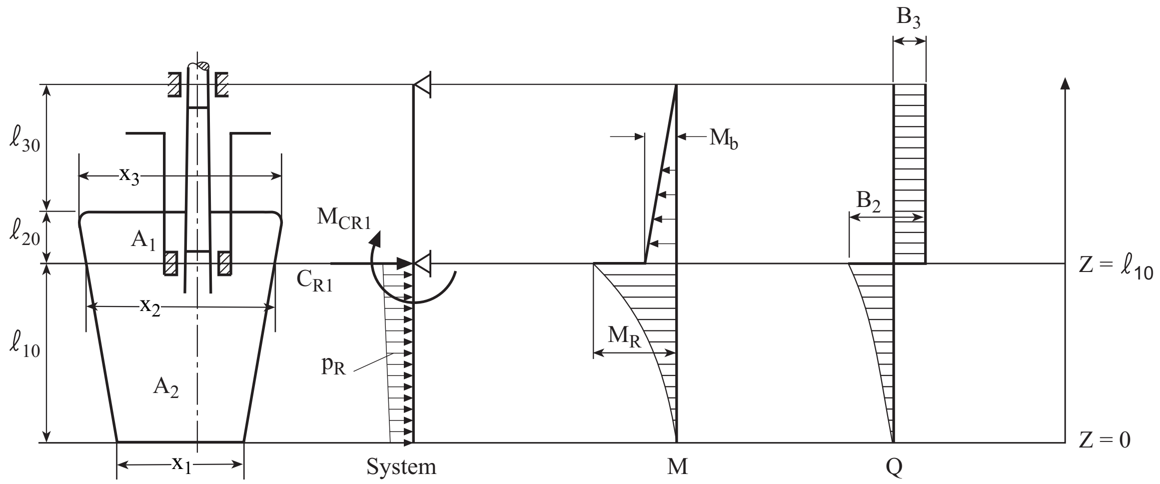


Fig. 14.6 Spade rudders with rudder trunks inside the rudder body

E.3.3 Moments and forces to be evaluated

E.3.3.1 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 E.2.1 and G.1 and by Section 13, C.3 and Section 13, C.4.

(IACS UR S10 Annex 3.)

E.3.3.2 For spade rudders (see Fig. 14.5) the moment M_b and forces B_2 and B_3 may be determined by the following formulae:

$$M_b = C_R \cdot \left(\ell_{20} + \frac{\ell_{10} \cdot (2 \cdot x_1 + x_2)}{3 \cdot (x_1 + x_2)} \right) \quad [\text{Nm}]$$

$$B_2 = C_R + B_3 \quad [\text{N}]$$

$$B_3 = \frac{M_b}{\ell_{30}} \quad [\text{N}]$$

$\ell_{10} - \ell_{30}$: lengths according to Fig. 14.5

x_1, x_2 : rudder breaths [m] according to Fig. 14.5

(IACS UR S10 Annex 4.)

E.3.3.3 For spade rudders with rudder trunks (see Fig. 14.6) the moment M_b and forces B_2 and B_3 may be determined by the following formulae:

$$M_{CR1} = C_{R1} \cdot \ell_{20} \cdot \left(1 - \frac{2 \cdot x_2 + x_3}{3 \cdot (x_2 + x_3)} \right) \quad [\text{Nm}]$$

$$M_{CR2} = C_{R2} \cdot \frac{\ell_{10} \cdot (2 \cdot x_1 + x_2)}{3 \cdot (x_1 + x_2)} \quad [\text{Nm}]$$

$$M_R = \max\left[M_{CR1} \, ; \, M_{CR2} \right]$$

$$M_b = M_{CR2} - M_{CR1} \quad [\text{Nm}]$$

$$B_3 = \frac{M_b}{\ell_{20} + \ell_{30}} \quad [\text{N}]$$

$$B_2 = C_R + B_3 \quad [N]$$

$\ell_{10} - \ell_{30}$: lengths according to Fig. 14.6

$x_1 - x_3$: rudder breaths $[m]$ according to Fig. 14.6

E.4 Rudder trunk

E.4.1 In case where the rudder stock is fitted with a rudder trunk welded in such a way the rudder trunk is loaded by the pressure induced on the rudder blade, as given in D.1.1, the bending stress σ_b in the rudder trunk, is to be in compliance with the following formula:

$$\sigma_b \leq \frac{80}{k} \quad [N/mm^2]$$

k : material factor as defined in Section 2, A.2, with:

$k \geq 0.7$

For the calculation of the bending stress, the span to be considered is the distance between the mid-height of the lower rudder stock bearing and the point where the trunk is clamped into the shell or the bottom of the skeg.

E.4.2 The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration.

Non destructive tests are to be conducted for all welds.

E.4.3 The minimum thickness of the shell or the bottom of the skeg is to be 0.4 times the wall thickness of the trunk at the connection.

The fillet shoulder radius is to be ground. The radius is to be as large as practicable but not less than 0.7 times the wall thickness of the trunk at the connection, if the wall thickness is greater than 50 mm. In case of smaller wall thickness, the radius is not to be less than 35 mm.

E.4.4 Alternatively a fatigue strength calculation based on the structural stress (hot spot stress) (see Section 20, A.2.6) can be carried out.

E.4.4.1 In case the rudder trunk is welded directly into the skeg bottom or shell, hot spot stress has to be determined acc. to Section 20, C.

In this case FAT class $\Delta\sigma_R = 100$ has to be used, see Section 20, C.3.

E.4.4.2 In case the trunk is fitted with a weld flange, the stresses have to be determined within the radius. FAT class $\Delta\sigma_R$ for the case E 2 or E 3 according to Section 20, Table 20.3 has to be used. In addition sufficient fatigue strength of the weld has to be verified e.g. by a calculation acc. to E.4.4.1.

Note

The radius may be obtained by grinding. If disc grinding is carried out, score marks are to be avoided in the direction of the weld.

The radius is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.

F Rudder Couplings

F.1 General

F.1.1 The couplings are to be designed in such a way as to enable them to transmit the full torque of the rudder stock.

F.1.2 The distance of the bolt axis from the edges of the flange is not to be less than 1.2 times the diameter of the bolt. In horizontal couplings, at least 2 bolts are to be arranged forward of the stock axis.

F.1.3 The coupling bolts are to be fitted bolts. The bolts and nuts are to be effectively secured against loosening.

F.1.4 For spade rudders horizontal couplings according to F.2 are permissible only where the required thickness of the coupling flanges t_f is less than 50 mm, otherwise cone couplings according to F.3 are to be applied. For spade rudders of the high lift type, only cone couplings according to F.3 are permitted.

F.1.5 If a cone coupling is used between the rudder stock or pintle, as the case can be, and the rudder blade or steering gear (see F.3), the contact area between the mating surfaces is to be demonstrated to the Surveyor by blue print test and should not be less than 70 % of the theoretical contact area (100 %). Non-contact areas should be distributed widely over the theoretical contact area. Concentrated areas of non-contact in the forward regions of the cone are especially to be avoided. The proof has to be demonstrated using the original components and the assembling of the components has to be done in due time to the creation of blue print to ensure the quality of the surfaces. In case of storing over a longer period, sufficient preservation of the surfaces is to be provided for.

If alternatively a male/female calibre system is used, the contact area between the mating surfaces is to be checked by blue print test and should not be less than 80 % of the theoretical contact area (100 %) and needs to be certified. After ten applications or five years the blue print proof has to be renewed.

F.2 Horizontal couplings

F.2.1 The diameter d_b of coupling bolts is not to be less than determined by the following formula:

$$d_b = 0.62 \cdot \sqrt{\frac{D^3 \cdot k_b}{k_r \cdot n \cdot e}} \quad [\text{mm}]$$

D : rudder stock diameter [mm] according to E

k_b : material factor for the bolts analogue to C.2

n : total number of bolts, which is not to be less than 6

e : mean distance [mm] of the bolt axes from the centre of bolt system

(IACS UR S10.6.1.1)

F.2.2 The thickness t_f of the coupling flanges is not to be less than determined by the following formula:

$$t_f = 0.62 \cdot \sqrt{\frac{D^3 \cdot k_f}{k_r \cdot n \cdot e}} \quad [\text{mm}] \qquad \text{with } t_f \geq t_{f,min}$$

D, n, e : parameters according to F.2.1

k_f : material factor for the coupling flanges analogue to C.2

$t_{f,min}$: minimum thickness [mm], defined as:

$$t_{f,min} = 0.9 \cdot d_b$$

The thickness of the coupling flanges clear of the bolt holes is not to be less than $0.65 \cdot t_f$.

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

(IACS UR S10.6.1.2)

F.2.3 The coupling flanges are to be equipped with a fitted key according to DIN 6885 or equivalent standard for relieving the bolts.

The fitted key may be dispensed with if the diameter of the bolts is increased by 10 %.

F.2.4 For the welded joint between the rudder stock and the flange see Section 19, B.4.4.

F.3 Cone couplings

F.3.1 Cone couplings with key

F.3.1.1 Cone couplings have to have a taper c on diameter of $1 : 8$ to $1 : 12$ and be secured by a slugging nut. The slugging nut itself is to be carefully secured, e.g. by a securing plate as shown in Fig. 14.7. The taper c is to be determined by the following formula:

$$c = \frac{d_0 - d_u}{\ell}$$

d_0, d_u : diameters according to Fig. 14.7

ℓ : coupling length according to Fig. 14.7; with:

$$\ell \geq 1.5 \cdot d_0$$

(IACS UR S10.6.2.1)

F.3.1.2 For couplings between stock and rudder a key is to be provided, the shear area a_s of which is not to be less than determined by the following formula:

$$a_s = \frac{16 \cdot Q_F}{d_k \cdot R_{eH,1}} \quad [\mathrm{cm}^2]$$

$R_{eH,1}$: yield strength $[\mathrm{N/mm}^2]$ of the key material

(IACS UR S10.6.2.1)

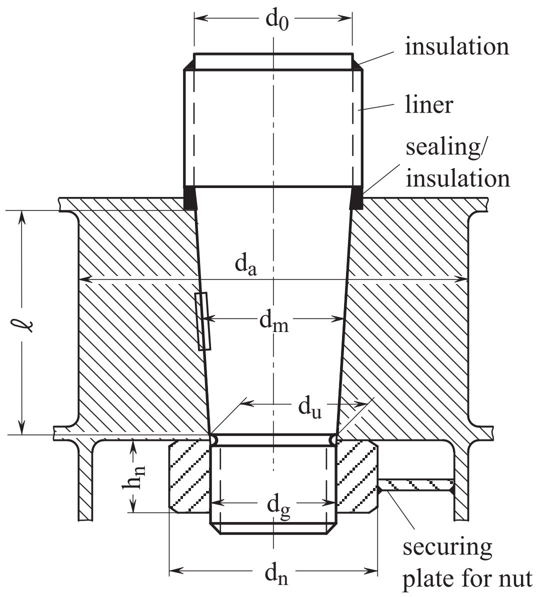


Fig. 14.7 Cone coupling with key and securing plate

F.3.1.3 The effective surface area a_k of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than determined by the following formula:

$$a_k = \frac{5 \cdot Q_F}{d_k \cdot R_{eH,2}} \quad [\mathrm{cm}^2]$$

$R_{eH,2}$: yield strength $[\mathrm{N/mm}^2]$ of the key, stock or coupling material, whichever is less.

F.3.1.4 The height h_n, outer diameter d_n and external thread diameter d_g of the slugging nut are to be at least as determined by the following formulae, see Fig. 14.7:

$$h_n = 0.60 \cdot d_g$$

$$d_n = \max\left[1.2 \cdot d_u \ ; 1.5 \cdot d_g\right]$$

$$d_g = 0.65 \cdot d_0$$

d_0, d_u : diameters according to Fig. 14.7

(IACS UR S10.6.2.2)

F.3.1.5 It is to be proved that 50 % of the design yield moment will be solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure and push-up length according to F.3.2.4 for a torsional moment $Q'_F = 0.5 \cdot Q_F$.

F.3.2 Cone couplings with special arrangements for mounting and dismounting the couplings

F.3.2.1 Where the stock diameter exceeds 200 mm the press fit is recommended to be effected by a hydraulic pressure connection. In such cases the cone is to be more slender, $c \approx 1 : 12$ to $\approx 1 : 20$.

(IACS UR S10.6.2.3)

F.3.2.2 In case of hydraulic pressure connections the nut is to be effectively secured against the rudder stock or the pintle. A securing plate for securing the nut against the rudder body is not to be provided, see Fig. 14.8.

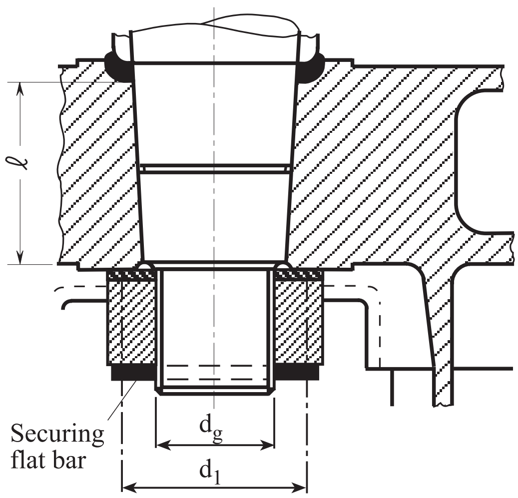


Fig. 14.8 Cone coupling without key and with securing flat bar

F.3.2.3 A securing flat bar will be regarded as an effective securing device of the nut, if its shear area A_s is not less than determined by the following formula:

$$A_s = \frac{P_s \cdot \sqrt{3}}{R_{eH}} \quad [\text{mm}^2]$$

P_s : shear force [N], defined as:

$$P_s = \frac{P_e}{2} \cdot \mu_1 \cdot \left(\frac{d_1}{d_g} - 0.6\right)$$

P_e : push-up force [N] as defined in F.3.2.4.2

μ_1 : frictional coefficient between nut and rudder body, with:

$\mu_1 = 0.3$ normally

d_1 : mean diameter of the frictional area between nut and rudder body, see Fig. 14.8

d_g : thread diameter of the nut

F.3.2.4 For the safe transmission of the torsional moment by the coupling between rudder stock and rudder body the push-up length and the push-up pressure are to be determined by the following formulae.

F.3.2.4.1 Push-up pressure

The push-up pressure p_{req} is not to be less than determined by the following formulae:

$$p_{req} = \max\left[p_{req,1}\ ;\ p_{req,2}\right]$$

$$p_{req,1} = \frac{2 \cdot Q_F}{d_m^2 \cdot \ell \cdot \pi \cdot \mu_0} \cdot 10^3 \quad [N/mm^2]$$

$$p_{req,2} = \frac{6 \cdot M_b}{\ell^2 \cdot d_m} \cdot 10^3 \quad [N/mm^2]$$

d_m : mean cone diameter $[mm]$

ℓ : cone length $[mm]$

μ_0 : frictional coefficient, defined as:

$\mu_1 \approx 0.3$

M_b : bending moment $[Nm]$ in the cone coupling (e.g. in case of spade rudders)

It has to be proved that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure is to be determined by the following formula:

$$p_{perm} = \frac{0.8 \cdot R_{eH} \cdot (1 - \alpha^2)}{\sqrt{3 + \alpha^4}}$$

R_{eH} : yield strength $[N/mm^2]$ of the material of the gudgeon

α : ratio of diameters, defined as:

$$\alpha = \frac{d_m}{d_a}$$

d_a : outer diameter $[mm]$ of the gudgeon, with:

$d_a \geq 1.5 \cdot d_m$

(IACS UR S10.6.2.3)

F.3.2.4.2 Push-up length

The push-up length $\Delta\ell$ is not to be less than determined by the following formula:

$$\Delta\ell = \min\left[\Delta\ell_1\ ;\ \Delta\ell_2\right]$$

$$\Delta\ell_1 = \frac{p_{req} \cdot d_m}{E \cdot \left(\frac{1 - \alpha^2}{2}\right) \cdot c} + \frac{0.8 \cdot R_{tm}}{c} \quad [mm]$$

$$\Delta\ell_2 = \frac{1.6 \cdot R_{eH} \cdot d_m}{\sqrt{3+\alpha^4} \cdot E \cdot c} + \frac{0.8 \cdot R_{tm}}{c}$$

p_{req} : push-up pressure according to F.3.2.4.1

d_m : mean cone diameter [mm]

R_{tm} : mean roughness [mm], with:

$$R_{tm} \approx 0.01$$

α : ratio of diameters according to F.3.2.4.1

c : taper on diameter according to F.3.2.1

(IACS UR S10.6.2.3)

Note

In case of hydraulic pressure connections the required push-up force P_e for the cone may be determined by the following formula:

$$P_e = p_{req} \cdot d_m \cdot \pi \cdot \ell \cdot \left(\frac{c}{2} + 0.02\right) \quad [N]$$

The value 0.02 is a reference for the friction coefficient using oil pressure. It varies and depends on the mechanical treatment and roughness of the details to be fixed.

Where due to the fitting procedure a partial push-up effect caused by the rudder weight is given, this may be taken into account when fixing the required push-up length, subject to approval by GL.

G Rudder Body, Rudder Bearings

G.1 Strength of rudder body

G.1.1 The rudder body is to be stiffened by horizontal and vertical webs in such a manner that the rudder body will be effective as a beam. The rudder is to be additionally stiffened at the aft edge.

(IACS UR S10.4.1)

G.1.2 The strength of the rudder body is to be proved by direct calculation considering loads according to E.3.

(IACS UR S10.4.2)

G.1.3 For rudder bodies without cut-outs the permissible stresses are not to exceed the following values:

$\sigma_b = 110\ N/mm^2$ for bending stresses due to M_R

$\tau = 50\ N/mm^2$ for shear stresses due to Q_1

$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} = 120\ N/mm^2$ for equivalent stresses due to bending and shear

M_R, Q_1 : moment and force according to E.3.3 and Fig. 14.3 and Fig. 14.4

(IACS UR S10.5.1(a))

G.1.4 In case of openings in the rudder plating for access to cone coupling or pintle nut the permissible stresses according to G.1.5 apply. Smaller permissible stress values may be required if the corner radii r_c are less than determined by the following formula:

$$r_c = 0.15 \cdot h_0$$

h_o : height of opening

G.1.5 In rudder bodies with cut-outs (semi-spade rudders) the following stress values are not to be exceeded:

$\sigma_b = 90 \text{ N/mm}^2$ for bending stresses due to M_R

$\tau = 50 \text{ N/mm}^2$ for shear stresses due to Q_1

$\tau_t = 50 \text{ N/mm}^2$ for torsional stresses due to M_t

$\sigma_{v1} = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} = 120 \text{ N/mm}^2$ for equivalent stresses due to bending and shear

$\sigma_{v2} = \sqrt{\sigma_b^2 + 3 \cdot \tau_t^2} = 100 \text{ N/mm}^2$ for equivalent stresses due to bending and torsion

M_R : bending moment [Nm], defined as:

$$M_R = C_{R2} \cdot f_1 + B_1 \cdot \frac{f_2}{2}$$

Q_1 : force [N], defined as:

$$Q_1 = C_{R2}$$

f_1, f_2 : distances [m] according to Fig. 14.9

(IACS UR S10.5.1(b))

As first approximation the torsional stress τ_t may be determined in a simplified manner by the following formula:

$$\tau_t = \frac{M_t}{2 \cdot \ell \cdot h \cdot t} \quad [\text{N/mm}^2]$$

M_t : torsional moment [Nm], defined as:

$$M_t = C_{R2} \cdot e$$

C_{R2} : partial rudder force [N] of the partial rudder area A_2 below the cross section under consideration

e : lever [m] for torsional moment. (horizontal distance between the centre of pressure of area A_2 and the centre line a-a of the effective cross sectional area under consideration, see Fig. 14.9. The centre of pressure is to be assumed at $0.33 \cdot c_2$ aft of the forward edge of area A_2, where c_2 = mean breadth of area A_2).

ℓ : distance [cm] between the vertical webs according to Fig. 14.9, with:

$$\ell_{max} = 1.2 \cdot h$$

h : breath [cm] of rudder half distance between the vertical webs according to Fig. 14.9

t : plate thickness [cm] according to Fig. 14.9

The radii in the rudder plating are not to be less than 4 – 5 times the plate thickness, but in no case less than 50 mm.

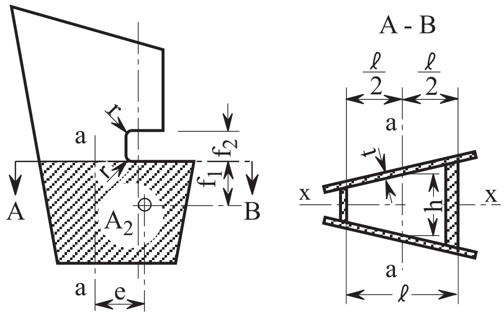


Fig. 14.9 Geometry of a semi-spade rudder

G.2 Rudder plating

G.2.1 The thickness t of the rudder plating is to be determined by the following formula:

$$t = 1.74 \cdot a \cdot \sqrt{p_R \cdot k} + 2.5 \quad [\mathrm{mm}] \qquad \text{with } t \geq t_{min}$$

a : the smaller unsupported width $[\mathrm{m}]$ of a plate panel

p_R : design pressure $[\mathrm{kN/mm^2}]$, defined as:

$$p_R = 10 \cdot \mathbf{T} + \frac{C_R}{10^3 \cdot A}$$

t_{min} : minimum thickness according to Section 6, B.2

The influence of the aspect ratio of the plate panels may be taken into account by the factor f_2 according to Section 3, B.2.2.

(IACS UR S10.5.2)

G.2.2 To avoid resonant vibration of single plate fields the frequency criterion as defined in Section 12, B.6.3 for shell structures applies analogously.

G.2.3 For rudder plating in way of coupling flanges see Section 19, B.4.4.1.

G.2.4 For connecting the side plating of the rudder to the webs tenon welding is not to be used. Where application of fillet welding is not practicable, the side plating is to be connected by means of slot welding to flat bars which are welded to the webs.

G.2.5 The thickness of the webs is not to be less than $70\,\%$ of the thickness of the rudder plating according to G.2.1, but not less than determined by the following formula:

$$t_{min} = 8 \cdot \sqrt{k} \quad [\mathrm{mm}]$$

Webs exposed to seawater are to be dimensioned according to G.2.1.

G.3 Transmitting of the rudder torque

G.3.1 For transmitting the rudder torque, the rudder plating according to G.2.1 is to be increased by $25\,\%$ in way of the coupling. A sufficient number of vertical webs is to be fitted in way of the coupling.

G.3.2 If the torque is transmitted by a prolonged shaft extended into the rudder, the latter is to have the diameter D_t or D_1, whichever is greater, at the upper $10\,\%$ of the intersection length. Downwards it may be tapered to $0.6\ D_t$, in spade rudders to 0.4 times the strengthened diameter, if sufficient support is provided for.

D_1 : increased rudder stock diameter according to E.2.1

D_t : diameter of the rudder stock according to E.1.1

G.4 Rudder bearings

G.4.1 In way of bearings liners and bushes are to be fitted. Their minimum thickness is to be less than:

$t_{min} = 8$ mm for metallic materials and synthetic material

Where in case of small ships bushes are not fitted, the rudder stock is to be suitably increased in diameter in way of bearings enabling the stock to be re-machined later.

G.4.2 An adequate lubrication is to be provided.

G.4.3 The bearing forces result from the direct calculation mentioned in E.3. As a first approximation the bearing force may be determined without taking account of the elastic supports. This can be done as follows:

- normal rudder with two supports:

  The rudder force C_R is to be distributed to the supports according to their vertical distances from the centre of gravity of the rudder area.

- semi-spade rudders:

$B_1 = C_R \cdot \frac{b}{c}$ [N] as support force in the rudder horn

$B_2 = C_R - B_1$ [N] as support force in the neck bearing

b, c : distances according to Section 13, Fig. 13.1

G.4.4 The projected bearing surface A_b (bearing height x external diameter of liner) is not to be less than determined by the following formula:

$$A_b = \frac{B_i}{q} \quad [mm^2]$$

B_i : support forces [N] B1 - B3 according to Fig. 14.3 to Fig. 14.6

q : permissible surface pressure according to Table 14.2

(IACS UR S10.8.1)

Table 14.2 Permissible surface pressure q

Bearing material	q [N / mm²]
white metal, oil lubricated	4.5
synthetic material [1]	5.5
steel [2], bronze and hot-pressed bronze-graphite materials	7.0

[1] Synthetic materials to be of approved type. Surface pressures exceeding $5.5\ N/mm^2$ may be accepted in accordance with bearing manufacturer's specification and tests, but in no case more than $10\ N/mm^2$.

[2] Stainless and wear resistant steel in an approved combination with stock liner. Higher surface pressures than $7\ N/mm^2$ may be accepted if verified by tests.

G.4.5 Stainless and wear resistant steels, bronze and hot-pressed bronze-graphit materials have a considerable difference in potential to non-alloyed steel. Respective preventive measures are required.

G.4.6 The bearing height is to be equal to the bearing diameter, however, is not to exceed 1.2 times the bearing diameter. Where the bearing depth is less than the bearing diameter, higher specific surface pressures may be allowed.

(IACS UR S10.8.2)

G.4.7 The wall thickness of pintle bearings in sole piece and rudder horn is to be approximately 1 / 4 of the pintle diameter.

G.5 Pintles

G.5.1 Pintles are to have scantlings complying with the conditions given in G.4.4 and G.4.6. The pintle diameter d is not to be less than determined by the following formula:

$$d = 0.35 \cdot \sqrt{B_1 \cdot k_r} \quad [mm]$$

B_1 : support force in the rudder horn according to G.4.3

(IACS UR S10.7.1)

G.5.2 The thickness t of any liner or bush is not to be less than determined by the following formula:

$$t = 0.01 \cdot \sqrt{B_1} \quad [mm] \qquad \text{with } t \geq t_{min}$$

B_1 : support force in the rudder horn according to G.4.3

t_{min} : minimum thickness of bearings liners and bushes according to G.4.1

G.5.3 Where pintles are of conical shape, their taper on diameter is to comply with the following:

1 : 8 to 1 : 12	if keyed by slugging nut
1 : 12 to 1 : 20	if mounted with oil injection and hydraulic nut

(IACS UR S10.7.1)

G.5.4 The required push-up pressure p_{req} for pintle bearings is to be determined by the following formula:

$$p_{req} = 0.4 \cdot \frac{B_1 \cdot d_0}{d_m^2 \cdot \ell} \quad [N / mm^2]$$

B_1 : support force in the rudder horn according to G.4.3

d_0 : pintle diameter [mm] according to Fig. 14.7

d_m : mean cone diameter [mm]

ℓ : cone length [mm]

G.5.5 The pintles are to be arranged in such a manner as to prevent unintentional loosening and falling out.

For nuts and threads the requirements of F.3.1.4 and F.3.2.2 apply accordingly.

(IACS UR S10.7.2)

G.6 Bearing clearances

G.6.1 For metallic bearing material the bearing clearance should not to be less than determined by the following formula:

$$\frac{d_b}{1\,000} + 1.0 \quad [mm]$$

d_b : inner diameter [mm] of bush

(IACS UR S10.8.3)

G.6.2 If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties.

(IACS UR S10.8.3)

G.6.3 The clearance is not to be taken less than 1.5 mm on diameter. In case of self lubricating bushes going down below this value can be agreed to on the basis of the manufacturer's specification.

(IACS UR S10.8.3)

H Design Yield Moment of Rudder Stock

The design yield moment Q_F of the rudder stock is to be determined by the following formula:

$$Q_F = 0.02664 \cdot \frac{D_t^3}{k_r} \quad [\mathrm{Nm}]$$

D_t : stock diameter [mm] according to E.1.1. Where the actual diameter D_{ta} is greater than the calculated diameter D_t, the diameter D_{ta} is to be used. However, D_{ta} need not be taken greater than $1.145 \cdot D_t$.

I Stopper, Locking Device

I.1 Stopper

The motions of quadrants or tillers are to be limited on either side by stoppers. The stoppers and their foundations connected to the ship's hull are to be of strong construction so that the yield strength of the applied materials is not exceeded at the design yield moment of the rudder stock.

I.2 Locking device

Each steering gear is to be provided with a locking device in order to keep the rudder fixed at any position. This device as well as the foundation in the ship's hull are to be of strong construction so that the yield strength of the applied materials is not exceeded at the design yield moment of the rudder stock as specified in H. Where the ship's speed exceeds 12 kn, the design yield moment need only be calculated for a stock diameter based on a speed $v_0 = 12$ kn.

I.3 Regarding stopper and locking device see also the GL Rules for Machinery Installations (I-1-2), Section 14.

J Propeller Nozzles

J.1 General

J.1.1 The following requirements are applicable to propeller nozzles having an inner diameter of up to 5 m. Nozzles with larger diameters will be specially considered.

J.1.2 Special attention is to be given to the support of fixed nozzles at the hull structure.

J.2 Design pressure

The design pressure p_d for propeller nozzles is to be determined by the following formula:

$$p_d = c \cdot p_{d0} \quad [kN/m^2]$$

c : factor, defined as:

$c = 1.00$	in zone 2 (propeller zone)
$c = 0.50$	in zones 1 and 3
$c = 0.35$	in zone 4

For zones $1 - 4$ see Fig. 14.10

p_{d0} : basic pressure $[N/mm^2]$, defined as:

$$p_{d0} = \varepsilon \cdot \frac{N}{A_p}$$

ε : factor, defined as:

$$\varepsilon = 0.21 - 2 \cdot 10^{-4} \cdot \frac{N}{A_p} \qquad \text{with } \varepsilon \geq 0.10$$

N : maximum shaft power $[kW]$

A_p : propeller disc area $[m^2]$, defined as:

$$A_p = D^2 \cdot \frac{\pi}{4}$$

D : propeller diameter $[m]$

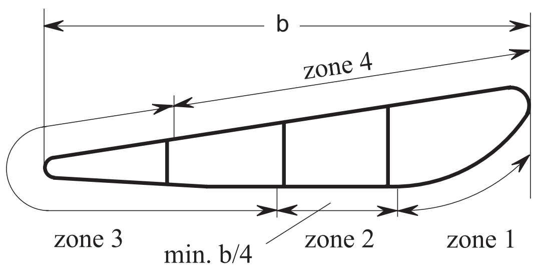


Fig. 14.10 Zones 1 to 4 of a propeller nozzle

J.3 Plate thickness

J.3.1 The thickness t of the nozzle shell plating is not to be less than determined by the following formula:

$$t = 5 \cdot a \cdot \sqrt{p_d} + t_K \quad [mm] \qquad \text{with } t \geq t_{min}$$

a : spacing $[m]$ of ring stiffeners

p_d : design pressure for propeller nozzles according to J.2

t_K : corrosion addition according to Section 3, G

t_{min} : minimum plate thickness $[mm]$, defined as:

$$t_{min} = 7.5$$

J.3.2 The web thickness of the internal stiffening rings is not be less than the nozzle plating for zone 3 (see Fig. 14.10), however, in no case be less than 7.5 mm.

J.4 Section modulus

The section modulus W of the cross section shown in Fig. 14.10 around its neutral axis is not to be less than determined by the following formula:

$$W = n \cdot d^2 \cdot b \cdot v_0^2 \quad [cm^3]$$

n : factor, defined as:

$n = 1.0$ for rudder nozzles

$n = 0.7$ for fixed nozzles

d : inner diameter $[m]$ of nozzle

b : length $[m]$ of nozzle

J.5 Welding

The inner and outer nozzle shell plating is to be welded to the internal stiffening rings as far as practicable by double continuous welds. Plug welding is only permissible for the outer nozzle plating.

K Devices for Improving Propulsion Efficiency

K.1 The operation of the ship and the safety of the hull, propeller and the rudder are not to be affected by damage, loss or removal of additional devices that improve the propulsion efficiency (e.g. spoilers, fins or ducts).

K.2 Documentation of strength and vibration analyses are to be submitted for devices of innovative design. In addition sufficient fatigue strength of the connection with the ship's structure has to be verified. The scantlings of the devices are to be in compliance with the required ice class, where applicable. The relevant load cases are to be agreed upon with GL.

L Fin Stabilizers

L.1 General

The hydrodynamic effects of fin stabilizers on the rolling behaviour of the ship are not part of the classification procedure. The classification however includes the integration of the system into the hull structure.

L.2 Integration into the hull structure

L.2.1 The complete bearing system and the drive unit directly mounted at the fin stock are to be located within an own watertight compartment at the ship's side or bottom of moderate size. For further details refer to the GL Rules for Machinery Installations (I-1-2), Section 14, H.

L.2.2 At the penetration of the fin stock and at the slot of retractable fins, the shell has to be strengthened in a sufficient way.

L.2.3 The watertight boundaries of the fin recess, if applicable and of the drive compartment have to be dimensioned according to Section 6. Special attention has to be given to the transmission of the fin support forces from the stock bearings into the ships structure.

Section 15 Strengthening for Navigation in Ice

A General

A.1 Ice class notations

A.1.1 The strengthenings for the various ice class notations are recommended for navigation under the following ice conditions:

Ice class notation	Ice conditions
E	Drift ice in mouths of rivers and coastal regions
E1 - E4	Ice conditions as in the Northern Baltic[1]

[1] See paragraph 1.1 of the Finnish-Swedish Ice Class Rules

A.1.2 Ships the ice-strengthening of which complies with the requirements of B. will have the notation **E1**, **E2**, **E3** or **E4** affixed to their Character of Classification.

A.1.3 The requirements for the ice class notations **E1** – **E4** embody all necessary conditions to be complied with for assignment of the ice classes **IC** – **IA Super** according to the Finnish-Swedish Ice Class Rules 2010 (23.11.2010 TRAFI / 31298 / 03.04.01.00 / 2010). Reference is also made to the Guidelines for the Application of the Finnish-Swedish Ice Class Rules (see 20.12.2011 TRAFI / 21816 / 03.04.01.01 / 2011). The ice class notations mentioned under 1.1 are equivalent to the Finnish-Swedish ice classes in the following way:

Ice class notation **E1** corresponds to ice class **IC**

Ice class notation **E2** corresponds to ice class **IB**

Ice class notation **E3** corresponds to ice class **IA**

Ice class notation **E4** corresponds to ice class **IA Super**

Note

*The Swedish Maritime Administration has provided ice class notations **IBV** and **ICV** for vessels navigating Lake Vänern ("Regulations and General Advice of the Swedish Maritime Administration on Swedish Ice Class for Traffic on Lake Vänern", SJÖFS 2003:16). The requirements for ice class notations **IBV** and **ICV** are the same as those for ice class notations **E2** and **E1**, respectively, except for the calculation of minimum propulsion machinery output, see A.3 When calculating the resistance of the vessel, the thickness of brash ice in mid channel, H_M, is to be taken as 0.65 m for ice class notation **IBV** and 0.50 m for ice class notation **ICV**. For vessels complying with the requirements for ice class notations **IBV** and **ICV**, a corresponding entry will be made in the Technical File to the Class Certificate.*

A.1.4 The ice class notations **E1** – **E4** can only be assigned to self-propelled ships when in addition to the requirements of this Section also the relevant GL Construction Rules for Machinery Installations (I-1-2), Section 13 are complied with. For example, the full Character of Classification then reads: **✠ 100A5 E1 MC E1**. Where the hull only is strengthened for a higher ice class notation, a corresponding entry will be made in the Technical File to the Class Certificate.

A.1.5 Ships the ice-strengthening of which complies with the requirements of C. will have the notation **E** affixed to their Character of Classification.

Upon request, the notation **E** may be assigned independently for hull or machinery.

A.1.6 Ships intended for navigation in polar waters may have the ice class notations **PC7 – PC1** affixed to their Character of Classification if the GL Guidelines for the Construction of Polar Class Ships (I-1-22) are complied with.

A.1.7 Ships which beyond the requirements for the ice class notations **E**, **E1** to **E4** or **PC7** to **PC1** have been specially designed, dimensioned and/or equipped for icebreaking will have affixed the notation **ICEBREAKER** in addition. Dimensioning of the structure with regard to the foreseen area of operation has to be harmonized with GL.

A.1.8 If the scantlings required by this Section are less than those required for ships without ice-strengthening, the scantlings required by the other Sections of these Rules are to be maintained.

A.2 Ice class draught for ships with notations E1 – E4

A.2.1 The upper ice waterline (UIWL) is to be the envelope of the highest points of the waterlines at which the ship is intended to operate in ice. The lower ice waterline (LIWL) is to be the envelope of the lowest points of the waterlines at which the ship is intended to operate in ice. Both the UIWL and LIWL may be broken lines.

A.2.2 The maximum and minimum ice class draughts at the forward perpendicular, amidships and at the aft perpendicular are to be determined in accordance with the upper/lower ice waterlines and are to be stated in the drawings submitted for approval. The ice class draughts, the minimum propulsion machinery output, P, according to A.3, as well as the corresponding ice class, will be stated in the Technical File to the Class Certificate.

If the summer load line in fresh water is anywhere located at a higher level than the UIWL, the ship's sides are to be provided with a warning triangle and with an ice class draught mark at the maximum permissible ice class draught amidships (see Annex B).

A.2.3 The draught and trim, limited by the UIWL, are not to be exceeded when the ship is navigating in ice. The salinity of the sea water along the intended route is to be taken into account when loading the ship.

The ship is always to be loaded down at least to the LIWL when navigating in ice. The LIWL is to be agreed upon with the owners. Any ballast tank adjacent to the side shell and situated above the LIWL, and needed to load the ship down to this waterline, is to be equipped with devices to prevent the water from freezing. In determining the LIWL, regard is to be paid to the need for ensuring a reasonable degree of ice-going capability in ballast. The propeller is to be fully submerged, entirely below the ice, if possible.

A.2.4 The minimum draught T_{min} at the forward perpendicular is not be less than determined by the following formula:

$$T_{min} = \max\left[T_{min,1} \; ; \; T_{min,2}\right]$$

$$T_{min,1} = h_0 \cdot (2 + 2.5 \cdot 10^{-4} \cdot D) \quad [m]$$

$$T_{min,2} = 4 \cdot h_0 \quad [m]$$

D : displacement [t] of the ship based on a horizontal waterline passing through the maximum ice class draught amidships

h_0 : design ice thickness according to B.2.1

A.3 Propulsion machinery output for ships with notations E1 – E4

A.3.1 The propulsion machinery output P in the context of this Section, is the total maximum output the propulsion machinery can continuously deliver to the propeller(s). If the output of the machinery is restricted by technical means or by any regulations applicable to the ship, P is to be taken as the restricted output.

A.3.2 The propulsion machinery output is not to be less than determined by the following formula:

$$P = K_e \cdot \frac{(R_{CH}/1000)^{3/2}}{D_P} \quad [kW] \qquad \text{with } P \geq P_{min}$$

The required propulsion machinery output, P, is to be calculated for ships on both the UIWL and the LIWL. The propulsion machinery output is not to be less than the greater of these two outputs.

P_{min} : required minimum propulsion machinery output [kW], defined as:

$P_{min} = 2\,800$ for ice class notation **E4**

$P_{min} = 1\,000$ for ice class notations **E1**, **E2** and **E3**

K_e : factor as defined in Table 15.2. The values in Table 15.2 apply only to conventional propulsion systems. Other methods may be used for determining the K_e values for advanced propulsion systems as specified in A.3.3.

Table 15.1 Factor K_e for the determination of minimum propulsion machinery output for ships of ice classes E3 and E4

Propeller type or machinery	K_e	
	CPP or electric or hydraulic propulsion machinery	FP propeller
1 propeller	2.03	2.26
2 propellers	1.44	1.60
3 propellers	1.18	1.31

D_P : diameter [m] of the propeller(s)

R_{CH} : resistance [N] of the ship in a channel due to brash ice and a consolidated layer:

$$R_{CH} = C_1 + C_2 + C_3 \cdot C_\mu \cdot (H_F + H_M)^2 \cdot (\mathbf{B} + C_\psi \cdot H_F) + C_4 \cdot L_{PAR} \cdot H_F^2 + C_5 \cdot \left(\frac{L_{pp} \cdot T}{\mathbf{B}^2}\right)^3 \cdot \frac{A_{wf}}{L_{pp}}$$

with $5 \leq \left(\frac{L_{pp} \cdot T}{\mathbf{B}^2}\right)^3 \leq 20$

C_1, C_2 : factors to take a consolidated upper layer of the brash ice into account, defined as:

$C_1 = 0$ for **E1 – E3**

$$C_1 = f_1 \cdot \frac{\mathbf{B} \cdot L_{PAR}}{2 \cdot \frac{T}{\mathbf{B}} + 1} + (1 + 0.021 \cdot \varphi_1) \cdot (f_2 \cdot \mathbf{B} + f_3 \cdot L_{BOW} + f_4 \cdot \mathbf{B} \cdot L_{BOW}) \quad \text{for } \mathbf{E4}$$

$C_2 = 0$ for **E1 – E3**

$$C_2 = (1 + 0.063 \cdot \varphi_1) \cdot (g_1 + g_2 \cdot \mathbf{B}) + g_3 \cdot \left(1 + 1.2 \cdot \frac{T}{\mathbf{B}}\right) \cdot \frac{\mathbf{B}^2}{\sqrt{L_{pp}}} \qquad \text{for } \mathbf{E4}$$

C_3, C_4, C_5 : factors, defined as:

$C_3 = 845 \quad kg/m^2/s^2$

$C_4 = 42 \quad kg/m^2/s^2$

$$C_5 = 825 \quad kg/s^2$$

C_μ, C_ψ : factors, defined as:

$$C_\mu = 0.15 \cdot \cos\varphi_2 + \sin\psi \cdot \sin\alpha \geq 0.45$$

$$C_\psi = 0.047 \cdot \psi - 2.115 \qquad \text{for } \psi > 45°$$

$$C_\psi = 0 \qquad \text{for } \psi \leq 45°$$

H_F : thickness [m] of the brash ice layer displaced by the bow, defined as:

$$H_F = 0.26 + \sqrt{H_M \cdot \mathbf{B}}$$

H_M : thickness [m] of the brash ice in mid channel, defined as:

$H_M = 1.0$ for ice class notations **E3** and **E4**

$H_M = 0.8$ for ice class notations **E2**

$H_M = 0.6$ for ice class notation **E1**

The ship parameters defined below are to be calculated on the UIWL using a horizontal waterline passing through the maximum ice class draught amidships, as defined in A.2.1, and on the LIWL using a horizontal waterline passing through the minimum ice class draught amidships, as defined in A.2.3. The ship dimensions L_{PP} and **B**, however, are always to be calculated on the UIWL. See also Fig. 15.1.

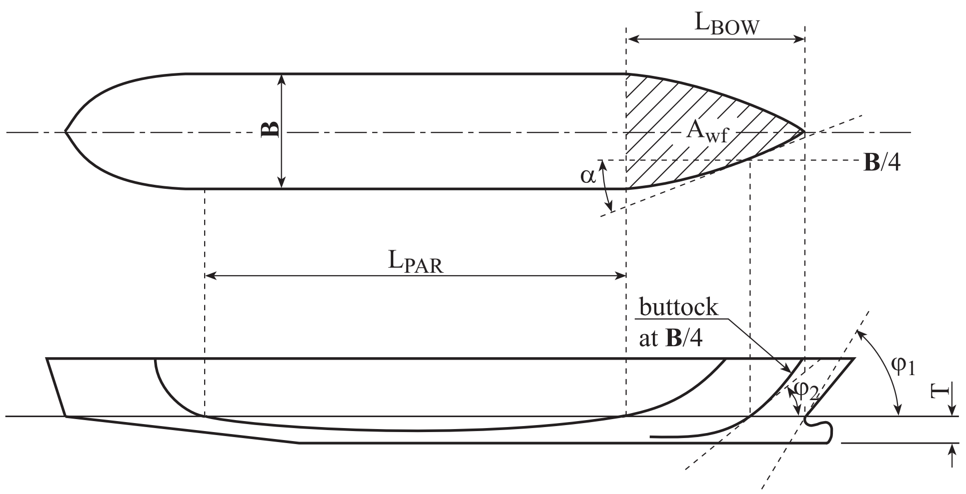


Fig. 15.1 Rake of the stem φ_1 and rake of the bow φ_2 at B/4 from CL

L_{PAR} : length [m] of the parallel midship body

L_{pp} : length [m] of the ship between perpendiculars

L_{BOW} : length [m] of the bow

T : maximum and minimum ice class draughts [m] amidship according to A.2.1 and A.2.3, respectively

A_{wf} : area [m^2] of the waterplane of the bow

φ_1 : rake [°] of the stem at the centreline. For a ship with a bulbous bow, φ_1 is to be taken as 90 °.

φ_2 : rake [°] of the bow at $\mathbf{B}/4, \varphi_{2max} = 90°$

α : angle [°] of the waterline at $\mathbf{B}/4$

ψ : angle [°], defined as:

$$\psi = \arctan \cdot \left(\frac{\tan\varphi_2}{\sin\alpha}\right)$$

f_1, f_2, f_3, f_4 : factors, defined as:

$$f_1 = 23 \text{ N} / \text{m}^2$$

$$f_2 = 45.8 \text{ N} / \text{m}$$

$$f_3 = 14.7 \text{ N} / \text{m}$$

$$f_4 = 29 \text{ N} / \text{m}^2$$

g_1, g_2, g_3 : factors, defined as:

$$g_1 = 1\,530 \text{ N}$$

$$g_2 = 170 \text{ N} / \text{m}$$

$$g_3 = 400 \text{ N} / \text{m}^{1.5}$$

Unless specially agreed with GL, ship's parameters are generally to be within the ranges of validity shown in Table 15.3 if the above formula for R_{CH} is to be used. Otherwise, alternative methods for determining R_{CH} are to be used as specified in A.3.3. When calculating the parameter D_P / T, T is to be measured on the UIWL amidships.

Table 15.2 Range of application of the formula for ship resistance R_{CH}

Parameter	Minimum	Maximum
α [°]	15	55
φ_1 [°]	25	90
φ_2 [°]	10	90
L_{pp} [m]	65.0	250.0
B [m]	11.0	40.0
T [m]	4.0	15.0
L_{BOW} / L_{pp}	0.15	0.40
L_{PAR} / L_{pp}	0.25	0.75
D_p / T	0.45	0.75
$A_{wf} / (L_{pp} \cdot B)$	0.09	0.27

A.3.3 For an individual ship, in lieu of the K_e or R_{CH} values defined in A.3.3, the use of K_e values based on more exact calculations or R_{CH} values based on model tests may be approved (see also paragraph 7.4 of the Guidelines for the Application of the Finnish-Swedish Ice Class Rules). The model test report is to be submitted to GL.

Such approvals will be given on the understanding that they can be revoked if warranted by the actual performance of the ship in ice.

The design requirement for ice classes is a minimum speed of 5 knots in the following brash ice channels:

- **E4**: $H_M = 1.0$ m and a 0.1 m thick consolidated layer of ice
- **E3**: $H_M = 1.0$ m
- **E2**: $H_M = 0.8$ m
- **E1**: $H_M = 0.6$ m

A.4 Definitions for ships with notations E1 – E4

A.4.1 Ice belt

A.4.1.1 The ice belt is the zone of the shell plating which is to be strengthened. The ice belt is divided into regions as follows, see Fig. 15.2:

A.4.1.1.1 Bow region

The region from the stem to a line parallel to and at the distance c aft of the borderline between the parallel midbody region and the fore ship:

- $c = 0.04 \cdot \mathbf{L}$, not exceeding 6 m for the ice class notations **E3** and **E4**, not exceeding 5 m for the ice class notations **E1** and **E2**
- $c = 0.02 \cdot \mathbf{L}$, not exceeding 2 m for the ice class notation **E**

A.4.1.1.2 Midbody region

The region from the aft boundary of the bow region, as defined in A.4.1.1.1 to a line parallel to and at the distance c aft of the borderline between the parallel midbody region and the aft ship.

A.4.1.1.3 Stern region

The region from the aft boundary of the midbody region, as defined in A.4.1.1.2 to the stern.

A.4.1.1.4 Forefoot region

(for ice class notation **E4** only)

The region below the ice belt from the stem to a position five main frame spaces abaft the point where the bow profile departs from the keel line.

A.4.1.1.5 Upper bow ice belt region

(for ice class notations **E3** and **E4** and with a speed $v_0 \geq 18$ kn only)

The region from the upper limit of the ice belt to 2 m above it and from the stem to a position 0.2 **L** abaft the forward perpendicular.

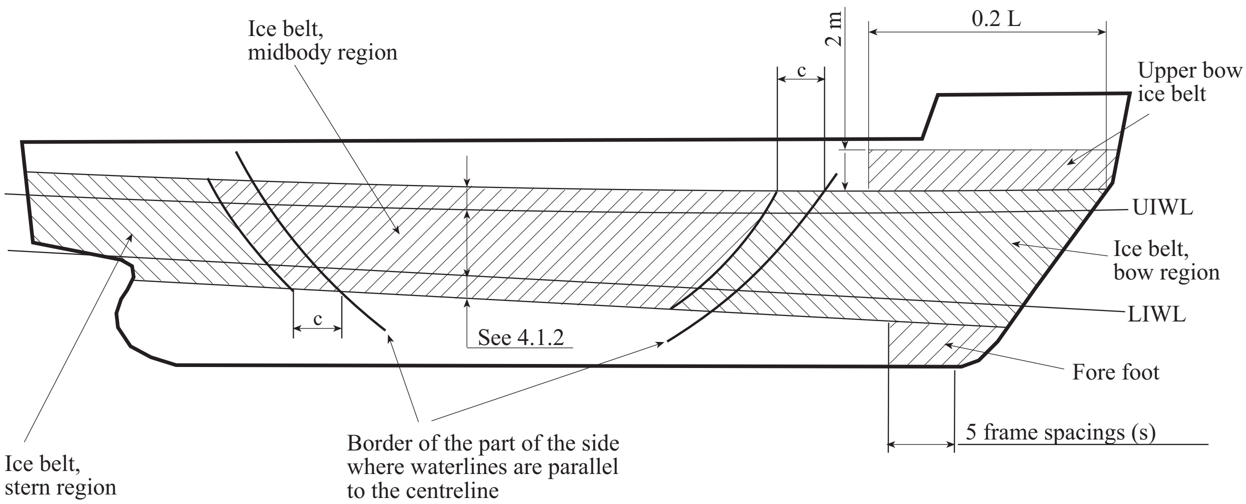


Fig. 15.2 Ice belt

A.4.1.2 The vertical extension of the bow, midbody and stern regions is to be determined from Table 15.4.

A.4.1.3 On the shell expansion plan submitted for approval, the location of the UIWL, LIWL and the upper/ lower limits of the ice belt, as well as the bow, midbody and stern regions (including forefoot and upper bow ice belt regions, if applicable), are to be clearly indicated.

A.4.1.4 The following terms are used in the formulae in B.:

$\mathbf{a}$: frame spacing [m], longitudinal or transverse, taking into account the intermediate frames, if fitted.

ℓ : unsupported span [m] of frames, web frames, stringer.

p : design ice pressure according to B.2.2

h : design height of ice pressure area [m] according to B.2.1

Table 15.3 Vertical extension of the bow, midbody and stern regions

Ice class notation	Hull region	Above UIWL [m]	Below LIWL [m]
E4	Bow	0.60	1.20
	Midbody		
	Stern		1.00
E3	Bow	0.50	0.90
	Midbody		0.75
	Stern		
E2, E1, E	Bow	0.40	0.70
	Midbody		0.60
	Stern		

The frame spacing and spans are normally to be measured in a vertical plane parallel to the centreline of the ship. However, if the ship's side deviates more than 20 ° from this plane, the frame spacing and spans are to be measured along the side of the ship.

B Requirements for the Notations E1 - E4

B.1 General

B.1.1 For transversely-framed plating, a typical ice load distribution is shown in Fig. 15.3. Due to differences in the flexural stiffness of frames and shell plating, maximum pressures (p_{max}) occur at the frames and minimum pressures occur between frames.

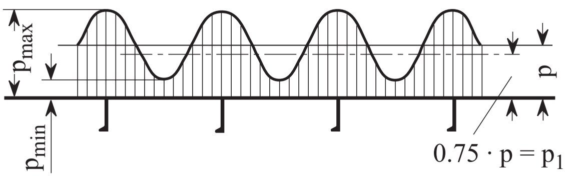


Fig. 15.3 Ice load distribution

Due to the finite height of the design ice load, h (see Table 15.5), the ice load distribution shown in Fig. 15.3 is not applicable for longitudinally-framed plating.

The formulae for determining the scantlings used in this Section are based on the following design loads:

$$p = \frac{1}{2} \cdot (p_{max} + p_{min}) \quad [N/mm^2]$$ for frames and longitudinally-framed shell plating

$$p_l = 0.75 \cdot p \quad [N/mm^2]$$ for transversely-framed shell plating

p : design ice pressure according to B.2.2

B.1.2 The formulae and values given in this Section may be substituted by direct calculation methods if they are deemed by GL to be invalid or inapplicable for a given structural arrangement or detail. Otherwise, direct analysis is not to be utilised as an alternative to the analytical procedures prescribed by the explicit requirements in B.3 (shell plating) and B.4 (frames, ice stringers, web frames).

Direct analyses are to be carried out using the load patch defined in B.2 (p, h and ℓ_a). The pressure to be used is $1.8 \cdot p$, where p is determined according to B.2.2. The load patch is to be applied at locations where the capacity of the structure under the combined effects of bending and shear are minimized. In particular, the structure is to be checked with the load centred on the UIWL, $0.5 \cdot h_0$ below the LIWL, and several vertical locations in between. Several horizontal locations are also to be checked, especially the locations centred at the mid-span or mid-spacing. Further, if the load length ℓ_a cannot be determined directly from the arrangement of the structure, several values of ℓ_a are to be checked using corresponding values for c_a.

The acceptance criterion for designs is that the combined stresses from bending and shear, using the von Mises yield criterion, are lower than the yield strength R_{eH}. When the direct calculation is performed using beam theory, the allowable shear stress is not to be greater than $0.9 \cdot \tau_y$, where $\tau_y = R_{eH} / \sqrt{3}$.

B.2 Ice loads

B.2.1 An ice-strengthened ship is assumed to operate in open sea conditions corresponding to a level ice thickness not exceeding h_0. The design ice load height, h, of the area actually under ice pressure is, however, assumed to be less than h_0. The values for h_0 and h are given in Table 15.5.

Table 15.4 Ice thickness h_0 and design ice load height h

Ice class notation	h_0 [m]	h [m]
E, E1	0.4	0.22
E2	0.6	0.25
E3	0.8	0.30
E4	1.0	0.35

B.2.2 The design ice pressure p is to be determined according to the following formula:

$$p = c_d \cdot c_1 \cdot c_a \cdot p_0 \quad [N/mm^2]$$

c_d : factor, defined as:

$$c_d = \frac{a \cdot k + b}{1\,000}$$ with $c_d \le 1.0$

k : factor, defined as:

$$k = \frac{\sqrt{D \cdot P}}{1\,000}$$

D : displacement [t] of the ship as defined in A.2.4

P : total maximum output [kW] the propulsion machinery can continuously deliver to the propeller(s), see also A.3.1. In case of ice class notation **E** the maximum output need not to be taken greater than 740 kW.

a, b : coefficients accordant to Table 15.6

c_1 : coefficient in accordance with Table 15.7

c_a : coefficient, defined as:

$$c_a = \sqrt{\frac{0{,}6}{\ell_a}} \qquad \text{with } 0.35 \le c_a \le 1.0$$

ℓ_a : effective length [m] as defined in Table 15.8

p_0 : nominal ice pressure [N / mm²], defined as:

$$p_0 = 5.6$$

Table 15.5 Coefficients a and b

Region	Bow		Midbody and Stern	
k	≤ 12	> 12	≤ 12	> 12
a	30	6	8	2
b	230	518	214	286

Table 15.6 Coefficient c_1

Ice class notation	Region		
	Bow	Midbody	Stern
E	0.3	-	-
E1	1.0	0.50	0.25
E2	1.0	0.70	0.45
E3	1.0	0.85	0.65
E4	1.0	1.00	0.75

Table 15.7 Effective length ℓ_a

Structure	Type of framing	ℓ_a
Shell	transverse	frame spacing
	longitudinal	1.7 x frame spacing
Frames	transverse	frame spacing
	longitudinal	span of frame
Ice stringer		span of stringer
Web frame		2 x web frame spacing

B.3 Thickness of shell plating in the ice belt

B.3.1 The thickness t of the shell plating is to be determined by the following formulae:

$$t = 667 \cdot \mathbf{a} \cdot \sqrt{\frac{f_1 \cdot p_1}{R_{eH}}} + t_c \quad [mm]$$ for transverse framing

$$t = 667 \cdot \mathbf{a} \cdot \sqrt{\frac{p}{f_2 \cdot R_{eH}}} + t_c \quad [mm]$$ for longitudinal framing

p, p_1 : design pressure according to in B.1.1 and B.2.2

f_1, f_2 : factors, defined as:

$$f_1 = 1.3 - \frac{4.2}{(1.8 + h/\mathbf{a})^2}$$ with $f_1 \le 1.0$

$$f_2 = 0.6 + \frac{0.4}{h/\mathbf{a}}$$ where $h/\mathbf{a} \le 1.0$

$$f_2 = 1.4 - \frac{0.4 \cdot h}{\mathbf{a}}$$ where $1.0 < h/\mathbf{a} \le 1.8$

t_c : allowance for abrasion and corrosion [mm]. Usually t_c amounts to 2 mm. If a special coating is applied and maintained, which by experience is shown to be capable of withstanding the abrasion of ice, the allowance may be reduced to 1 mm.

B.3.2 Where the draught is smaller than 1.5 m, e.g. in the ballast condition, or where the distance between the lower edge of the ice belt and the keel plate is smaller than 1.5 m, the thickness of the bottom plating in way of the bow region ice belt is not to be less than required for the ice belt. In the same area, the thickness of the plate floors is to be increased by 10 %.

B.3.3 Side scuttles are not to be situated in the ice belt. If the weather deck in any part of the ship is situated below the upper limit of the ice belt, see A.4.1.2 (e.g. in way of the well of a raised quarter decker), the bulwark is to have at least the same strength as is required for the shell in the ice belt. Special consideration has to be given to the design of the freeing ports.

B.3.4 For ships with the ice class notation **E4**, the forefoot region according to A.4.1.1.4 is to have at least the thickness of the midbody region.

B.3.5 For ships with the ice class notation **E3** or **E4**, and with a speed $v_0 \ge 18$ kn, the upper bow ice belt region according to A.4.1.1.4 is to have at least the thickness of the midbody region.

A similar strengthening of the bow region is also advisable for a ship with a lower service speed when it is evident that the ship will have a high bow wave, e.g. on the basis of model tests.

B.4 Frames, ice stringers, web frames

B.4.1 General

B.4.1.1 Within the ice-strengthened area, all frames are to be effectively attached to the supporting structures. Longitudinal frames are generally to be attached to supporting web frames and bulkheads by brackets. Brackets may be omitted with an appropriate increase in the section modulus of the frame (see B.4.3.1) and with the addition of heel stiffeners (heel stiffeners may be omitted on the basis of direct calculations, subject to approval by GL). Brackets and heel stiffeners are to have at least the same thickness as the web plate of the frame and the free edge has to be appropriately stiffened against buckling. When a transverse frame terminates at a stringer or deck, a bracket or similar construction is to be fitted. When a frame is running through the supporting structure, both sides of the web are to be connected to the structure by direct welding, collar plate or lug.

B.4.1.2 For the ice class notation **E4**, for the ice class notation **E3** within the bow and midbody regions, and for the ice class notations **E2** and **E1** within the bow region, the following applies:

B.4.1.2.1 Frames which are unsymmetrical, or having webs which are not perpendicular to the shell plating, or having an unsupported span ℓ greater than 4.0 m, are to be supported against tripping by brackets, intercostal plates, stringers or similar at a distance not exceeding 1 300 mm.

B.4.1.2.2 The frames are to be attached to the shell by double continuous welds. No scalloping is allowed except when crossing shell plate butt welds.

B.4.1.2.3 The web thickness t_W of the frames is not to be less than determined by the following formulae:

$$t_W = \max\left[t_{W1}\ ;\ t_{W2}\ ;\ t_{W3}\ ;\ t_{W4}\right]$$

$$t_{W1} = h_W \cdot \sqrt{R_{eH}} / C \quad [\mathrm{mm}]$$

$$t_{W2} = 25 \cdot \mathbf{a} \quad [\mathrm{mm}] \qquad \text{for transverse frames}$$

t_{W3} = half the thickness of the shell plating t [mm]

$$t_{W4} = 9\ \mathrm{mm}$$

h_W : web height [mm]

C : factor to take the section type into account, defined as:

$C = 805$ for profiles

$C = 282$ for flat bars

For the purpose of calculating the web thickness of frames, the yield strength R_{eH} of the plating is not be taken greater than that of the framing. The minimum web thickness of 9 mm is independent of the yield strength R_{eH}.

B.4.1.2.4 Where there is a deck, tank top (or tank bottom), bulkhead, web frame or stringer in lieu of a frame, its plate thickness is to be in accordance with A.4.1.2.3 above, to a depth corresponding to the height of adjacent frames. In the calculation of t_{W1}, h_W is to be taken as the height of adjacent frames and C is to be taken as 805.

B.4.1.3 For transverse framing above UIWL and below LIWL, as well as longitudinal framing below LIWL, the vertical extension of the ice-strengthened framing b_E is to be determined according to Table 15.9.

Where the vertical extension of ice-strengthened transverse framing b_E would extend beyond a deck or a tank top (or tank bottom) by not more than 250 mm, it may be terminated at that deck or tank top (or tank bottom).

Table 15.8 Vertical extension b_E of ice-strengthened framing

Ice class notation	Hull region	b_E Above UIWL [m]	b_E Below LIWL [m]
E4	Bow	1.2	Down to double bottom or below top of floors
	Midbody		2.0
	Stern		1.6
	Upper bow ice belt [1]	Up to top of ice belt	

E3, E2, E1	Bow	1.0	1.6
	Midbody		1.3
	Stern		1.0
	Upper bow ice belt [1]	Up to top of ice belt	
E		1.0	1.0
[1] If required according to A.4.1.1.5			

The boundary conditions referred to in Table 15.10 are those for the intermediate frames. Other boundary conditions for main frames and 'tweendeck frames are assumed to be covered by interaction between the frames. This influence is included in the m_0 values. The load centre of the ice load is taken at $\ell / 2$.

B.4.2 Transverse frames

B.4.2.1 The section modulus W of a main, 'tweendeck or intermediate transverse frame is to be determined according to the following formula:

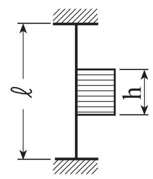
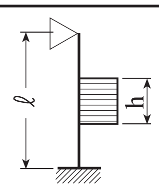
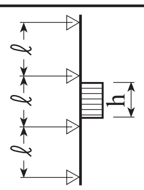
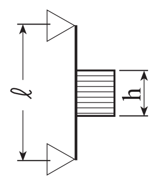
$$W = \frac{p \cdot \mathbf{a} \cdot h \cdot \ell}{m_t \cdot R_{eH}} \cdot 10^6 \quad [cm^3]$$

m_t : factor, defined as:

$$m_t = \frac{7 \cdot m_0}{7 - 5 \cdot \frac{h}{\ell}}$$

m_0 : coefficient according to Table 15.10

Table 15.9 Boundary conditions for transverse frames

Boundary condition	**m_0**	**Example**
	7	Frames in a bulk carrier with top wing tanks
	6	Frames extending from the tank top to a single deck
	5,7	Continuous frames between several decks or stringers
	5	Frames extending between two decks only

B.4.2.2 The effective shear area of a main, 'tweendeck or intermediate transverse frame is to be determined according to the following formula:

$$A = \frac{\sqrt{3} \cdot f_3 \cdot p \cdot h \cdot \mathbf{a}}{2 \cdot R_{eH}} \cdot 10^4 \quad [cm^2]$$

f_3 : factor which takes into account the maximum shear force versus the load location and shear stress distribution; defined as:

$f_3 = 1.2$

Where less than $15\ \%$ of the frame span ℓ, is situated within the ice-strengthened zone for frames as defined in B.4.1.3, ordinary frame scantlings may be used.

B.4.2.3 Upper end of transverse framing

A.1.1.1.1 The upper end of the ice-strengthened part of all frames is to be attached to a deck, tanktop (or tank bottom) or an ice stringer according to B.4.4.

A.1.1.1.2 Where a frame terminates above a deck or stringer, which is situated at or above the upper limit of the ice belt (see A.4.1.2), the part above the deck or stringer need not be ice-strengthened. In such cases, the upper part of the intermediate frames may be connected to the adjacent main or 'tweendeck frames by a horizontal member of the same scantlings as the main and 'tweendeck frames, respectively.

B.4.2.4 Lower end of transverse framing

A.1.1.1.3 The lower end of the ice-strengthened part of all frames is to be attached to a deck, inner bottom, tanktop (or tank bottom) or ice stringer according to B.4.4.

A.1.1.1.4 Where an intermediate frame terminates below a deck, tanktop (or tank bottom) or ice stringer which is situated at or below the lower limit of the ice belt (see A.4.1.2), its lower end may be connected to the adjacent main or 'tweendeck frames by a horizontal member of the same scantlings as the main and 'tweendeck frames, respectively.

B.4.3 Longitudinal frames

B.4.3.1 The section modulus W and the effective shear area A of longitudinal frames with all end conditions are to be determined according to the following formulae:

$$W = \frac{f_4 \cdot p \cdot h \cdot \ell^2}{m \cdot R_{eH}} \cdot 10^6 \quad [cm^3]$$

$$A = \frac{\sqrt{3} \cdot f_4 \cdot f_5 \cdot p \cdot h \cdot \ell}{2 \cdot R_{eH}} \cdot 10^4 \quad [cm^2]$$

The shear area of brackets is not to be taken into account when calculating the effective shear area of the frames.

f_4 : factor which accounts for the distribution of load to adjacent frames, defined as:

$f_4 = 1 - 0.2 \cdot h / \mathbf{a}$

f_5 : factor which takes into account the maximum shear force versus load location and the shear stress distribution; defined as:

$f_5 = 2.16$

m : factor to take boundary conditions into account, defined as:

$m = 13.3$	for a continuous beam with double end brackets
$m = 11.0$	for a continuous beam without double end brackets

Where the boundary conditions are considerably different from those of a continuous beam, e.g. in an end field, a smaller factor m may be determined

B.4.4 Ice stringers

B.4.4.1 Ice stringers within the ice belt

The section modulus W and the effective shear area I of a stringer situated within the ice belt are to be determined by the following formulae:

$$W = \frac{f_6 \cdot f_7 \cdot p \cdot h \cdot \ell^2}{m \cdot R_{eH}} \cdot 10^6 \quad [cm^3]$$

$$A = \frac{\sqrt{3} \cdot f_6 \cdot f_7 \cdot f_8 \cdot p \cdot h \cdot \ell}{2 \cdot R_{eH}} \cdot 10^4 \quad [cm^2]$$

In both formulae the term $p \cdot h$ is not to be taken less than 0.15.

m : factor to take boundary conditions into account, as defined in B.4.3

f_6 : factor which accounts for the distribution of load to the transverse frames; defined as:

$f_6 = 0.9$

f_7 : safety factor of stringers; defined as:

$f_6 = 1.8$

f_8 : factor which takes into account the maximum shear force versus load location and the shear stress distribution; defined as:

$f_6 = 1.2$

B.4.4.2 Ice stringers outside the ice belt

The section modulus W and the effective shear area I of a stringer situated outside the ice belt, but supporting frames subjected to ice pressure, are to be determined by the following formulae:

$$W = \frac{f_9 \cdot f_{10} \cdot p \cdot h \cdot \ell^2}{m \cdot R_{eH}} \cdot \left(1 - \frac{h_s}{\ell_s}\right) \cdot 10^6 \quad [cm^3]$$

$$A = \frac{\sqrt{3} \cdot f_9 \cdot f_{10} \cdot f_{11} \cdot p \cdot h \cdot \ell}{2 \cdot R_{eH}} \cdot \left(1 - \frac{h_s}{\ell_s}\right) \cdot 10^4 \quad [cm^2]$$

In both formulae the term $p \cdot h$ is not to be taken less than 0.15.

f_9 : factor which accounts for the distribution of load to the transverse frames; defined as:

$f_9 = 0.8$

f_{10} : safety factor of stringers; defined as:

$f_{10} = 1.8$

f_{11} : factor which takes into account the maximum shear force versus load location and the shear stress distribution; defined as:

$f_{11} = 1.2$

m : factor to take boundary conditions into account, as defined in B.4.3

h_s : distance $[m]$ of the stringer to the ice belt

ℓ_s : distance $[m]$ of the stringer to the adjacent ice stringer, deck or similar structure

B.4.4.3 Deck strips

A.1.1.1.5 Narrow deck strips abreast of hatches and serving as ice stringers are to comply with the section modulus and shear area requirements in B.4.4.1 and B.4.4.2, respectively. In the case of very long hatches, the product $p \cdot h$ may be taken less than 0.15 but in no case less than 0.10.

A.1.1.1.6 When designing weatherdeck hatchcovers and their fittings, the deflection of the ship's sides due to ice pressure in way of very long hatch openings (greater than $\mathbf{B}/2$) is to be considered.

B.4.5 Web frames

B.4.5.1 The ice load transferred to a web frame from a stringer or from longitudinal framing is to be calculated according to the following formula:

$$P = f_{12} \cdot p \cdot h \cdot e \cdot 10^3 \quad [\mathrm{kN}]$$

In the formula the term $p \cdot h$ is not to be taken less than 0.15.

e : web frame spacing $[\mathrm{m}]$

f_{12} : safety factor of web frame; defined as:
$f_{12} = 1.8$

In case the supported stringer is outside the ice belt, the load P may be multiplied by:

$$\left(1 - \frac{h_s}{\ell_s}\right)$$

h_s : distance $[\mathrm{m}]$ of the stringer to the ice belt

ℓ_s : distance $[\mathrm{m}]$ of the stringer to the adjacent ice stringer, deck or similar structure

B.4.5.2 Shear area and section modulus

The section modulus W and effective shear area I of web frames are to be determined by the following formulae:

$$W = \frac{M}{R_{eH}} \cdot \sqrt{\frac{1}{1 - \left[\gamma \cdot \frac{A}{A_a}\right]^2}} \cdot 10^3 \quad [\mathrm{cm}^3]$$

$$A = \frac{\sqrt{3} \cdot \alpha \cdot f_{13} \cdot Q}{R_{eH}} \cdot 10 \quad [\mathrm{cm}^2]$$

M : maximum calculated bending moment $[\mathrm{kNm}]$ under the ice load P, defined as:
$M = 0.193 \cdot P \cdot \ell$

P : ice load according to B.4.5.1

A_a : actual shear area, defined as:
$A_a = A_f + A_w$

γ : coefficient according to Table 15.11

α : coefficient according to Table 15.11

A_f : actual cross sectional area of free flange

A_w : actual effective cross sectional area of web plate

f_{13} : factor which takes into account the shear force distribution, defined as:
$f_{13} = 1.1$

Q : maximum calculated shear force $[\mathrm{kN}]$ under the ice load P, defined as:
$Q = P$

Table 15.10 Coefficients α and γ for the calculation of required shear area and section modulus

$\frac{A_f}{A_w}$	0.00	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
α	1.50	1.23	1.16	1.11	1.09	1.07	1.06	1.05	1.05	1.04	1.04
γ	0.00	0.44	0.62	0.71	0.76	0.80	0.83	0.85	0.87	0.88	0.89

B.5 Stem

B.5.1 The stem is to be made of rolled, cast or forged steel, or of shaped steel plates (see Fig. 15.4).

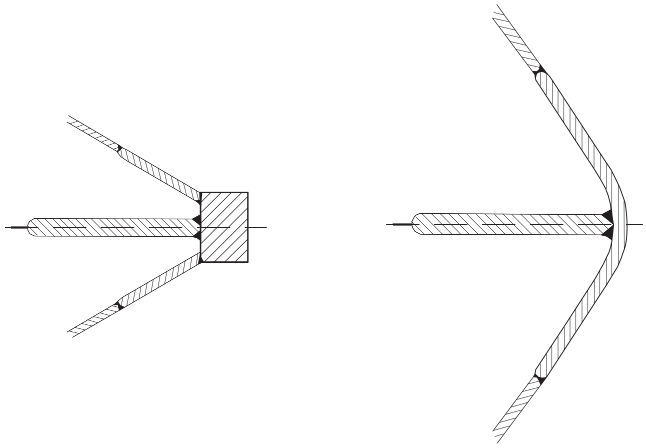


Fig. 15.4 Stem

B.5.2 The plate thickness of a shaped plate stem and, in the case of a blunt bow, any part of the shell where $\alpha \geq 30\,°$ and $\psi \geq 75\,°$ (see A.3.2 for definitions), is to be calculated according to the formulae in B.3.1 observing that:

p : design pressure according to in B.1.1 and B.2.2

p_1 : design pressure, defined as:

$$p_1 = p$$

$\mathbf{a}$: smaller of the two unsupported widths $[m]$ of the plate panel

ℓ_a : spacing $[m]$ of vertical supporting elements (see also Table 15.8)

B.5.3 The stem, and the part of a blunt bow defined in B.5.2 (if applicable), are to be supported by floors or brackets spaced not more than $0.6\ m$ apart and having a thickness of at least half the plate thickness according to B.5.2. The reinforcement of the stem is to extend from the keel to a point $0.75\ m$ above UIWL or, in case an upper bow ice belt is required (see also A.4.1.1), to the upper limit of the upper bow ice belt region.

B.6 Stern

B.6.1 Propulsion arrangements with azimuthing thrusters or "podded" propellers, which provide an improved manoeuvrability, result in increased ice loading of the stern region.

Due consideration is to be given to this increased ice loading in the design and dimensioning of the stern region and aft structure.

B.6.2 In order to avoid very high loads on propeller blade tips, the minimum distance between propeller(s) and hull (including stern frame) should not be less than h_0 (see B.2.1).

B.6.3 On twin and triple screw ships, the ice-strengthening of the shell and framing is to be extended to the double bottom to an extent of 1.5 m forward and aft of the side propellers.

B.6.4 Shafting and stern tubes of side propellers are generally to be enclosed within plated bossings. If detached struts are used, their design, strength and attachment to the hull are to be duly considered.

B.7 Rudder and steering gear

B.7.1 When calculating the rudder force and torsional moment according to Section 14, D.1 the ship's speed v_0 is not to be taken less than that given in Table 15.12.

All scantlings dimensioned according to the rudder force and the torsional moment respectively (rudder stock, rudder coupling, rudder horn etc.) as well as the capacity of the steering gear are to be increased accordingly where the speed stated in Table 15.12 exceeds the ship's service speed.

Independent of rudder profile the coefficient κ_2 according to Section 14, D.1.1 need not be taken greater than $\kappa_2 = 1.1$ in connection with the speed values given in Table 15.12.

Table 15.11 Minimum speed for the dimensioning of rudder

Ice class notation	v_0 [kn]
E1	14
E2	16
E3	18
E4	20

The factor κ_3 according to Section 14, D.1.1 need not be taken greater than 1.0 for rudders situated behind a nozzle.

B.7.2 The local scantlings of rudders are to be determined assuming that the whole rudder belongs to the ice belt (according to A.4.1). Further, the rudder plating and frames are to be designed using the ice pressure p for the plating and framing in the midbody region (see B.2.2). The thickness of webs is not to be less than half the rudder plating thickness.

B.7.3 For the ice class notations **E3** and **E4**, the rudder stock and the upper edge of the rudder are to be protected from direct contact with intact ice by an ice knife that extends below the LIWL, if practicable (or equivalent means). Special consideration is to be given to the design of the rudder and the ice knife for vessels with a flap-type rudder.

B.7.4 For ships with the ice class notations **E3** and **E4**, due regard is to be paid to the excessive loads arising when the rudder is forced out of the midship position while going astern in ice or into an ice ridge. Suitable arrangements such as rudder stoppers or locking devices (see Section 14, I.2) are to be installed to absorb these loads.

Note

For ships sailing in low temperature areas, small gaps between the rudder and ship's hull may cause the rudder to become fixed to the hull through freezing. It is therefore recommended to avoid gaps less than 1 / 20 of the rudder body width or 50 mm, whichever is less, or to install suitable means such as heating arrangements.

B.8 Lateral thruster grids

B.8.1 The following requirements apply in case ice-strengthening of lateral thruster grids is required (see GL Rules for Machinery Installations (I-1-2), Section 13, C.).

In general, lateral thruster tunnels are to be located outside the icebelt defined in A.4.1 by the bow, mid-body, and stern regions, as well as the forefoot region for ice class notation **E4**. Grids installed at the inlets of such tunnels may be subjected to loads arising from broken ice and are to be designed according to B.8.2 and B.8.3 below.

Any portion of the grid located within the icebelt may be subjected to loads arising from intact ice and is to be specially considered.

B.8.2 For a grid of standard construction, intercostal bars are to be fitted perpendicular to continuous bars (see Fig. 15.5). Continuous and intercostal bars are to be evenly spaced not more than $s_{c,max} = s_{i,max} = 500$ mm (minimum 2 x 2 bars).

The grid is not to protrude outside the surface of the hull and it is recommended to align continuous bars with the buttock lines at the leading edge of the thruster tunnel (see Fig. 15.5).

Grids of non-standard construction are to have an equivalent strength to that of the standard configuration described in B.8.3.

B.8.3 The section modulus W_c of continuous bars, is not to be less than determined by the following formula:

$$W_c = \frac{s_c \cdot D^2}{4 \cdot R_{eH}} \cdot (1 - \kappa) \cdot 10^{-4} \quad [\text{cm}^3] \qquad W_c \geq 35 \text{ cm}^3$$

s_c : spacing [mm] of continuous bars

D : diameter [mm] of thruster tunnel

κ : coefficient, defined as:

$$\kappa = 0.4 \cdot \frac{I_i}{I_c} \cdot \frac{s_c}{s_i} \qquad \kappa \leq 0.5$$

I_i/I_c : ratio of moments of inertia of intercostal and continuous bars

s_c/s_i : ratio of spacings of continuous and intercostal bars

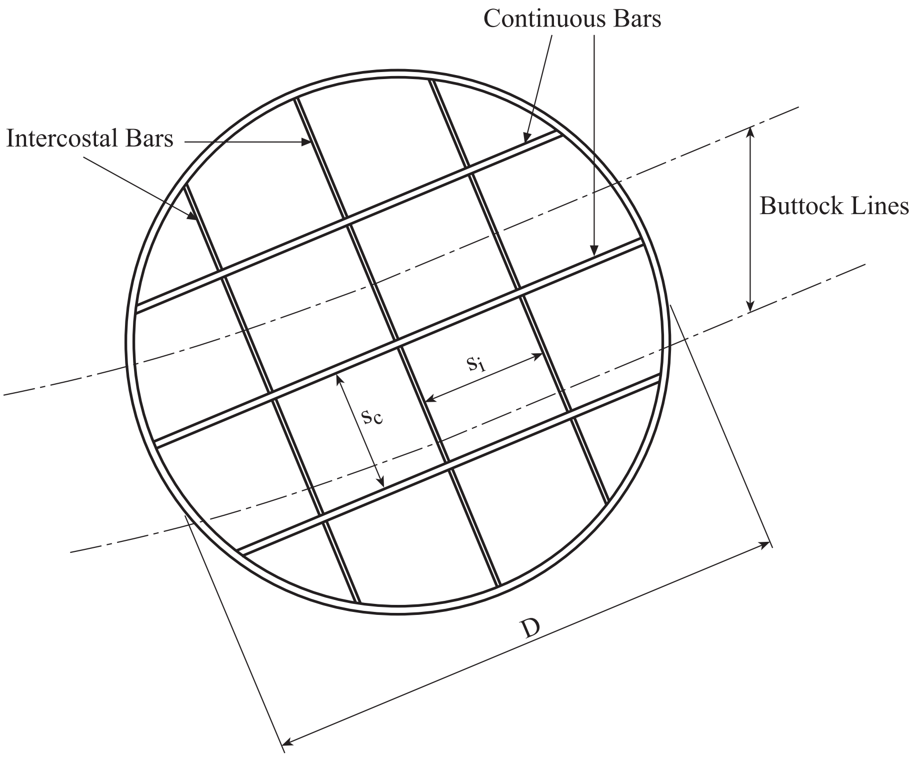


Fig. 15.5 Standard construction of lateral thruster grid

C Requirements for the Notation E

C.1 Shell plating within the ice belt

C.1.1 Within the ice belt the shell plating is to have a strengthened strake extending over the bow regionthe thickness of which is to be determined according to B.3.

C.1.2 The midship thickness of the side shell plating is to be maintained forward of amidships up to the strengthened plating.

C.2 Frames

C.2.1 In the bow region the section modulus of the frames is to comply with the requirements given in B.4.

C.2.2 Tripping brackets spaced not more than 1.3 m apart are to be fitted within the ice belt in line with the tiers of beams and stringers required in Section 9, B.5 in order to prevent tripping of the frames. The tripping brackets are to be extended over the bow region.

C.3 Stem

The thickness of welded plate stems up to 600 mm above UIWL is to be 1.1 times the thickness required according to Section 13, B.2, however, need not exceed 25 mm. The thickness above a point 600 mm above the UIWL may be gradually reduced to the thickness required according to Section 13, B.2.

Section 16 Superstructures and Deckhouses

A General

A.1 References

Paragraphs of this section are based on the following international convention(s) and / or code(s):

IACS UR S3 Rev.1

At the end of each relevant paragraph of this section, the corresponding paragraphs of the international convention(s) and / or code(s) are given in brackets.

Note

Concerning the use of non-magnetisable material in the wheel house in way of a magnetic compass, the requirements of the national Administration concerned are to be observed.

A.2 Definitions

Superstructures

A superstructure is a decked structure on the freeboard deck extending from side to side of the ship or with the side plating not being inboard of the shell plating more than $0.04\,\mathbf{B}$.

Superstructures extending into the range of $0.4\,\mathbf{L}$ amidships and the length of which exceeds $0.15\,\mathbf{L}$ are defined as effective superstructures.

All superstructures being located beyond $0.4\,\mathbf{L}$ amidships or having a length of less than $0.15\,\mathbf{L}$ or less than 12 m are, for the purpose of this Section, considered as non-effective superstructures.

Deckhouse

A deckhouse is a decked structure above the strength deck the side plating being inboard of the shell plating more than $0.04\,\mathbf{B}$.

A long deckhouse is a deckhouse the length of which within $0.4\,\mathbf{L}$ amidships exceeds $0.2\,\mathbf{L}$ or 12 m, where the greater value is decisive. The strength of a long deckhouse is to be specially considered.

A short deckhouse is a deckhouse not covered by the definition above.

Symbols

a : spacing [m] of stiffeners

g : gravity [m / s^2], defined as:

$$g = 9.81$$

G : mass [t] of the fully equipped deckhouse

k : material factor according to Section 2, A.2

ℓ : unsupported span [m]; for superstructure end bulkheads and deckhouse walls, ℓ is to be taken as the superstructure height or deckhouse height respectively, however, not less than 2.0 m.

L_{200} : corresponds to the length of the ship as L, but L_{200} is not to be taken greater than 200 m

L_{300} : corresponds to the length of the ship as L, but L_{300} is not to be taken greater than 300 m

p_A : load on superstructure end bulkheads and deckhouse walls according to Section 4, B.8

p_{BW} : load on breakwaters and whalebacks according to Section 4, B.9

p_S : load on ship's sides according to Section 4, B.2

p_E : load stern structures according to Section 4, B.4

p_D : external load on weather decks according to Section 4, B.1

p_{DA} : load on decks of superstructures and deckhouses according to Section 4, B.7

p_L : load on cargo decks according to Section 4, C.1

t_K : corrosion according to Section 3, G

B Strengthenings at the ends of superstructures and deckhouses

B.1 At the ends of superstructures and deckhouses one or both end bulkheads of which are located within 0.4 **L** amidships, the thickness of the sheer strake, the strength deck in a breadth of 0.1 **B** from the shell, as well as the thickness of the superstructure and deckhouse side plating are to be strengthened as specified in Table 16.1. The strengthenings are to extend over a region from 4 frame spacings abaft the end bulkhead to 4 frame spacings forward of the end bulkhead.

Table 16.1 Strengthening [%] at the ends of superstructures

Type of superstructure	strength deck and sheer strake	side plating of superstructure
effective superstructure	30	20
non-effective superstructure	20	10

B.2 Under strength decks in way of 0.6 **L** amidships, girders are to be fitted in alignment with longitudinal walls, which are to extend at least over three frame spacings beyond the end points of the longitudinal walls. The girders are to overlap with the longitudinal walls by at least two frame spacings.

C Transverse structure of superstructures and deckhouses

The transverse structure of superstructures and deckhouses is to be sufficiently dimensioned by a suitable arrangement of end bulkheads, web frames, steel walls of cabins and casings, or by other measures.

D Side Plating and Decks of Superstructures

D.1 Side plating and decks of effective superstructures

The side plating is to be treated as shell plating and their deck as strength deck (see Section 6, C and Section 7, B).

D.2 Side plating and decks of non-effective superstructures

D.2.1 Side plating

D.2.1.1 The thickness t of the side plating above the strength deck is not to be less than determined by the following formula:

$$t = 1.21 \cdot \mathbf{a} \cdot \sqrt{p \cdot k} + t_K \quad [\mathrm{mm}] \qquad \text{with } t \geq 0.8 \cdot t_{min}$$

p : design pressure $[\mathrm{kN/m^2}]$, defined as:

$p = p_S$ or p_E as the case may beapplicable

t_{min} : minimum thickness of the side plating according to Section 6, B.2

D.2.1.2 The thickness t of the side plating of upper tier superstructures may be reduced if the stress level permits such reduction.

D.2.2 Deck plating

D.2.2.1 The thickness t of deck plating is not to be less than determined by the following formula:

$$t = C \cdot \mathbf{a} \cdot \sqrt{p \cdot k} + t_K \quad [\mathrm{mm}] \qquad \text{with } t \geq t_{min}$$

C : coefficient, defined as:

$C = 1.21$ if $p = p_{DA}$

$C = 1.10$ if $p = p_L$

p : design pressure $[\mathrm{kN/m^2}]$, defined as:

$p = \max\left[p_{DA}\ ;\ p_L\right]$

t_{min} : minimum thickness $[\mathrm{mm}]$, defined as:

$$t_{min} = \left(5.5 + 0.02 \cdot \mathbf{L}_{200}\right) \cdot \sqrt{k}$$

D.2.2.2 Where additional superstructures are arranged on non-effective superstructures located on the strength deck, the thickness required by D.2.2.1 may be reduced by $10\ \%$.

D.2.2.3 Where plated decks are protected by sheathing, the thickness of the deck plating according to D.2.2.1 and D.2.2.2 may be reduced by t_K, however, it is not to be less than $5\ \mathrm{mm}$.

Where a sheathing other than wood is used, attention is to be paid that the sheathing does not affect the steel. The sheathing is to be effectively fitted to the deck.

D.2.3 Deck beams, supporting deck structure, frames

D.2.3.1 The scantlings of the deck beams and the supporting deck structure are to be determined in accordance with Section 10.

D.2.3.2 The scantlings of superstructure frames are given in Section 9, B.3.

E Superstructure End Bulkheads and Deckhouse Walls

E.1 General

The following requirements apply to superstructure end bulkheads and deckhouse walls forming the only protection for openings as per Regulation 18 of **ICLL** and for accommodations.

(IACS UR S.3.1)

E.2 Scantlings

E.2.1 Plate thickness

The thickness t of the plating is to be determined by the following formula:

$$t = 0.9 \cdot a \cdot \sqrt{p_A \cdot k} + t_K \quad [\mathrm{mm}]$$ with $t \geq t_{min}$

t_{min} : minimum thickness $[\mathrm{mm}]$, defined as:

$$t_{min} = \left(5.0 + \frac{\mathbf{L}_{300}}{100}\right) \cdot \sqrt{k}$$ for the lowest tier

$$t_{min} = \left(4.0 + \frac{\mathbf{L}_{300}}{100}\right) \cdot \sqrt{k} \geq 5.0$$ for the upper tiers

(IACS UR S.3.4)

E.2.2 Stiffeners

The section modulus W of the stiffeners is to be determined by the following formula:

$$W = 0.35 \cdot a \cdot \ell^2 \cdot p_A \cdot k \quad [\mathrm{cm}^3]$$

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

The section modulus of house side stiffeners needs not to be greater than that of side frames on the deck situated directly below; if their spacing a and unsupported span ℓ are equal.

(IACS UR S.3.3)

F Decks of Short Deckhouses

F.1 Plating

The thickness t of deck plating exposed to weather but not protected by sheathing is not to be less than determined by the following formula:

$$t = 8 \cdot a \cdot \sqrt{k} + t_K \quad [\mathrm{mm}]$$ with $t \geq t_{min}$

t_{min} : minimum thickness $[\mathrm{mm}]$, defined as:

$$t_{min} = 5.0$$

For weather decks protected by sheathing and for decks within deckhouses the thickness may be reduced by t_K. However, in no case the thickness is to be less than the minimum thickness $t_{min} = 5.0\ \mathrm{mm}$.

F.2 Deck beams

The deck beams and the supporting deck structure are to be determined according to Section 10.

G Elastic Mounting of Deckhouses

G.1 General

G.1.1 The elastic mountings are to be type approved by GL. The stresses acting in the mountings which have been determined by calculation are to be proved by means of prototype testing on testing machines. Determination of the grade of insulation for transmission of vibrations between hull and deckhouses is not part of this type approval.

G.1.2 The height of the mounting system is to be such that the space between deck and deckhouse bottom remains accessible for repair, maintenance and inspection purposes. The height of this space is normally not to be less than 600 mm.

G.1.3 For the fixed part of the deckhouse on the weather deck, a coaming height of 380 mm is to be observed, as required by **ICLL** for coamings of doors in superstructures which do not have access openings to under deck spaces.

G.1.4 For pipelines, see the GL Rules for Machinery Installations (I-1-2), Section 11.

G.1.5 Electric cables are to be fitted in bends in order to facilitate the movement. The minimum bending radius prescribed for the respective cable is to be observed. Cable glands are to be watertight. For further details, see the GL Rules for Electrical Installations (I-1-3).

G.1.6 The following scantling requirements for rails, mountings, securing devices, stoppers and substructures in the hull and the deckhouse bottom apply to ships in unrestricted service. For special ships and for ships intended to operate in restricted service ranges requirements differing from those given below may be applied.

G.2 Design loads

G.2.1 Weight induced loads

G.2.1.1 The weight induced loads result from the weight of the fully equipped deckhouse, considering also the acceleration due to gravity and the acceleration due to the ship's movement in the seaway. The weight induced loads are to be assumed to act in the centre of gravity of the deckhouse.

Due to the accelerations a_φ and a_ϕ the following load P and its components P_x, P_y and P_z are to be determined by the following formulae:

$$P = G \cdot a_\varphi \cdot g \quad [\text{kN}]$$ acting in the y-z-plane

$$P_x = G \cdot a_{\phi(x)} \cdot g \quad [\text{kN}]$$ acting in longitudinal direction

$$P_y = G \cdot a_{\varphi(y)} \cdot g \quad [\text{kN}]$$ acting in transverse direction

$$P_z = G \cdot a_{\varphi(z)} \cdot g \quad [\text{kN}]$$ acting vertically to the baseline

a_φ : combined acceleration in the y-z-plane according to Section 4, E with $f = 1.0$ to determine the wave coefficient c_0 for the basic acceleration and $k = 1.0$ to determine the transverse acceleration a_y

$a_{\phi(x)}$: horizontal acceleration component of a_ϕ

a_ϕ : combined acceleration in the x-z-plane to be determined analogous to a_φ

$a_{\varphi(y)}$: horizontal acceleration component of a_φ

$a_{\varphi(z)}$: vertical acceleration component of a_φ

G.2.2 Water pressure and wind pressure

G.2.2.1 The water pressure p_{wa} and load P_{wa} due to the wash of the sea is assumed to be acting on the front wall in the longitudinal direction only and are to be determined by the following formulae:

$$p_{wa} = 0.5 \cdot p_A \quad [kN/m^2] \qquad \text{with } p_{wa} \ge p_{wa,min}$$

$$P_{wa} = p_{wa} \cdot A_f \quad [kN]$$

$p_{wa,min}$: minimum design water pressure $[kN/m^2]$, defined as:

$p_{wa,min} = 25$ at the lower edge of the front wall

$p_{wa,min} = 0$ at the level of the first tier above the deck-house bottom

A_f . loaded area $[m^2]$ of deckhouse front wall

G.2.2.2 The design wind pressure p_{wi} and load P_{wi} acting on the front wall and on the side walls are to be determined by the following formulae:

$$p_{wi} = 1.0 \quad [kN/m^2]$$

$$P_{wi} = p_{wi} \cdot A_D \quad [kN]$$

A_D : loaded area $[m^2]$ of front or side wall

G.2.3 Reaction forces due to weight in induced loads and water and wind pressure

G.2.3.1 The reaction forces due to weight and water and wind pressure are to be determined according to Fig. 16.1.

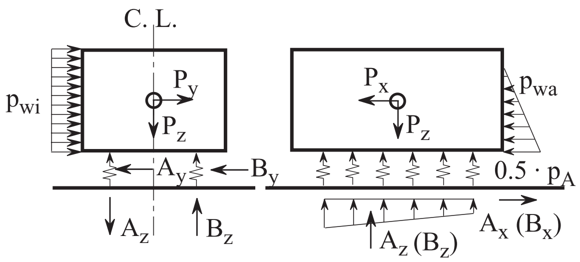


Fig. 16.1 Loads and reaction forces due to wind and water pressure

G.2.3.2 The support forces in the vertical and horizontal directions are to be determined for the various angles φ. The scantlings are to be determined for the respective maximum values (see also Fig. 16.2).

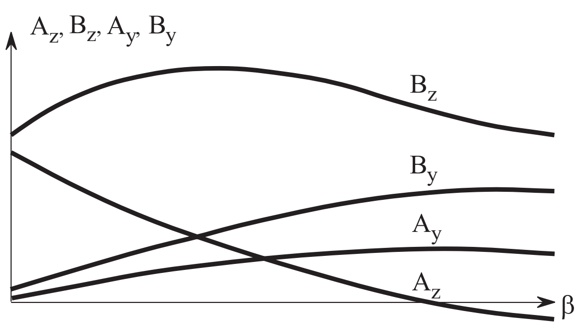


Fig. 16.2 Support forces

G.2.4 Load on the deckhouse bottom

The load on the deckhouse bottom is governed by the load acting on the particular deck on which the deckhouse is located. Additionally, the support forces resulting from the loads specified in G.2.1 and G.2.2 are to be taken into account.

G.2.5 Load on deck beams and girders

For designing the deck beams and girders of the deck on which the deckhouse is located the following loads are to be taken:

- below the deckhouse:

  load p_u according to the pressure head due to the distance between the supporting deck and the deckhouse bottom $[kN / m^2]$

- outside the deckhouse:

  load p_D

- bearing forces in accordance with the load assumptions G.2.1 and G.2.2

G.3 Load cases

For design purposes the following load cases in G.3.1 to G.3.3 are to be investigated separately (see also Fig. 16.1).

G.3.1 Service load cases

The forces P_{x1}, P_{y1} and P_{z1} due to external loads are to be determined by the following formulae:

Transverse direction (z-y-plane):

$$P_{y1} = P_y + P_{wi} \quad [kN]$$ acting in transverse direction

$$P_{z1} = P_z \quad [kN]$$ acting vertically to the baseline

Longitudinal direction (z-x-plane):

$$P_{x1} = P_x + P_{wa} + P_{wi} \quad [kN]$$ acting in longitudinal direction

$$P_{z1} = P_z \quad [kN]$$ acting vertically to the baseline

P_x, P_y, P_z : weight induced loads according to G.2.1.1

P_{wi} : wind load according to G.2.2.2

P_{wa} : water load according to G.2.2.1

G.3.2 Load case for securing devices

For designing the securing devices to prevent the deckhouse from being lifted, the force P_z (in upward direction) is not to be taken less than determined from the following formula:

$$P_{z2} = 0.5 \cdot g \cdot G \quad [kN]$$

G.3.3 Extraordinary load cases

G.3.3.1 Collision force in longitudinal direction

$$P_{x3} = 0.5 \cdot g \cdot G \quad [kN]$$

G.3.3.2 Forces due to static heel of 45 °

$$P_{y3} = 0.71 \cdot g \cdot G \quad [kN]$$ acting in transverse direction

$$P_{z3} = 0.71 \cdot g \cdot G \quad [kN]$$ acting vertically to the baseline

G.3.3.3 The possible consequences of a fire for the elastic mounting of the deckhouse are to be examined (e.g. failure of rubber elastic mounting elements, melting of glue). Even in this case, the mounting elements between hull and deckhouse bottom is to be capable of withstanding the horizontal force P_{y3} according to G.3.3.2 in transverse direction.

G.3.3.4 For designing of the securing devices to prevent the deckhouse from being lifted, a force not less than the buoyancy force of the deckhouse resulting from a water level of 2 m above the freeboard deck is to be taken.

G.4 Scantlings of rails, mounting elements and substructures

G.4.1 General

G.4.1.1 The scantlings of those elements are to be determined in accordance with the load cases stipulated under G.3. The effect of deflection of main girders need not be considered under the condition that the deflection is so negligible that all elements take over the loads equally.

G.4.1.2 Strength calculations for the structural elements with information regarding acting forces are to be submitted for approval.

G.4.2 Permissible stresses

G.4.2.1 The permissible stresses given in Table 16.2 are not to be exceeded in the rails and the steel structures of mounting elements and in the substructures (deck beams, girders of the deckhouse and the deck, on which the deckhouse is located).

Table 16.2 Permissible stress in the rails and the steel structures at mounting elements and in the substructures $[N / mm^2]$

Type of stress	service load cases	extra-ordinary load cases
normal stress σ_n	$0.6 \cdot R_{eH}$ or $0.4 \cdot R_m$	$0.75 \cdot R_{eH}$ or $0.5 \cdot R_m$
shear stress τ	$0.35 \cdot R_{eH}$ or $0.23 \cdot R_m$	$0.43 \cdot R_{eH}$ or $0.3 \cdot R_m$
equivalent stress: $\sigma_v = \sqrt{\sigma_n^2 + 3 \cdot \tau^2}$	$0.75 \cdot R_{eH}$	$0.9 \cdot R_{eH}$

G.4.2.2 The permissible stresses for designing the elastic mounting elements of various systems will be considered from case to case. Sufficient data are to be submitted for approval.

G.4.2.3 The stresses in the securing devices to prevent the deckhouse from being lifted are not to exceed the stress values specified in G.4.2.1.

G.4.2.4 In screwed connections, the permissible stresses given in Table 16.3 are not to be exceeded.

G.4.2.5 Where turnbuckles in accordance with DIN 82008 are used for securing devices, the load per bolt under load conditions G.3.2 and G.3.3.4 may be equal to the proof load (2 times safe working load).

Table 16.3 Permissible stress in screwed connections $[N / mm^2]$

Type of stress	service load cases	extra-ordinary load cases
longitudinal tension σ_n	$0.5 \cdot R_{eH}$	$0.8 \cdot R_{eH}$
bearing pressure p_ℓ	$1.0 \cdot R_{eH}$	$1.0 \cdot R_{eH}$
equivalent stress from longitudinal tension σ_n, tension τ_t due to tightening torque and shear τ if applicable: $\sigma_v = \sqrt{\sigma_n^2 + 3 \cdot \left(\tau^2 + \tau_t^2\right)}$	$0.6 \cdot R_{eH}$	$1.0 \cdot R_{eH}$

G.5 Corrosion addition

For the deck plating below elastically mounted deckhouses a minimum corrosion addition of $t_K = 3.0$ mm applies.

H External Funnel Walls

Scantlings of external funnel walls are to be determined as for deckhouses.

I Breakwater

I.1 Arrangement

If cargo is intended to be carried on deck forward of $x / \mathbf{L} \geq 0.85$, a breakwater or an equivalent protecting structure (e.g. whaleback or turtle deck) is to be installed.

I.2 Dimensions of the breakwater

I.2.1 The recommended average height h_w of the breakwater is to be determined by the following formulae:

$$h_W = 0.8 \cdot (b \cdot c_L \cdot c_0 - z) \quad [m] \qquad\qquad h_W \geq h_{W,min}$$

b : distribution factor according to Section 4, B.9

c_L : length coefficient according to Section 4, A.3

c_0 : wave coefficient according to Section 4, A.3

z : the vertical distance [m] between the summer load line and the bottom line of the breakwater

$h_{W,min}$: minimum required average height [m] of the breakwater, defined as:

$$h_{W,min} = 0.6 \cdot (b \cdot c_L \cdot c_0 - z)$$

However, the minimum required average height $h_{W,min}$ need not to be more than the maximum height of the deck cargo stowed between the breakwater and 15 m aft of it.

The average height h_w of whalebacks or turtle decks has to be determined analogously according to Fig. 16.3.

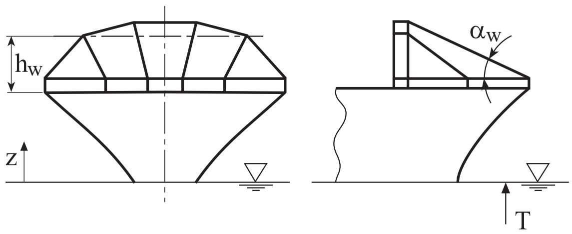


Fig. 16.3 Whaleback

However, IMO requirements regarding navigation bridge visibility are to be considered.

I.2.2 The breakwater has to be at least as broad as the width of the area behind the breakwater, intended for carrying deck cargo.

I.3 Scantlings

I.3.1 Plate thickness

I.3.1.1 Breakwaters with $\alpha_w \leq 90$ ° and whalebacks with $\alpha_w > 20$ °

The plate thickness t of the stiffeners are to be determined by the following formula:

$$t = 0.9 \cdot a \cdot \sqrt{p_{BW} \cdot k} + t_K \quad [mm] \qquad \text{with } t \geq t_{min}$$

t_{min} : minim plate thickness $[mm]$, defined as:

$$t_{min} = \left(5.0 + \frac{L_{300}}{100}\right) \cdot \sqrt{k}$$

I.3.1.2 Whalebacks with $\alpha_w < 20$ °

The plate thickness t is to be the same as for decks of non-effective superstructures according to D.2.2.1.

I.3.2 Stiffeners

I.3.2.1 General

Stiffeners are to be connected on both ends to the structural members supporting them.

I.3.2.2 Breakwaters with $\alpha_w \leq 90$ ° and whalebacks with $\alpha_w > 20$ °

The section modulus W of the stiffeners is to be determined by the following formula:

$$W = 0.35 \cdot a \cdot \ell^2 \cdot p_{BW} \cdot k \quad [cm^3]$$

I.3.2.3 Whalebacks with $\alpha_w < 20$ °

The scantlings of stiffeners are to be the same as for deck beams of non-effective superstructures according to D.2.3.

I.3.3 Primary supporting structure

I.3.3.1 General

Sufficient supporting structures are to be provided.

I.3.3.2 Breakwaters with $\alpha_w \leq 90$ ° and whalebacks with $\alpha_w > 20$ °

For primary supporting members of the structure a stress analysis has to be carried out. The equivalent stress is not to exceed the following permissible stress σ_{perm}:

$$\sigma_{perm} = \frac{230}{k} \quad [N / mm^2]$$

I.3.3.3 Whalebacks with $\alpha_w < 20$ °

The scantlings of primary supporting members are to be the same as for primary supporting members of decks of non-effective superstructures accordant to D.2.3.

I.4 Cutouts

Cutouts in the webs of primary supporting members of the breakwater are to be reduced to their necessary minimum. Free edges of the cutouts are to be reinforced by stiffeners.

If cutouts in the plating are provided to reduce the load on the breakwater, the area of single cutouts should not exceed $0.2\ m^2$ and the sum of the cutout areas not $3\ \%$ of the overall area of the breakwater plating.

J Recommendations regarding deckhouse vibration

J.1 *The natural frequencies of the basic global deckhouse vibration modes (longitudinal, transverse, torsional) should not coincide with major excitation frequencies at the nominal revolution rate of the propulsion plant. This should be verified during the design stage by a global vibration analysis.*

J.2 *The natural frequencies of local deck panel structure components (plates, stiffeners, deck frames, longitudinal girders, deck grillages) should not coincide with major excitation frequencies at the nominal revolution rate of the propulsion plant. This should be verified during the design stage by a local vibration analysis.*

The natural frequencies of plate fields and stiffeners can be estimated by POSEIDON or by means of the software tool GL LocVibs which can be downloaded from the GL homepage www.gl-group.com/gl-locvibs.

J.3 *It is recommended to design the local deck structures in such a way that their natural frequencies exceed twice propeller blade rate, and in case of rigidly mounted engines ignition frequency, by at least 20 %. This recommendation is based on the assumption of a propeller with normal cavitation behaviour, i.e. significant decrease of pressure pulses with increasing blade harmonic are to be ensured.*

J.4 *Cantilever navigation bridge wings should be supported by pillars or brackets extending from the outer wing edge to at least the deck level below. If this is not possible, the attachment points of the pillars/ brackets at the deckhouse structure have to be properly supported.*

J.5 *The base points of the main mast located on the compass deck should be preferably supported by walls or pillars. The natural frequencies of the basic main mast vibration modes (longitudinal, transverse, torsional) should not coincide with major excitation frequencies at the nominal revolution rate of the propulsion plant. This should be verified during the design stage by a mast vibration analysis.*

Section 17 Cargo Hatchways

A General

A.1 Application

A.1.1 The requirements of this Section are applicable to hatch covers and hatch coamings of stiffened plate construction and its closing arrangements.

(IACS UR S21A.1.1)

A.1.2 The hatch covers and coamings are to be made out of steel. In case of alternative materials and innovative designs the approval is to be subject to GL.

(IACS UR S21A.1.1)

A.1.3 This Section does not apply to portable covers secured weathertight by tarpaulins and battening devices, or pontoon covers, as defined in ICLL Regulation 15.

(IACS UR S21A.1.1)

Note

Special requirements of National Administrations regarding hatchways, hatch covers, tightening and securing arrangements are to be observed.

A.2 References

A.2.1 Paragraphs of this section are based on the following international convention(s) and/or code(s):

IACS UR S14 Rev.4

IACS UR S21 Rev.5

IACS UR S21A Corr.1

At the end of each relevant paragraph of this section, the corresponding paragraphs of the international convention(s) and/or code(s) are given in brackets.

A.2.2 For corrosion protection of hatch coamings and hatch covers of bulk carriers, ore carriers and combination carriers, see Section 35, G.

A.3 Definitions

Single skin cover

A hatch cover made of steel or equivalent material that is designed to comply with **ICLL** Regulation 16. The cover has continuous top and side plating, but is open underneath with the stiffening structure exposed. The cover is weathertight and fitted with gaskets and clamping devices unless such fittings are specifically excluded.

(IACS UR S21A.1.2.1)

Double skin cover

A hatch cover as above but with continuous bottom plating such that all the stiffening structure and internals are protected from the environment.

(IACS UR S21A.1.2.1)

Pontoon type cover

A special type of portable cover, secured weathertight by tarpaulins and battening devices. Such covers are to be designed in accordance with **ICLL** Regulation 15 and are not covered by this Section.

(IACS UR S21A.1.2.1)

Note

Modern hatch cover designs of lift-away-covers are in many cases called pontoon covers. This definition does not fit to the definition above. Modern lift-away hatch cover designs should belong to one of the two categories single skin covers or double skin cover.

(IACS UR S21A.1.2.1)

Symbols

a : spacing $[m]$ of stiffeners

g : gravitational acceleration $[m/s^2]$, defined as:

$$g = 9.81$$

h_N : superstructure standard height $[m]$ according to **ICLL**

$$h_N = 1.05 + 0.01 \cdot \mathbf{L_c} \qquad \text{with } 1.8 \le h_N \le 2.3$$

k : material factor, defined as:

$$k = \frac{235}{R_{eH}}$$

k_ℓ : material factor, defined as:

$$k_\ell = \left(\frac{235}{R^*_{eH}}\right)^e$$

R^*_{eH} : yield strength $[N/mm^2]$, with:

$$R^*_{eH} \le 0.7 \cdot R_m$$

e : exponent, defined as:

$$e = 0.75 \qquad \text{for } R_{eH} > 235\ N/mm^2$$

$$e = 1.00 \qquad \text{for } R_{eH} \le 235\ N/mm^2$$

$\mathbf{L}_{300}$: corresponds to the length of the ship as $\mathbf{L}$, but $\mathbf{L}_{300}$ is not to be taken greater than $300\ m$

$\mathbf{L}_{c340}$: corresponds to the length of the ship as $\mathbf{L}_c$, but $\mathbf{L}_{c340}$ is not to be taken greater than $340\ m$

ℓ : unsupported span $[m]$ of stiffener, to be taken as the spacing of main girders or the distance between a main girder and the edge support for hatch covers and as the spacing of coaming stays for hatch coamings, as applicable

p_A : load $[kN/m^2]$ on superstructure end bulkheads, deckhouse walls, transverse hatch coamings and hatch cover skirt plates according to Section 4, B.8

p_D : load on weather decks according to Section 4, B.1

p_H : load on weather deck hatches according to Table 17.2

p_L : load on cargo decks according to Section 4, C.1

p_{T1}, p_{T2} : load on tank structures according to Section 4, D.1

p_{T3} : load on tank structures according to Section 4, D.2

t : thickness [mm] of structural member, defined as:

$$t = t_{net} + t_K$$

t_{net} : net thickness [mm]

t_K : corrosion addition [mm] as defined in Table 17.1

x : distance of mid point of the assessed hatch cover from aft end of length $\mathbf{L}$ or $\mathbf{L_c}$, as applicable

A.4 Corrosion additions

For the scantlings of hatch covers and coamings the corrosion additions t_K according to Table 17.1 are to be applied.

(IACS UR S21.6.1, IACS UR S21.6.2 and IACS UR S21A.7.1)

Table 17.1 Corrosion additions for hatch coamings and hatch covers

Application	Structure	t_K [mm]
Weather deck hatches of container ships, car carriers, paper carriers, passenger vessels	Hatch covers	1.0
	Hatch coamings	according to Section 3, G.1
Weather deck hatches of all other ship types (t_K-values in brackets are to be applied to bulk carriers according to Section 23)	Hatch covers in general	2.0
	Weather exposed plating and bottom plating of double skin hatch covers	1.5 (2.0)
	Internal structure of double skin hatch covers and closed box girders	1.0 (1.5)
	Hatch coamings not part of the longitudinal hull structure	1.5
	Hatch coamings part of the longitudinal hull structure	according to Section 3, G.1
	Coaming stays and stiffeners	1.5
Hatches within enclosed spaces	Hatch covers:	
	• top plating	1.2
	• remaining structures	1.0
	Hatch coamings	according to Section 3, G.1 - Section 3, G.3

(IACS UR S21A Table 9)

B Hatch Covers

B.1 General

B.1.1 Primary supporting members and secondary stiffeners of hatch covers are to be continuous over the breadth and length of 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 provide 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. When strength calculation is carried out by FE analysis according to B.4.4, this requirement can be waived.

(IACS UR S21A.1.4)

B.1.2 For hatch covers the application of steel with $R_{eH} > 355\ N/mm^2$ is to be agreed with GL.

B.2 Design loads

Structural assessment of hatch covers and hatch coamings according to C is to be carried out according to the following design loads:

(IACS UR S21A.2)

B.2.1 Load case A:

B.2.1.1 The vertical design load p_H for weather deck hatch covers is to be taken from Table 17.2. Refer to Section 1, A.3.3 and Fig. 17.1 for definitions of Position 1 and 2.

(IACS UR S21A.2.1)

B.2.1.2 In general, the vertical design load p_H needs not to be combined with load cases B and C according to B.2.2 and B.2.3.

(IACS UR S21A.2.1)

B.2.1.3 Where an increased freeboard is assigned, the design load for hatch covers according to Table 17.2 on the actual freeboard deck may be as required for a superstructure deck, provided the summer freeboard is such that the resulting draught will not be greater than that corresponding to the minimum freeboard calculated from an assumed freeboard deck situated at a distance equal to a standard superstructure height h_N below the actual freeboard deck, refer to Fig. 17.2.

(IACS UR S21A.2.1)

B.2.1.4 The vertical design load p_H is in no case to be less than the deck design load p_D according to Section 4, B.1 Instead of the deck height z the height of hatch cover plating above baseline is then to be inserted.

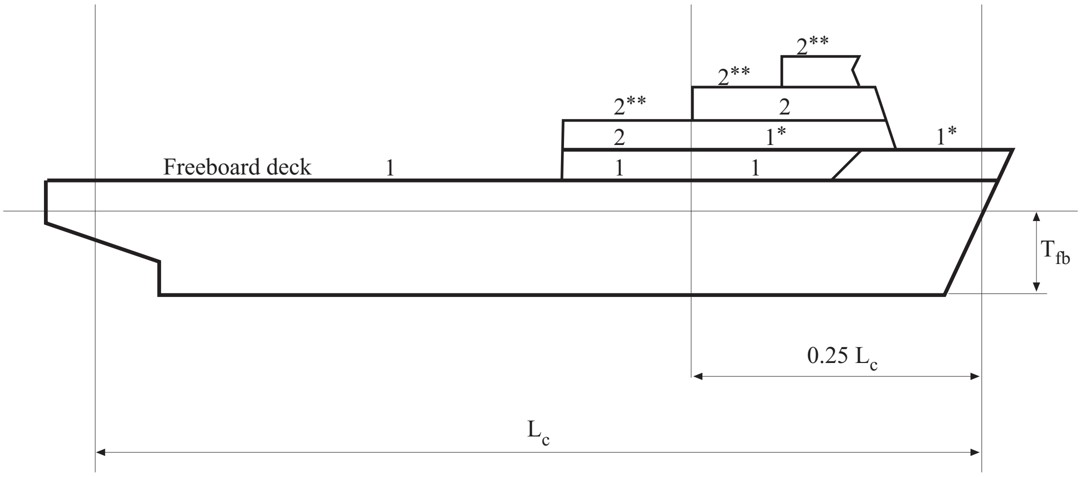
B.2.1.5 The horizontal design load p_A for the outer edge girders (skirt plates) of weather deck hatch covers and for hatch coamings is to be determined analogously as for superstructure walls in the respective position.

(IACS UR S21A.2.2)

Table 17.2 Design load p_H of weather deck hatches

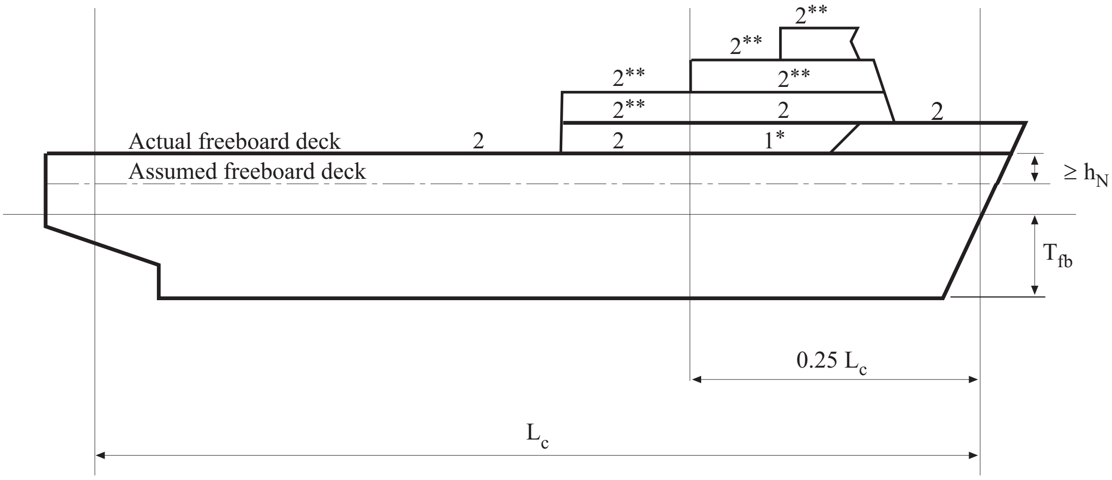
<table>
<tr><th rowspan="2">Position</th><th colspan="2">Design load p_H [kN / m²]</th></tr>
<tr><th>$\frac{x}{\mathbf{L_c}} \le 0.75$</th><th>$0.75 < \frac{x}{\mathbf{L_c}} \le 1.0$</th></tr>
<tr><td rowspan="8">1</td><td colspan="2">for $\mathbf{L_c} \le 100$ m</td></tr>
<tr><td rowspan="2">$p_H = \frac{9.81}{76} \cdot (1.5 \cdot \mathbf{L_c} + 116)$</td><td>on freeboard deck
$$p_H = \frac{9.81}{76} \cdot \left[(4.28 \cdot \mathbf{L_c} + 28) \cdot \frac{x}{\mathbf{L_c}} - 1.71 \cdot \mathbf{L_c} + 95\right]$$</td></tr>
<tr><td>upon exposed superstructure decks located at least one superstructure standard height h_N above the freeboard deck
$$p_H = \frac{9.81}{76} \cdot (1.5 \cdot \mathbf{L_c} + 116)$$</td></tr>
<tr><td colspan="2">for $\mathbf{L_c} > 100$ m</td></tr>
<tr><td rowspan="3">$p_H = 9.81 \cdot 3.5$</td><td>on freeboard deck for type B ships according to **ICLL**
$$p_H = 9.81 \cdot \left[(0.0296 \cdot L_{c340} + 3.04) \cdot \frac{x}{\mathbf{L_c}} - 0.0222 \cdot L_{c340} + 1.22\right]$$</td></tr>
<tr><td>on freeboard deck for ships with less freeboard than type B according to **ICLL**
$$p_H = 9.81 \cdot \left[(0.1452 \cdot L_{c340} - 8.52) \cdot \frac{x}{\mathbf{L_c}} - 0.1089 \cdot L_{c340} + 9.89\right]$$</td></tr>
<tr><td>upon exposed superstructure decks located at least one superstructure standard height h_N above the freeboard deck
$$p_H = 9.81 \cdot 3.5$$</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="5">2</td><td colspan="2">for $\mathbf{L_c} \le 100$ m</td></tr>
<tr><td colspan="2">$$p_H = \frac{9.81}{76} \cdot (1.1 \cdot \mathbf{L_c} + 87.6)$$</td></tr>
<tr><td colspan="2">for $\mathbf{L_c} > 100$ m</td></tr>
<tr><td colspan="2">$$p_H = 9.81 \cdot 2.6$$</td></tr>
<tr><td colspan="2">upon exposed superstructure decks located at least one superstructure standard height h_N above the lowest Position 2 deck
$$p_H = 9.81 \cdot 2.1$$</td></tr>
</table>

(IACS UR S21A Table 1)



* Reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck
** Reduced load upon exposed superstructure decks of vessels with L_c > 100 m located at least one superstructure standard height above the lowest Position 2 deck

Fig. 17.1 Positions 1 and 2



* Reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck
** Reduced load upon exposed superstructure decks of vessels with L_c > 100 m located at least one superstructure standard height above the lowest Position 2 deck

Fig. 17.2 Positions 1 and 2 for an increased freeboard

B.2.2 Load case B:

Where cargo is intended to be carried on hatch covers they are to be designed for the loads as given in Section 4, C.1.

If cargo with low stowage height is carried on weather deck hatch covers Section 4, B.1 is to be observed.

(IACS UR S21A.2.3.1 and 2.3.2)

B.2.3 Load case C:

B.2.3.1 Container loads

Where containers are stowed on hatch covers the following support forces A_z, B_z and B_y in y- and z-direction at the forward and aft stack corners due to heave, pitch, and the ship's rolling motion are to be considered and to be determined by the following formulae, see also Fig. 17.3:

$$A_z = 9.81 \cdot \frac{M}{2} \cdot (1 + a_v) \cdot \left(0.45 - 0.42 \cdot \frac{h_m}{b}\right) \quad [\text{kN}]$$

$$B_z = 9.81 \cdot \frac{M}{2} \cdot (1 + a_v) \cdot \left(0.45 + 0.42 \cdot \frac{h_m}{b}\right) \quad [kN]$$

$$B_y = 2.4 \cdot M \quad [kN]$$

M : maximum designed mass [t] of container stack

a_v : acceleration addition according to Section 4, A.3

h_m : designed height [m] of centre of gravity of stack above hatch cover supports

When strength of the hatch cover structure is assessed by FE analysis according to B.4.4, h_m may be taken as the designed height of centre of gravity of stack above the hatch cover top plate.

Values of M and h_m applied for the assessment of hatch cover strength are to be shown in the drawings of the hatch covers.

b : distance [m] between foot points

B.2.3.2 In case of container stacks secured to lashing bridges or carried in cell guides the forces acting on the hatch cover may be specially considered.

(IACS UR S21A.2.4)

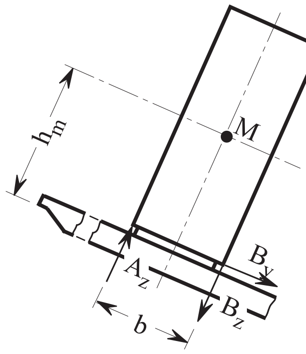


Fig. 17.3 Forces due to load case C acting on hatch cover

B.2.3.3 Load cases with partial loading

The load cases B and C are also to be considered for partial loading which may occur in practice, e.g. where specified container stack places are empty.

The load case partial loading of container hatch covers may be evaluated using a simplified approach, where the hatch cover is loaded without the outermost stacks, see Fig. 17.4.

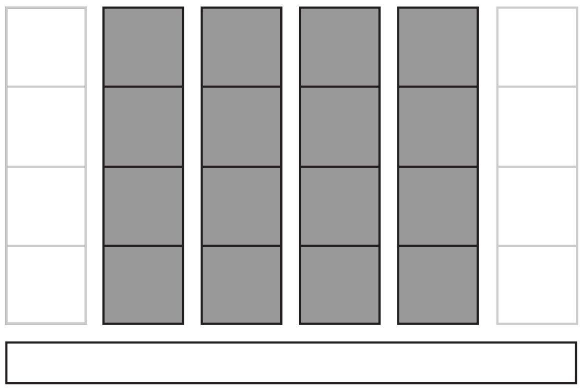


Fig. 17.4 Partial loading of a container hatch cover

The design load for other cargo than containers subject to lifting forces is to be determined separately.

(IACS UR S21A.2.4.1)

B.2.4 Load case D:

Hatch covers of hold spaces intended to be filled with liquids are to be designed for the loads specified in Section 4, D.1 and Section 4, D.2 irrespective of the filling height of hold spaces.

B.2.5 Load case E:

Hatch covers, which in addition to the loads according to the above are loaded in the ship's transverse direction by forces due to elastic deformations of the ship's hull, are to be designed such that the sum of stresses does not exceed the permissible values given in B.3.

(IACS UR S21A.2.5)

B.2.6 Horizontal mass forces

For the design of the securing devices against shifting according to B.5.7 the horizontal mass forces are to be determined by the following formula:

$$F_h = m \cdot a_i$$

m : sum of mass of cargo lashed on the hatch cover and of the hatch cover

a_i : acceleration, defined as:

$a_i = 0.2 \cdot g$ for acceleration in longitudinal direction

$a_i = 0.5 \cdot g$ for acceleration in transverse direction

(IACS UR S21A.6.2.1)

B.3 Permissible stresses and deflections

B.3.1 Permissible stresses

The equivalent stress σ_v in steel hatch cover structures related to the net thickness is not to exceed $0.8 \cdot R_{eH}$.

For load cases B to E according to B.2, the equivalent stress σ_v related to the net thickness is not to exceed $0.9 \cdot R_{eH}$ when the stresses are assessed by means of FEM according to B.4.4.

For steels with $R_{eH} > 355\ N/mm^2$, the value of R_{eH} to be applied throughout this section is to be agreed with GL but is not to be more than the minimum yield strength of the material.

For beam element calculations and grillage analysis, the equivalent stress σ_v may be taken as follows:

$$\sigma_v = \sqrt{\sigma^2 + 3 \cdot \tau^2} \quad [N/mm^2]$$

σ : stress component $[N/mm^2]$, defined as:

$$\sigma = \sigma_b + \sigma_n$$

σ_b : bending stress $[N/mm^2]$

σ_n : normal stress $[N/mm^2]$

τ : shear stress $[N/mm^2]$

For FEM calculations, the equivalent stress σ_v may be taken as follows:

$$\sigma_v = \sqrt{\sigma_x^2 - \sigma_x \cdot \sigma_y + \sigma_y^2 + 3\tau^2} \quad [N/mm^2]$$

σ_x : normal stress $[N/mm^2]$ in x-direction

σ_y : normal stress $[N/mm^2]$ in y-direction

τ : shear stress $[N/mm^2]$ in the x-y plane

Indices x and y denominate axes of a two-dimensional cartesian coordinate system in the plane of the considered structural element.

(IACS UR S21.3.1 and IACS UR S21A.3.1.1)

B.3.2 Permissible deflections

The deflection f of weather deck hatch covers under the vertical design load p_H is not to exceed:

$$f = 0.0056 \cdot \ell_g \quad [m]$$

ℓ_g : largest span $[m]$ of girders

Note

Where hatch covers are arranged for carrying containers and mixed stowage is allowed, i.e. a $40'$-container on stowages places for two $20'$- containers, the deflections of hatch covers have to be particularly observed. Further the possible contact of deflected hatch covers with in hold cargo has to be observed.

(IACS UR S21.3.7 and IACS UR S21A.3.1.2)

B.3.3 Where hatch covers are made of aluminium alloys, Section 2, D is to be observed. For permissible deflections B.3.2 applies.

B.3.4 The permissible stresses specified under B.3.1 apply to primary girders of symmetrical cross section. For unsymmetrical cross sections equivalence in regard to strength and safety is to be proved, see also Section 3, B.3.7.

B.4 Strength calculation for hatch covers

B.4.1 General

B.4.1.1 Strength calculation for hatch covers may be carried out by either, using beam theory, grillage analysis or FEM.

Strength calculations are to be based on net thickness:

$$t_{net} = t - t_K$$

The corrosion addition t_K used for calculation are to be indicated in the drawings.

(IACS UR S21.3.1, IACS UR S21A.1.5 and S21A.3.5)

B.4.1.2 For hatch cover structures sufficient buckling strength is to be demonstrated. Verifications of buckling strength according to Section 3, D are to be based on $t = t_{net}$ and stresses corresponding to t_{net} applying the following safety factors S:

- $S = 1.25$ for hatch covers when subjected to the vertical design load p_H according to B.2.1
- $S = 1.10$ for hatch covers when subjected to the horizontal design load p_A according to B.2.1 as well as to load cases B to E according to B.2.2 through B.2.5.

For verification of buckling strength of plate panels stiffened with U-type stiffeners a correction factor $F_1 = 1.3$ may be applied.

(IACS UR S21.3.1 and IACS UR S21A.3.6)

B.4.1.3 For all structural components of hatch covers for spaces in which liquids are carried, the minimum thickness for tanks according to Section 12, B.1.3 is to be observed.

B.4.2 Hatch cover supports

Supports and stoppers of hatch covers are in general to be so arranged that no constraints due to hull deformations occur in the hatch cover structure and at stoppers respectively, see also load case E according to B.2.5

Deformations due to the design loads according to B.2 between coaming and weathertight hatch covers, as well as between coaming and covers for hold spaces in which liquids are carried, are not to lead to leakiness, refer to D.

For bulk carriers according to Section 23 force transmitting elements are to be fitted between the hatch cover panels with the purpose of restricting the relative vertical displacements. However, each panel has to be assumed as independently load-bearing.

If two or more deck panels are arranged on one hatch, clearances in force transmitting elements between panels have generally to be observed.

Stiffness of securing devices, where applicable, and clearances are to be considered.

B.4.3 Strength calculations for beam and girder grillages

B.4.3.1 Cross-sectional properties are to be determined considering the effective breadth according to D Cross sectional areas of stiffeners parallel to the girder web within the effective breadth can be included, see Section 3, D.3.2.

Special calculations may be required for determining the effective breadth of one-sided or non-symmetrical flanges.

The effective cross sectional area of plates is not to be less than the cross sectional area of the face plate.

The effective width of flange plates under compression with stiffeners perpendicular to the girder web is to be determined according to Section 3, D.3.2.

(IACS UR S21A.3.5.1)

B.4.3.2 In way of larger cutouts in girder webs it may be required to consider second order bending moments.

B.4.4 FEM calculations

For strength calculations of hatch covers by means of finite elements, the cover geometry is to be idealised as realistically as possible. Element size is to be appropriate to account for effective breadth. In no case element width is to be larger than stiffener spacing. In way of force transfer points, cutouts and one-sided or non-symmetrical flanges the mesh has to be refined where applicable.

The ratio of element length to width is not to exceed 4. The element height of girder webs is not to exceed one-third of the web height. Stiffeners, supporting plates against lateral loads, have to be included in the idealization. Buckling stiffeners may be disregarded for the stress calculation.

(IACS UR S21A.3.5.2)

B.5 Scantlings

B.5.1 Hatch cover plating

B.5.1.1 Top plating

B.5.1.1.1 The thickness of the hatch cover top plating is to be obtained from the calculation according to B.4. under consideration of permissible stresses according to B.3.1.

However, the thickness t is not to be less than determined by the following formulae:

$$t = \max\left[t_1 \; ; \; t_2\right] \qquad \text{with } t \geq t_{min}$$

$$t_1 = 16.2 \cdot c_p \cdot a \cdot \sqrt{\frac{p}{R_{eH}}} + t_K \quad [\text{mm}]$$

$$t_2 = 10 \cdot a + t_K \quad [\text{mm}]$$

c_p : coefficient, defined as:

$$c_p = 1.5 + 2.5 \cdot \left(\frac{|\sigma|}{R_{eh}} - 0.64\right) \geq 1.5 \qquad \text{for } p = p_H \text{ or } p_L$$

$$c_p = 1.0 + 2.5 \cdot \left(\frac{|\sigma|}{R_{eh}} - 0.64 \right) \geq 1.0$$ for $p = p_D;\ p_{T1},\ p_{T2}$ or p_{T3}

σ : normal stress $[N / mm^2]$ of main girders

p : design load $[kN / m^2]$, defined as:

$$p = \max[p_D\ ;\ p_H\ ;\ p_L\ ;\ p_{T1}\ ;\ p_{T2}\ ;\ p_{T3}]$$ as applicable

t_{min} : minimum thickness $[mm]$, defined as:

$$t_{min} = 6.0 + t_K \quad [mm]$$

For flange plates under compression sufficient buckling strength according to Section 3, D is to be verified.

(IACS UR S21.3.3 and IACS UR S21A.3.2)

B.5.1.1.2 For hatch covers subject to wheel loading the plate thickness is not to be less than according to Section 7, C.2.

(IACS UR S21A.3.2.1)

B.5.1.2 Lower plating of double skin hatch covers and box girders

The thickness is to be obtained from the calculation according to B.4 under consideration of permissible stresses according to B.3.1.

The thickness t is not to be less than determined by the following formula:

$$t = 6.5 \cdot a + t_K \quad [mm]$$ with $t \geq t_{min}$

t_{min} : minimum thickness $[mm]$, defined as:

$$t_{min} = 5.0 + t_K$$

The lower plating of hatch covers for spaces in which liquids are carried is to be designed for the liquid pressure and the thickness is to be determined according to B.5.1.1.1.

(IACS UR S21A.3.2.2)

B.5.2 Main girders

B.5.2.1 Scantlings of main girders are obtained from the calculation according to B.4 under consideration of permissible stresses according to B.3.1.

For all components of main girders sufficient safety against buckling is to be verified according to Section 3, D. For biaxially compressed flange plates this is to be verified within the effective widths according to Section 3, D.3.2.

The thickness t of main girder webs is not to be less than determined by the following formulae:

$$t = 6.5 \cdot a + t_K \quad [mm]$$ with $t \geq t_{min}$

t_{min} : minimum thickness $[mm]$, defined as:

$$t_{min} = 5.0 + t_K$$

(IACS UR S21.3.5 and IACS UR S21A.3.4.1)

B.5.2.2 For hatch covers of bulk carriers according to Section 23 the ratio of flange width to web height is not to exceed 0.4, if the unsupported length of the flange between two flange supports of main girders is larger than 3.0 m. The ratio of flange outstand to flange thickness is not to exceed 15.

(IACS UR S21.3.5)

B.5.2.3 At intersections of flanges from two girders, notch stresses have to be observed.

B.5.3 Edge girders (Skirt plates)

B.5.3.1 Scantlings of edge girders are obtained from the calculations according to B.4 under consideration of permissible stresses according to B.3.1.

The thickness t of the outer edge girders exposed to wash of sea is not to be less than the largest value determined by the following formulae:

$$t = \max\left[t_1 \; ; \; t_2\right] \qquad \text{with } t \geq t_{min}$$

$$t_1 = 16.2 \cdot a \cdot \sqrt{\frac{p_A}{R_{eH}}} + t_K \quad [\mathrm{mm}]$$

$$t_2 = 8.5 \cdot a + t_K \quad [\mathrm{mm}]$$

t_{min} : minimum thickness $[\mathrm{mm}]$, defined as:

$$t_{min} = 5.0 + t_K$$

The stiffness of edge girders of weather deck hatch covers is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia I of edge girders is not to be less than determined by the following formula:

$$I = 6 \cdot q \cdot s^4 \quad [\mathrm{cm}^4]$$

q : packing line pressure $[\mathrm{N/mm}]$, with:

$$q \geq q_{min} = 5$$

s : spacing $[\mathrm{m}]$ of securing devices

(IACS UR S21.5.1 and IACS UR S21A.3.4.2)

B.5.3.2 For all components of edge girders sufficient safety against buckling is to be verified according to Section 3, D.

B.5.3.3 For hatch covers of spaces in which liquids are carried, the packing line pressure is also to be ensured in case of hatch cover loading due to liquid pressure.

B.5.4 Hatch cover stiffeners

The net section modulus W_{net} and net shear area A_{snet} of uniformly loaded hatch cover stiffeners constraint at both ends is not be less than determined by the following formulae:

$$W_{net} = \frac{104}{R_{eH}} \cdot a \cdot \ell^2 \cdot p \quad [\mathrm{cm}^3]$$

$$A_{snet} = \frac{10 \cdot a \cdot \ell \cdot p}{R_{eH}} \quad [\mathrm{cm}^2]$$

p : design load $[\mathrm{kN/m}^2]$, defined as:

$$p = \max\left[p_D \; ; \; p_H \; ; \; p_L \; ; \; p_{T1} \; ; \; p_{T2} \; ; \; p_{T3}\right] \qquad \text{as applicable}$$

The net section modulus of the stiffeners is to be determined based on an attached plate width assumed equal to the stiffener spacing.

For flat bar stiffeners and buckling stiffeners, the ratio h / t_w is to be not greater than $15 \cdot \sqrt{k}$, where:

h : height of the stiffener

t_w : net thickness of the stiffener

Stiffeners parallel to main girder webs and arranged within the effective breadth according to Section 3, D are to be continuous at crossing transverse girders and may be regarded for calculating the cross sectional properties of main girders. It is to be verified that the resulting combined stress of those stiffeners, induced by the bending of main girders and lateral pressures, does not exceed the permissible stress according to B.3.1.

For hatch cover stiffeners under compression sufficient safety against lateral and torsional buckling according to Section 3, D is to be verified.

For hatch covers subject to wheel loading stiffener scantlings are to be determined by direct calculations under consideration of the permissible stresses according to B.3.1.

((IACS UR S21.3.4 and IACS UR S21A.3.3)

B.5.5 Hatch cover supports

B.5.5.1 For the transmission of the support forces resulting from the load cases specified in B.2.1 – B.2.6, supports are to be provided which are to be designed such that the nominal surface pressures in general do not exceed $p_{n,max}$ determined by the following formula:

$$p_{n,\,max} = d \cdot p_n \quad [N/mm^2]$$ in general

$$p_{n,\,max} = 3 \cdot p_n \quad [N/mm^2]$$ for metallic supporting surfaces not subjected to relative displacements

d : factor, defined as:

$$d = 3.75 - 0.015 \cdot \mathbf{L}$$ with $d_{min} \le d \le 3.0$

d_{min} : minimum factor, defined as:

$d_{min} = 1.0$ in general

$d_{min} = 2.0$ for partial loading conditions (see B.2.4)

p_n : permissible nominal surface pressure as defined in Table 17.3

Where large relative displacements of the supporting surfaces are to be expected, the use of material having low wear and frictional properties is recommended.

(IACS UR S21A.6.2.2)

Table 17.3 Permissible nominal surface pressure p_n

Support material	p_n [N / mm²] when loaded by vertical force	p_n [N / mm²] when loaded by horizontal force (on stoppers)
Hull structural steels	25	40
hardened steels	35	50
plastic materials on steel	50	—

(IACS UR S21A Table 8)

B.5.5.2 Drawings of the supports are to be submitted. In the drawings of the supports the permitted maximum pressure given by the material manufacturer related to long time stress is to be specified.

(IACS UR S21A.6.2.2)

B.5.5.3 If necessary, sufficient abrasive strength may be shown by tests demonstrating an abrasion of support surfaces of not more than 0.3 mm per one year in service at a total distance of shifting of 15 000 m / year.

(IACS UR S21A.6.2.2)

B.5.5.4 The substructures of the supports have to be of such a design, that a uniform pressure distribution is achieved.

(IACS UR S21A.6.2.2)

B.5.5.5 Irrespective of the arrangement of stoppers, the supports are to be able to transmit the force P_h in the longitudinal and transverse direction, determined by the following formula:

$$P_h = \mu \cdot \frac{P_v}{\sqrt{d}}$$

μ : frictional coefficient, defined as:

$\mu = 0.50$	for steel on steel
$\mu = 0.35$	for non-metallic, low-friction support materials on steel

P_v : vertical supporting force

d : factor according to B.5.5.1

(IACS UR S21A.6.2.2)

B.5.5.6 Supports as well as the adjacent structures and substructures are to be designed such that the permissible stresses according to B.3.1 are not exceeded.

(IACS UR S21A.6.2.2)

B.5.5.7 For substructures and adjacent structures of supports subjected to horizontal forces P_h, a fatigue strength analysis is to be carried out according to Section 20 by using the stress spectrum B and applying the horizontal force P_h.

(IACS UR S21A.6.2.2)

B.5.6 Securing of weather deck hatch covers

B.5.6.1 Securing devices between cover and coaming and at cross-joints are to be provided to ensure weathertightness. Sufficient packing line pressure is to be maintained. The packing line pressure is to be specified in the drawings.

Securing devices are to be appropriate to bridge displacements between cover and coaming due to hull deformations.

Securing devices are to be of reliable construction and effectively attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

Sufficient number of securing devices is to be provided at each side of the hatch cover considering the requirements of B.5.3.1. This applies also to hatch covers consisting of several parts.

Specifications of materials of securing devices and their weldings are to be shown in the drawings of the hatch covers.

(IACS UR S21.5.1 and IACS UR S21A.6.1.1)

B.5.6.2 Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

(IACS UR S21.5.1 and IACS UR S21A.6.1.2)

B.5.6.3 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.

(IACS UR S21.5.1 and IACS UR S21A.6.1.3)

B.5.6.4 The gross cross-sectional area of the securing devices is not to be less than determined by the following formula:

$$A = 0.28 \cdot q \cdot s \cdot k_\ell \quad [\mathrm{cm}^2]$$

q : packing line pressure $[N / mm]$, with

$q_{min} = 5$

s : spacing $[m]$ between securing devices, with:

$s_{min} = 2$

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding $5\ m^2$ in area.

Securing devices of special design in which significant bending or shear stresses occur may be designed according to B.5.6.5. As load the packing line pressure q multiplied by the spacing between securing devices s is to be applied.

(IACS UR S21.5.1 and IACS UR S21A.6.1.4)

B.5.6.5 The securing devices of hatch covers, on which cargo is to be lashed, are to be designed for the lifting forces according to B.2.3, load case C, refer to Fig. 17.5. Unsymmetrical loadings, which may occur in practice, are to be considered. Under these loadings the equivalent stress in the securing devices is not to exceed:

$$\sigma_v = \frac{150}{k_\ell} \quad [N / mm^2]$$

(IACS UR S21A.6.1.5)

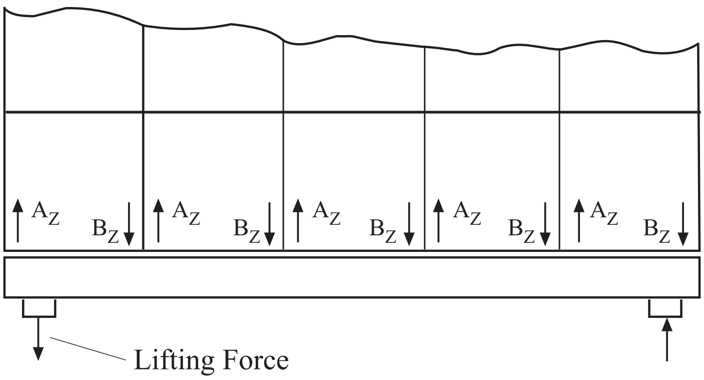


Fig. 17.5 Lifting forces at a hatch cover

B.5.6.6 Securing devices of hatch covers for spaces in which liquids are carried are to be designed for the lifting forces according to B.2.4, load case D.

B.5.6.7 Cargo deck hatch covers consisting of several parts have to be secured against accidental lifting.

B.5.7 Hatch cover stoppers

Hatch covers are to be sufficiently secured against shifting.

Stoppers are to be provided for hatch covers on which cargo is carried as well as for hatch covers, which edge girders have to be designed for $p_A > 175\ kN / m^2$ according to B.2.1.5.

Design forces for the stoppers are obtained from the loads according to B.2.1.5 and B.2.6.

The permissible stress in stoppers and their substructures in the cover and of the coamings is to be determined according to B.3.1. The provisions in B.5.5 are to be observed.

(IACS UR S21.5.2 and IACS UR S21A.6.2.3)

B.5.8 Cantilevers, load transmitting elements

B.5.8.1 Cantilevers and load transmitting elements which are transmitting the forces exerted by hydraulic cylinders into the hatchway covers and the hull are to be designed for the forces stated by the manufacturer. The permissible stresses according to B.3.1 are not to be exceeded.

B.5.8.2 Structural members subjected to compressive stresses are to be examined for sufficient safety against buckling, according to Section 3, D.

B.5.8.3 Particular attention is to be paid to the structural design in way of locations where loads are introduced into the structure.

B.5.9 Container foundations on hatch covers

Container foundations and their substructures are to be designed for the loads according to B.2, load cases B and C, respectively, applying the permissible stresses according to B.3.1.

(IACS UR S21A.4.1)

C Hatch Coamings and Girders

C.1 General

C.1.1 Hatchways on freeboard and superstructure decks are to have coamings, the minimum height of which above the deck is to be as follows:

- in position 1: 600 mm
- in position 2: 450 mm

C.1.2 A deviation from the requirements under C.1.1 may only be granted for hatchways on exposed decks which are closed by weathertight, self tightening steel covers. The respective exemption, in accordance with **ICLL** Regulation 14-1, has to be applied for in advance from the competent flag state authority.

C.1.3 Where an increased freeboard is assigned, the height of hatchway coamings according to C.1.1 on the actual freeboard deck may be as required for a superstructure deck, provided the summer freeboard is such that the resulting draught will not be greater than that corresponding to the minimum freeboard calculated from an assumed freeboard deck situated at a distance equal to a standard superstructure height h_N below the actual freeboard deck.

C.1.4 Coamings are not required for hatchways below the freeboard deck or within weathertight closed superstructures unless they are required for strength purposes.

C.1.5 Hatch coamings which are part of the longitudinal hull structure are to be designed according to Section 5.

For hatch way coamings which are designed on the basis of strength calculations as well as for hatch girders, cantilevers and pillars, see Section 10.

In case of transverse coamings of ships with large deck openings Section 5, E.8 is to be observed.

For structural members welded to coamings and for cutouts in the top of coaming sufficient fatigue strength according to Section 20 is to be verified.

(IACS UR S21A.5.4.1)

C.1.6 Longitudinal hatch coamings with a length exceeding $0.1 \cdot \mathbf{L}$ are to be provided with tapered brackets or equivalent transitions and a corresponding substructure at both ends. At the end of the brackets they are to be connected to the deck by full penetration welds of minimum 300 mm in length.

(IACS UR S21A.5.4.1)

C.1.7 Adequate safety against buckling according to Section 3, D is to be proved for longitudinal coamings which are part of the longitudinal hull structure.

(IACS UR S21A.3.6)

C.1.8 Hatchway coamings are to be adequately supported by stays

C.1.9 Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

Coaming stays are to be supported by appropriate substructures.

Under deck structures are to be designed under consideration of permissible stresses according to B.3.1.

(IACS UR S21.4.5, IACS UR S21A.5.3.1 and S21A.5.4.2)

C.1.10 On ships carrying cargo on deck, such as timber, coal or coke, the stays are to be spaced not more than 1.5 m apart. For containers on deck, see also Section 21, H.3.4.

(IACS UR S21A.5.4.3)

C.1.11 Coaming girders are to extend to the lower edge of the deck transverses; they are to be flanged or fitted with face bars or half-round bars.

(IACS UR S21A.5.4.4)

C.1.12 Coamings which are 600 mm or more in height are to be stiffened by a horizontal stiffener. Where the unsupported height of a coaming exceeds 1.2 m additional stiffeners are to be arranged. Additional stiffeners may be dispensed with if this is justified by the ship's service and if sufficient strength is verified (e.g. in case of container ships).

C.1.13 Stiffeners of hatch coamings are to be continuous over the breadth and length of hatch coamings.

(IACS UR S21A.1.4)

C.1.14 The connection of the coamings to the deck at the hatchway corners is to be carried out with special care. For bulk carriers, see also Section 23, C.8.

For rounding of hatchway corners, see also Section 7, B.3.

C.2 Scantlings

C.2.1 Plating

C.2.1.1 The thickness t of weather deck hatch coamings is not to be less than determined by the following formula:

$$t = c \cdot a \cdot \sqrt{\frac{p_A}{R_{eH}}} + t_K \quad [\mathrm{mm}] \qquad \text{with } t \geq t_{min}$$

t_{min} : minimum thickness of weather deck hatch coamings [mm], defined as:

$t_{min} = 9.5 + t_K \quad [\mathrm{mm}]$ for bulk carrier according to Section 23

$t_{min} = 6 + \frac{L_{300}}{100} + t_K \quad [\mathrm{mm}]$ for all other ships

c : coefficient, defined as:

$c = 16.4$ for bulk carrier according to Section 23

$c = 14.6$ for all other ships

The thickness of weather deck hatch coamings, which are part of the longitudinal hull structure, is to be designed analogously to side shell plating according to Section 6.

(IACS UR S21.4.2 and IACS UR S21A.5.1)

C.2.1.2 For grab operation see also Section 23, J.

C.2.2 Coaming stays

C.2.2.1 Coaming stays are to be designed for the loads and permissible stresses according to B.

(IACS UR S21A.5.3)

C.2.2.2 The net section modulus W_{net} of coaming stays of coamings having a height of $h_s < 1.6$ m and which are to be designed for the load p_A, is not to be less than determined by the following formula:

$$W_{net} = \frac{526}{R_{eH}} \cdot e \cdot h_s^2 \cdot p_A \quad [cm^3]$$

e : spacing [m] of coaming stays

h_s : height [m] of coaming stays

Coaming stays of coamings having a height of 1.6 m or more are to be designed using direct calculations.

For the calculation of W_{net} the effective breadth of the coaming plate is not to be larger than the effective plate width according to Section 3, D.3.2.

Face plates may only be included in the calculation if an appropriate substructure is provided and welding ensures an adequate joint.

(IACS UR S21.4.4 and IACS UR S21A.5.3.1)

C.2.2.3 The web thickness t_w of coaming stays at its lower end is not to be less than determined by the following formula:

$$t_w = \frac{2}{R_{eH}} \cdot \frac{e \cdot h_s \cdot p_A}{h_w} + t_K \quad [mm]$$

e : spacing [m] of coaming stays

h_s : height [m] of coaming stays

h_w : web height [m] of coaming stay at its lower end

Webs are to be connected to the decks by fillet welds on both sides with a throat thickness of $a = 0.44 \cdot t_w$. For toes of stay webs within $0.15 \cdot h_w$ the throat thickness is to be increased to $a = 0.7 \cdot t_w$ for $t_w \le 10$ mm. For $t_w > 10$ mm deep penetration double bevel welds are to be provided in this area.

(IACS UR S21.4.4, IACS UR S21.4.5 and IACS UR S21A.5.3.2)

C.2.2.4 For coaming stays, which transfer friction forces at hatch cover supports, sufficient fatigue strength according to Section 20 is to be verified, refer also to B.5.5.

(IACS UR S21A.5.3.3)

C.2.3 Horizontal stiffeners

The stiffeners are to be continuous at the coaming stays. For stiffeners with both ends constraint the elastic net section modulus W_{net} and net shear area $A_{s,net}$ are not to be less than determined by the following formulae:

$$W_{net} = \frac{c \cdot a \cdot \ell^2 \cdot p_A}{f_p \cdot R_{eH}} \quad [cm^3]$$

$$A_{s,net} = \frac{10 \cdot a \cdot \ell \cdot p_A}{R_{eH}} \quad [cm^2]$$

c : coefficient, defined as:

$c = 75$ for bulk carrier according to Section 23

$c = 83$ for all other ships

f_p : ratio of plastic and elastic section modulus, defined as:

$$f_p = \frac{W_{p\ell}}{W_{e\ell}} \le \frac{R_m}{R_{eH}}$$ for bulk carrier according to Section 23

$f_p = 1.16$ can be used in the absence of more precise evaluation

$f_p = 1.0$ for ships other than bulk carrier according to Section 23

$W_{p\ell}$: plastic section modulus

$W_{e\ell}$: elastic section modulus

For sniped stiffeners at coaming corners section modulus and shear area at the fixed support have to be increased by $35\ \%$. The thickness of the coaming plate at the sniped stiffener end is not to be less than according to Section 3, B.2.3.

Horizontal stiffeners on hatch coamings, which are part of the longitudinal hull structure, are to be designed analogously to longitudinals according to Section 9.

(IACS UR S21.4.3 and IACS UR S21A.5.2)

D Weather tightness of hatch cover systems

D.1 General

For weather deck hatch covers packings are to be provided, for exceptions see D.3.

D.2 Packing material

D.2.1 The packing material is to be suitable for all expected service conditions of the ship and is to be compatible with the cargoes to be transported.

The packing material is to be selected with regard to dimensions and elasticity in such a way that expected deformations can be carried. Forces are to be carried by the steel structure only.

The packings are to be compressed so as to give the necessary tightness effect for all expected operating conditions.

Special consideration is to be given to the packing arrangement in ships with large relative movements between hatch covers and coamings or between hatch cover sections.

(IACS UR S21A.4.2.1)

D.2.2 If the requirements in D.3 are fulfilled the weather tightness can be dispensed with.

D.3 Non-weathertight hatch covers

D.3.1 Upon request and subject to compliance with the following conditions the fitting of weather tight gaskets according to D.2 may be dispensed with for hatch covers of cargo holds solely for the transport of containers:

- The hatchway coamings are to be not less than $600\ \text{mm}$ in height.
- The exposed deck on which the hatch covers are located is situated above a depth $H(x)$, which is to be shown to comply with the following calculated criteria:

$$H(x) \ge T_{fb} + f_b + h \quad [\text{m}]$$

T_{fb} : draught [m] corresponding to the assigned summer load line

f_b : minimum required freeboard [m] determined in accordance with **ICLL**

h : height [m], defined as:

$$h = 4.6 \qquad \text{for } \frac{x}{L} \le 0.75$$

$$h = 6.9 \qquad \text{for } \frac{x}{L} > 0.75$$

- Labyrinths or equivalents are to be fitted proximate to the edges of each panel in way of the coamings. The clear profile of these openings is to be kept as small as possible.
- Where a hatch is covered by several hatch cover panels the clear opening of the gap in between the panels is to be not wider than 50 mm.
- The labyrinths and gaps between hatch cover panels are to be considered as unprotected openings with respect to the requirements of intact and damage stability calculations.
- With regard to drainage of cargo holds and the necessary fire-fighting system reference is made to the GL Rules for Machinery Installations (I-1-2), Sections 11 and 12.
- Bilge alarms should be provided in each hold fitted with non-weathertight covers.
- Furthermore, the requirements for the carriage of dangerous goods are to be complied with, refer to Chapter 3 of IMO MSC/Circ. 1087.

  (IACS UR S21A.4.2.2)

D.3.2 Securing devices

In the context of D.3 an equivalence to B.5.6 can be considered subject to:

- the proof that in accordance with B.2.3 (load case C) securing devices are not to be required and additionally
- the transverse cover guides are effective up to a height h_E above the cover supports, see Fig. 17.6. The height h_E is not be less than determined by the following formula:

$$h_E = 1.75 \cdot \sqrt{2 \cdot e \cdot s} \quad [\text{mm}] \qquad \text{with } h_E \ge h_F + 150$$

h_F : height [mm]of the face plate

e : largest distance [mm] of the cover guides from the longitudinal face plate

s : total clearance [mm], with:

$$10 \le s \le 40$$

The transverse guides and their substructure are to be dimensioned in accordance with the loads given in B.2.6 acting at the position h_E using the equivalent stress level $\sigma_v = R_{eH}$ [N/mm²].

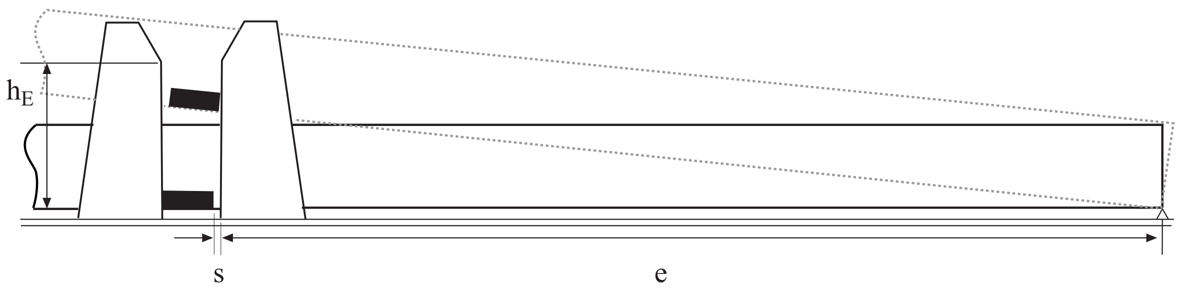


Fig. 17.6 Height of transverse cover guides

D.4 Drainage arrangements

D.4.1 Drainage arrangement at hatch covers

Cross-joints of multi-panel covers are to be provided with efficient drainage arrangements.

(IACS UR S21A.4.2.3)

D.4.2 Drainage arrangement at hatch coamings

If drain channels are provided inside the line of gasket by means of a gutter bar or vertical extension of the hatch side and end coaming, drain openings are to be provided at appropriate positions of the drain channels.

Drain openings in hatch coamings are to be arranged with sufficient distance to areas of stress concentration (e.g. hatch corners, transitions to crane posts).

Drain openings are to be arranged at the ends of drain channels and are to be provided with non-return valves to prevent ingress of water from the outside. It is unacceptable to connect fire hoses to the drain openings for this purpose.

If a continuous outer steel contact between cover and ship structure is arranged, drainage from the space between the steel contact and the gasket is also to be provided for.

(IACS UR S21A.5.4.5)

D.5 Tightness test, trials

D.5.1 The self-tightening steel hatch covers on weather decks and within open superstructures are to be hose tested. The water pressure in the hose nozzle is not to be less than 2 bar and the hose nozzle is to be held at a distance of not more than 1.5 m from the hatch cover to be tested. The nozzle diameter is not to be less than 12 mm. During frost periods equivalent tightness tests may be carried out to the satisfaction of the Surveyor.

(IACS UR S14.4.4.3 and Table 1)

D.5.2 Upon completion of the hatchway cover system trials for proper functioning are to be carried out in presence of the Surveyor.

(IACS UR S14.4.1)

Section 18 Equipment

A General

A.1 Application

A.1.1 Every ship is to be equipped with at least one anchor windlass.

A.1.2 The equipment of anchors and chain cables as well as the recommended equipment of wires and ropes is to be determined from Table 18.2 in accordance with the equipment numeral Z_1 or Z_2, respectively.

A.1.3 For ships having the navigation notation **RSA (20)** or **RSA (50)** affixed to their character of classification, the equipment may be determined as for one numeral range lower than required in accordance with the equipment numeral Z_1 or Z_2, respectively.

A.1.4 The anchoring equipment required by this Section is intended of temporary mooring of a vessel within a harbour or sheltered area when the vessel is awaiting berth, tide, etc.

The equipment is, therefore, not designed to hold a ship off fully exposed coasts in rough weather or to stop a ship which is moving or drifting. In this condition the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost owing to the high energy forces generated, particularly in large ships.

The anchoring equipment required by this Section is designed to hold a ship in good holding ground in conditions such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors will be significantly reduced.

The equipment numeral formula for anchoring equipment required under this Section is based on an assumed current speed of $2.5\ \mathrm{m/sec}$, wind speed of $25\ \mathrm{m/sec}$ and a scope of chain cable between 6 and 10, the scope being the ratio between length of chain paid out and water depth.

It is assumed that under normal circumstances a ship will use only one bower anchor and chain cable at a time.

(IACS UR A1.1)

A.2 References

A.2.1 Paragraphs of this section are based on the following international convention(s) and/or code(s):

IACS UR A1 Rev. 3

IACS UR A2 Rev. 3

At the end of each relevant paragraph, the corresponding paragraphs of the international convention(s) and / or code(s) are given in brackets.

A.2.2 For the substructures of windlasses and chain stoppers, see Section 10, B.3.

A.2.3 For the location of windlasses and chain lockers on tankers, see Section 24.

A.2.4 When determining the equipment for ships having the navigation notation **RSA (SW)** affixed to their character of classification, the provisions of Section 30, F are to be observed.

A.2.5 When determining the equipment for tugs, Section 25, G is to be observed.

A.2.6 When determining the equipment of barges and pontoons, Section 31, F is to be observed.

A.2.7 Windlasses and chain stoppers, if fitted, are to comply with the GL Rules for Machinery Installations (I-1-2), Section 14, D.

A.2.8 For Seagoing ships navigating on inland waters and rivers are to have anchor equipment also complying with the Regulations of the competent authorities.

A.3 Definitions

Stern anchor

A stern anchor in the sense of these Rules is named a stream anchor of small seagoing ships, i.e. up to and including the equipment numeral of $Z_1 = 205$.

Shipboard fitting

Shipboard fittings mean those components limited to the following: bollards and bitts, fairleads, stand rollers, chocks used for the mooring of the vessel and the similar components used for the towing of the vessel.

(IACS UR A2.0)

Supporting hull structure

Supporting hull structures means that part of the ship structure on/in which the shipboard fitting is placed and which is directly submitted to the forces exerted on the shipboard fitting.

(IACS UR A2.0)

Symbols

D : moulded displacement [t] in sea water having a density of $1.025\ t/m^3$ to the summer load waterline

B Equipment numeral

B.1 The equipment numeral Z_1 for anchors and chain cables is to be determined by the following formula:

$$Z_1 = D^{2/3} + 2 \cdot h \cdot \mathbf{B} + \frac{A}{10}$$

h : effective height [m] from the summer load waterline to the top of the uppermost house, defined as:

$$h = a + \sum h_i$$

a : distance [m] from the summer load waterline, amidships, to the upper deck at side

$\sum h_i$: sum of height [m] of superstructures and deckhouses on the upper deck, measured on the centreline of each tier having a breadth greater than $\mathbf{B}/4$. Deck sheer, if any, is to be ignored. For the lowest tier, h is to be measured at centreline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck.

A : area [m^2], in profile view of the hull, superstructures and deckhouses, having a breadth greater than $\mathbf{B} / 4$, above the summer load waterline within the length $\mathbf{L}$ and up to the height h

Where a deckhouse having a breadth greater than $\mathbf{B} / 4$ is located above a deckhouse having a breadth of $\mathbf{B} / 4$ or less, the wider house is to be included and the narrow house ignored.

Screens of bulwarks $1.5\ \mathrm{m}$ or more in height are to be regarded as parts of houses when determining h and A, e.g. the area shown in Fig. 18.1 as A_1 is to be included in A. The height of the hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A.

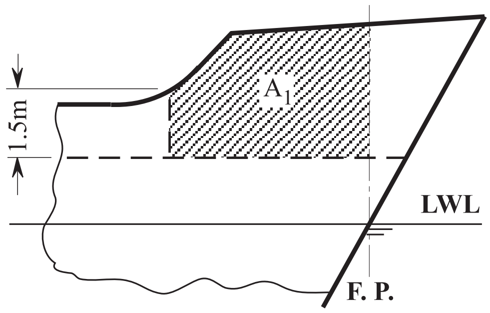


Fig. 18.1 Effective area A_1 of bulwark

(IACS UR A1.2)

B.2 The equipment numeral Z_2 for the recommended selection of ropes as well as for the determination of the design load for shipboard towing and mooring equipment and supporting hull structure is to be determined by the following formula:

$$Z_2 = D^{2/3} + 2 \cdot h \cdot \mathbf{B} + \frac{A}{10}$$

h : effective height [m] from the summer load waterline to the top of the uppermost house, defined as:

$$h = a + \sum h_i$$

a : distance [m] from the summer load waterline, amidships, to the upper deck at side

$\sum hi$: sum of height [m] of superstructures and deckhouses on the upper deck, measured on the centreline of each tier. Deck sheer, if any, is to be ignored. For the lowest tier, h is to be measured at centreline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck.

A : area [m^2] in profile view of the hull, superstructures and deckhouses above the summer load waterline within the length $\mathbf{L}$.

Screens of bulwarks, hatch coamings and deck equipment, e.g., masts and lifting gear, as well as containers on deck have to be observed for the calculation of A.

C Anchors

C.1 General

C.1.1 The number of bower anchors is to be determined according to column 3 of Table 18.2. Two of the rule bower anchors are to be connected to their chain cables and positioned on board ready for use.

Where in column 3 of Table 18.2 two bower anchors are required, a stream anchor is to be on board as a third anchor. Its mass is to be according to column 5 of the table. Length and breaking load of chain or stream wire respectively are to be as given in columns 10 and 11.

Where in column 3 of Table 18.2 three bower anchors are required, the third anchor is intended as a spare bower anchor. Installation of the spare bower anchor on board is not required.

The spare anchor is not required as a condition of classification and, with owner's consent, may be dispensed with.

(IACS UR A1.4.2)

C.1.2 It is to be ensured that each anchor can be stowed in the hawse and hawse pipe in such a way that it remains firmly secured in seagoing conditions. Details have to be coordinated with the owner.

C.1.3 National regulations concerning the provision of a spare anchor, stream anchor or a stern anchor may need to be observed.

C.2 Stock anchors

For stock anchors, the total mass of the anchor, including the stock, is to comply with the values in Table 18.2. The mass of the stock is to be 20 % of this total mass.

C.3 Ordinary (stockless) anchors

C.3.1 Ordinary anchors of “stockless” type are to be generally adopted and they are to be of approved design.

(IACS UR A1.4.1.1(a))

C.3.2 The mass of the heads of patent (ordinary stockless) anchors, including pins and fittings, is not to be less than 60 % of the total mass of the anchor.

(IACS UR A1.4.1.1(b))

C.3.3 The mass of each individual bower anchor may vary by up to 7 % above or below the required individual mass provided that the total mass of all the bower anchors is not less than the sum of the required individual masses.

(IACS UR A1.4.1.1(c))

C.4 High Holding Power Anchors

C.4.1 "High Holding Power Anchors" are anchors which are suitable for ship's use at any time and which do not require prior adjustment or special placement on the sea bed.

(IACS UR A1.4.1.2(a))

C.4.2 Where special anchors approved as "High Holding Power Anchors" are used, the anchor mass may be 75 % of the anchor mass as per Table 18.2.

(IACS UR A1.4.1.2(b))

C.4.3 For approval as a "High Holding Power Anchor", satisfactory tests are to be made on various types of bottom and the anchor is to have a holding power at least twice that of a patent anchor ("Admiralty Standard Stockless") of the same mass. The mass of anchors to be tested should be representative of the full range of sizes intended to be manufactured. The tests are to be carried out on at least two sizes of anchors in association with the chain cables appropriate to the weight. The anchors to be tested and the standard stockless anchors should be of approximately the same mass.

The chain length used in the tests should be approximately 6 to 10 times the depth of water.

The tests are normally to be carried out from a tug, however, alternative shore based tests (e.g. with suitable winches) may be accepted.

Three tests are to be carried out for each anchor and type of bottom. The pull is to be measured by means of a dynamometer or recorded by a recording instrument. Measurements of pull based on rpm/bollard pull curve of the tug may be accepted.

Testing by comparison with a previously approved HHP anchor may be accepted as a basis for approval. The maximum mass of an anchor thus approved may be 10 times the mass of the largest size of anchor tested.

The dimensioning of the chain cable and of the windlass is to be based on the undiminished anchor mass according to the Tables.

(IACS UR A1.4.1.2(c))

C.5 Stern anchor

C.5.1 Where stern anchor equipment is fitted, the diameter of the chain cables is to be determined from the Tables in accordance with the anchor mass. The stern anchor is to be connected to the chain cable and positioned on board ready for use. It is to be ensured that the anchor can be stowed in such a way that it remains firmly secured in seagoing conditions. Where a stern anchor windlass is fitted the requirements of the GL Rules for Machinery Installations (I-1-2), Section 14, are to be observed.

C.5.2 Where a steel wire rope is to be used for the stern anchor instead of a chain cable the following has to be observed:

C.5.2.1 The strength of the steel wire rope is to be at least of the value for the required chain of grade K1.

C.5.2.2 Between anchor and steel wire rope a shot of $12.5 \mathrm{~m}$ in length or of the distance between stowed anchor and windlass is to be provided. The smaller length has to be taken.

C.5.2.3 A cable winch is to be provided according to the requirements for windlasses in the GL Rules for Machinery Installation (I-1-2), Section 14, B.

D Chain Cables

D.1 The chain cable diameters given in the Tables apply to chain cables made of chain cable materials specified in the GL Rules for Metallic Materials (II-1), for the following grades:

- Grade K1 (ordinary quality)
- Grade K2 (special quality)
- Grade K3 (extra special quality)

(IACS UR A1.5.1.1)

D.2 Grade K1 material used for chain cables in conjunction with "High Holding Power Anchors" is to have a tensile strength R_m of not less than $400 \mathrm{~N/mm^2}$.

D.3 Grade K2 and K3 chain cables are to be post production quenched and tempered and purchased from recognized manufacturers only.

D.4 The total length of chain given in Table 18.2 is to be divided in approximately equal parts between the two bower anchors.

(IACS UR A1.2 Note 5)

D.5 Either stud link or short link chain cables may be used for stream anchors.

D.6 For connection of the anchor with the chain cable approved Kenter-type anchor shackles may be chosen in lieu of the common Dee-shackles. A forerunner with swivel is to be fitted between anchor and chain cable. In lieu of a forerunner with swivel an approved swivel shackle may be used. However, swivel shackles are not to be connected to the anchor shank unless specially approved. A sufficient number of suitable spare shackles are to be kept on board to facilitate fitting of the spare anchor at any time. On owner's request the swivel shackle may be dispensed with.

D.7 The attachment of the inboard ends of the chain cables to the ship's structure is to be provided with means suitable to permit, in case of emergency, an easy slipping of the chain cables to sea operable from an accessible position outside the chain locker.

The inboard ends of the chain cables are to be secured to the structures by a fastening able to withstand a force not less than 15 % nor more than 30 % of the rated breaking load of the chain cable.

E Chain Locker

E.1 The chain locker is to be of capacity and depth adequate to provide an easy direct lead of the cables through the chain pipes and self-stowing of the cables.

The minimum required stowage capacity without mud box for the two bower anchor chains is as follows:

$$S = 1.1 \cdot d^2 \cdot \ell \cdot 10^{-5} \quad [m^3]$$

d : chain diameter [mm] according to Table 18.2

ℓ : total length of stud link chain cable according to Table 18.2

The total stowage capacity is to be distributed on two chain lockers of equal size for the port and starboard chain cables. The shape of the base areas is as far as possible to be quadratic with a maximum edge length of $33 \cdot d$. As an alternative, circular base areas may be selected, the diameter of which is not to exceed $30 - 35 \cdot d$.

Above the stowage of each chain locker in addition a free depth h of is to be provided, which is to be determined by the following formula:

$$h = 1\,500 \quad [mm]$$

E.2 The chain locker boundaries and their access openings are to be watertight.

E.2.1 Special requirements to minimize the ingress of water

E.2.1.1 Spurling pipes and cable lockers are to be watertight up to the weather deck.

E.2.1.2 Where means of access is provided, it is to be closed by manhole covers of international standard or recognised national standard.

E.2.1.3 Spurling pipes through which anchor cables are led are to be provided with permanently attached closing appliances to minimize water ingress.

E.3 Adequate drainage facilities of the chain locker are to be provided.

E.4 Where the chain locker boundaries are also tank boundaries their scantlings of stiffeners and plating are to be determined as for tanks in accordance with Section 12.

Where this is not the case the plate thickness is to be determined as for t_2 and the section modulus as for W_2 in accordance with Section 12, B.1 and Section 12, B.2 respectively. The distance from the load centre to the top of the chain locker pipe is to be taken for calculating the load.

E.5 For the location of chain lockers on tankers Section 24, D.3 is to be observed.

F Mooring Equipment

F.1 Shipboard fittings and supporting deck structures

F.1.1 Strength

The strength of shipboard fittings used for mooring operations and their supporting hull structures are to comply with the requirements of the following paragraphs.

(IACS UR A2.2.1)

F.1.2 Load considerations

F.1.2.1 Unless greater safe working load (SWL_{GL}) of shipboard fittings is specified by the applicant, the design load applied to shipboard fittings and supporting hull structures is to be 1.25 times the breaking strength of the mooring line according to Table 18.2 for the equipment numeral Z_2.

When ropes with increased breaking strength are used, the design load needs not to be in excess of 1.25 times the breaking strength of the mooring line according to Table 18.2 for the equipment numeral Z_2. This is not applicable, if the breaking strength of the ropes is increased in accordance with F.3.4.

(IACS UR A2.2.3.1)

F.1.2.2 The design load applied to supporting hull structures for winches, etc. is to be the design load according to F.1.2.1. For capstans, the minimum design load is to be 1.25 times the maximum hauling-in force.

(IACS UR A2.2.3.2)

F.1.2.3 The design load is to be applied through the mooring line according to the arrangement shown on the towing and mooring arrangement plan.

(IACS UR A2.2.3.3)

F.1.2.4 The method of application of the design load to the fittings and supporting hull structures is to be taken into account such that the total load need not be more than twice the design load specified in F.1.2.1 above, i.e. no more than one turn of one line, see Fig. 18.2

(IACS UR A2.2.3.4)

F.1.2.5 When a specific SWL_{GL}, that is greater than required in F.1.5.1, is applied for a fitting at the request of the applicant, the fitting and the supporting hull structure have to be designed using the requested SWL_{GL} times 1.875 as design load.

(IACS UR A2.2.3.5)

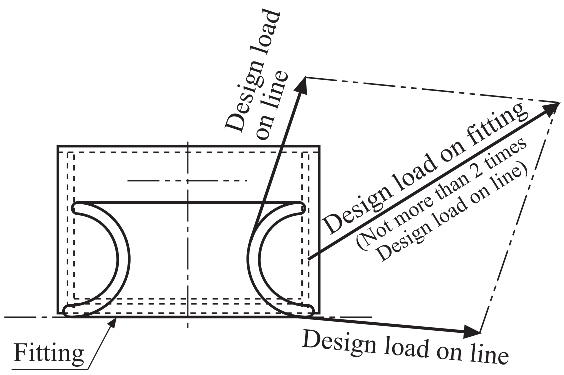


Fig. 18.2 Application of design loads

F.1.3 Shipboard fittings

F.1.3.1 Arrangement

Shipboard fittings for mooring are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the mooring load. Other arrangements may be accepted provided the strength is confirmed adequate for the service.

(IACS UR A2.2.2)

F.1.3.2 Selection

The selection of shipboard fittings is to be made by the shipyard in accordance with an industry standard (e.g. ISO 3913 Shipbuilding Welded Steel Bollards) accepted by GL. In such cases the safety factors of the standard are to be complied with. When the shipboard fitting is not selected from an accepted industry standard, the design load used to assess its strength and its attachment to the ship is to be assessed in accordance with F.1.2.

(IACS UR A2.2.4)

F.1.4 Supporting hull structures

F.1.4.1 Strength

Strength calculations for supporting hull structures of mooring equipment are to be based on net thicknesses.

$$t_{net} = t - t_K \quad [\mathrm{mm}]$$

t_k : corrosion addition as defined in F.1.4.5

(IACS UR A2.0)

F.1.4.2 Arrangement

Arrangement of the reinforced members beneath shipboard fittings is to consider any variation of direction (horizontally and vertically) of the mooring forces (which is to be not less than the design load as per F.1.2) acting through the arrangement of connection to the shipboard fittings.

(IACS UR A2.2.5(1))

F.1.4.3 Acting point of mooring force

The acting point of the mooring force on shipboard fittings is to be taken at the attachment point of a mooring line or at a change in its direction.

For bollards, the acting point of the design load is to be taken at least equivalent to the diameter of the pipe above deck level. Special designs have to be evaluated individually.

(IACS UR A2.2.5(2))

F.1.4.4 Allowable stresses

Allowable stresses under the design load conditions as specified in F.1.2 are as follows:

$\sigma_N \le R_{eH}$	for normal stresses
$\tau \le 0.6 \cdot R_{eH}$	for shear stresses
$\sigma_v \le R_{eH}$	for equivalent stresses

(IACS UR A2.2.5(3))

F.1.4.5 Corrosion addition

The total corrosion addition t_k for both sides of the hull supporting structure is not to be less than the following values:

$t_k = 2.0 \quad \text{mm}$ in general

$t_k = 1.0 \quad \text{mm}$ in dry spaces

(IACS UR A2.4)

F.1.5 Safe working load (SWL_{GL})

F.1.5.1 The safe working load SWL_{GL} for fittings is to be determined by the following formula:

$$SWL_{GL} = \frac{F_D}{1.875}$$

F_D : design load according to F.1.2

F.1.5.2 The SWL_{GL} of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for mooring.

F.1.5.3 The above requirements on SWL_{GL} apply for a single post basis (no more than one turn of one cable).

F.1.5.4 The towing and mooring arrangement plan mentioned in H is to define the method of use of mooring lines.

(IACS UR A2.2.6)

F.2 Equipment for mooring at single point moorings (SPM)

F.2.1 Upon request from the owner, GL is prepared to certify that the vessel is specially fitted for compliance with the applicable sections of "Recommendations for Equipment Employed in the Bow Mooring of Conventional Tankers at Single Point Moorings" published by the Oil Companies International Marine Forum (OCIMF), 2007.

F.2.2 For tankers employed in shuttle service using single point moorings (SPM) Section 24, P has to be observed.

F.3 Ropes

F.3.1 The following items F.3.2 to F.3.4 and the Table 18.1 and Table 18.2 for tow lines and mooring ropes are recommendations only, a compliance with which is not a condition of Class.

F.3.2 For tow lines and mooring lines, steel wire ropes as well as fibre ropes made of natural or synthetic fibres or wire ropes consisting of steel wire and fibre cores may be used. The breaking loads specified in Table 18.2 are valid for wire ropes and ropes of natural fibre (manila) only. Where ropes of synthetic fibre are used, the breaking load is to be increased above the table values. The extent of increase depends on the material quality.

The required diameters of synthetic fibre ropes used in lieu of steel wire ropes may be taken from Table 18.1.

Table 18.1 Wire / fibre ropes diameter

Steel wire ropes [1]	Synthetic wire ropes	Fibre ropes		
	polyamide [2]	polyamide	polyester	polypro-pylene
12	30	30	30	30
13	30	32	32	32
14	32	36	36	36
16	32	40	40	40
18	36	44	44	44
20	40	48	48	48
22	44	48	48	52
24	48	52	52	56
26	56	60	60	64
28	60	64	64	72
32	68	72	72	80
36	72	80	80	88
40	72	88	88	96

[1] according to DIN 3068 or similar.
[2] Regular laid ropes of refined polyamide monofilaments and filament fibres.

F.3.3 Where the stream anchor is used in conjunction with a rope, this is to be a steel wire rope.

F.3.4 For individual mooring lines with a breaking load above 490 kN the following alternatives may be applied:

- The breaking load of the individual mooring lines specified in Table 18.2 may be reduced with corresponding increase of the number of mooring lines, provided that the total breaking load of all lines aboard ship is not less than the rule value as per Table 18.2. No mooring line, however, should have a breaking load of less than 490 kN.
- The number of mooring lines may be reduced with corresponding increase of the breaking load of the individual mooring lines, provided that the total breaking load of all lines aboard ship is not less than the rule value specified in Table 18.2, however, the number of lines should not be less than 6.

(IACS UR A2.2.3 Note 3)

G Towing Equipment

G.1 Shipboard fittings and supporting hull structures

G.1.1 Strength

G.1.1.1 The strength of shipboard fittings used for normal towing operations (not emergency towing) at bow, sides and stern and their supporting hull structures are to be determined on the basis of the following paragraphs.

(IACS UR A2.1.1)

G.1.2 Load considerations

G.1.2.1 Unless greater safe working load (SWL_{GL}) of shipboard fittings is specified by the applicant, the minimum design load to be used is the following value of 1. or 2., whichever is applicable:

1. for normal towing operations (e.g., in harbour) using fittings at bow, sides and stern, 1.875 times the intended maximum towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangement plan.

   If the intended maximum towing load is not specified by the applicant, 1.25 times the nominal breaking strength of the corresponding mooring lines according to Table 18.2 for the equipment numeral Z_2 is to be applied.

2. for other towing service using the forward main towing fittings, in general arranged on forecastle deck at the vessel's centre line, the nominal breaking strength of the tow line according to Table 18.2 for the equipment numeral Z_2.

(IACS UR A2.1.3)

G.1.2.2 The design load is to be applied through the tow line according to the arrangement shown on the towing and mooring arrangement plan.

(IACS UR A2.1.3)

G.1.2.3 When a specific SWL_{GL}, that is greater than required in G.1.5 is applied for a fitting at the request of the applicant, the fitting and the supporting hull structure have to be designed using the following design loads:

- requested SWL_{GL} times 1.875 for normal towing operations
- requested SWL_{GL} times 1.500 for other towing service

(IACS UR A2.1.3)

G.1.2.4 The method of application of the design load to the fittings and supporting hull structures is to be taken into account such that the total load need not be more than twice the design load, i.e. no more than one turn of one line, see Fig. 18.2.

(IACS UR A2.1.3)

G.1.3 Shipboard fittings

G.1.3.1 Arrangement

Shipboard fittings for towing are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the towing load. Other arrangements may be accepted provided the strength is confirmed adequate for the intended service.

(IACS UR A2.1.2)

G.1.3.2 Selection

The selection of shipboard fittings is to be made by the shipyard in accordance with an Industry standard (e.g. ISO3913 Shipbuilding Welded Steel Bollards) accepted by the society. When the shipboard fitting is not selected from an accepted Industry standard, the design load used to assess its strength and its attachment to the ship is to be in accordance with G.1.2.

(IACS UR A2.1.4)

G.1.4 Supporting hull structures

G.1.4.1 Strength

Strength calculations are to be based on net thicknesses:

$$t_{net} = t - t_K \quad [\mathrm{mm}]$$

t_k : corrosion addition according to F.1.4.5

(IACS UR A2.0)

G.1.4.2 Arrangement

The reinforced members beneath shipboard fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the towing forces (which is to be not less than the Design Load according to G.1.2) acting through the arrangement of connection to the shipboard fittings.

(IACS UR A2.1.5(1))

G.1.4.3 Acting point of towing force

The acting point of the towing force on shipboard fittings is to be taken at the attachment point of a towing line or at a change in its direction.

For bollards, the acting point of the design load is to be taken at least equivalent to the diameter of the pipe above deck level. Special designs have to be evaluated individually.

(IACS UR A2.1.5(2))

G.1.4.4 Allowable stresses

Allowable stresses under the design load conditions as specified in G.1.2 are to be taken according to F.1.4.4.

(IACS UR A2.1.5(3))

G.1.5 Safe working load (SWL_{GL})

G.1.5.1 The safe working load for a shipboard fitting used for towing operations is not to exceed the following value:

$$SWL_{GL} = \frac{F_D}{S}$$

F_D : design load, defined as:

F_D according to G.1.2 (1)	for normal towing operations
F_D according to G.1.2 (2)	for other towing service (i.e., for the forward main towing fittings)
F_D according to Panama Canal Regulations	for chocks and bollards of which the strength is to comply with Panama Canal Regulations

S : safety factor, defines as:

$S = 1.875$	for normal towing operations and
	for chocks and bollards of which the strength is to comply with Panama Canal Regulations
$S = 1.500$	for other towing service (i.e., for the forward main towing fittings)

(IACS UR A2.1.6.1)

G.1.5.2 The SWL_{GL} of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for towing.

For fittings, which are used for different mooring or towing operations, the greater of the safe working loads SWL_{GL} is to be marked.

(IACS UR A2.1.6.2)

G.1.5.3 The above requirements on SWL_{GL} apply for a single post basis (no more than one turn of one cable).

(IACS UR A2.1.6.3)

G.1.5.4 The towing and mooring arrangement plan mentioned in H is to define the method of use of towing lines.

(IACS UR A2.1.6.4)

G.2 Shipboard fittings and supporting hull structures for escort towing

For shipboard fittings intended to be used for escort towing as required e.g. for laden tankers in some areas in the United States, the provisions in G.1 as given for other towing services are to be applied analogously.

H Towing and Mooring Arrangement Plan

The SWL_{GL} for the intended use for each shipboard fitting is to be noted in the towing and mooring arrangement plan available on board for the guidance of the Master.

Information provided on the plan is to include in respect of each shipboard fitting:

- location on the ship
- fitting type
- SWL_{GL}
- purpose (mooring, normal towing operations / other towing services)
- manner of applying towing or mooring line load including limiting fleet angles
- the arrangement of mooring lines showing number of lines and the breaking strength of each mooring line

This information is to be incorporated into the pilot card in order to provide the pilot proper information on harbour / escorting operations.

Table 18.2 Anchor, Chain Cables and Ropes

No. for Reg.	Equipment numeral Z_1 or Z_2	Stockless anchor			Stud link chain cables						Recommended ropes				
		Bower anchor		Stream anchor	Bower anchors				Stream wire or chain for stream anchor		Towline		Mooring ropes		
		Number [1]	Mass per anchor		Total length	Diameter			Length	Br. Load [2]	Length	Br. Load [2]	Number	Length	Br. Load [2]
						d_1	d_2	d_3							
			[kg]		[m]	[mm]			[m]	[kN]	[m]	[kN]		[m]	[kN]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
101	up to 50	2	120	40	165	12,5	12,5	12,5	80	65	180	100	3	80	35
102	50 – 70	2	180	60	220	14	12,5	12,5	80	65	180	100	3	80	35
103	70 – 90	2	240	80	220	16	14	14	85	75	180	100	3	100	40
104	90 – 110	2	300	100	247.5	17.5	16	16	85	80	180	100	3	110	40
105	110 – 130	2	360	120	247.5	19	17.5	17.5	90	90	180	100	3	110	45
106	130 – 150	2	420	140	275	20.5	17.5	17.5	90	100	180	100	3	120	50
107	150 – 175	2	480	165	275	22	19	19	90	110	180	100	3	120	55
108	175 – 205	2	570	190	302.5	24	20.5	20.5	90	120	180	110	3	120	60
109	205 – 240	3	660		302.5	26	22	20.5			180	130	4	120	65
110	240 – 280	3	780		330	28	24	22			180	150	4	120	70
111	280 – 320	3	900		357.5	30	26	24			180	175	4	140	80
112	320 – 360	3	1020		357.5	32	28	24			180	200	4	140	85
113	360 – 400	3	1140		385	34	30	26			180	225	4	140	95
114	400 – 450	3	1290		385	36	32	28			180	250	4	140	100
115	450 – 500	3	1440		412.5	38	34	30			180	275	4	140	110
116	500 – 550	3	1590		412.5	40	34	30			190	305	4	160	120
117	550 – 600	3	1740		440	42	36	32			190	340	4	160	130
118	600 – 660	3	1920		440	44	38	34			190	370	4	160	145
119	660 – 720	3	2100		440	46	40	36			190	405	4	160	160

120	720 – 780	3	2280	467.5	48	42	36			190	440	4	170	170
121	780 – 840	3	2460	467.5	50	44	38			190	480	4	170	185
122	840 – 910	3	2640	467.5	52	46	40			190	520	4	170	200
123	910 – 980	3	2850	495	54	48	42			190	560	4	170	215
124	980 – 1060	3	3060	495	56	50	44			200	600	4	180	230
125	1060 – 1140	3	3300	495	58	50	46			200	645	4	180	250
126	1140 – 1220	3	3540	522.5	60	52	46			200	690	4	180	270
127	1220 – 1300	3	3780	522.5	62	54	48			200	740	4	180	285
128	1300 – 1390	3	4050	522.5	64	56	50			200	785	4	180	305
129	1390 – 1480	3	4320	550	66	58	50			200	835	4	180	325
130	1480 – 1570	3	4590	550	68	60	52			220	890	5	190	325
131	1570 – 1670	3	4890	550	70	62	54			220	940	5	190	335
132	1670 – 1790	3	5250	577,5	73	64	56			220	1025	5	190	350
133	1790 – 1930	3	5610	577.5	76	66	58			220	1110	5	190	375
134	1930 – 2080	3	6000	577.5	78	68	60			220	1170	5	190	400
135	2080 – 2230	3	6450	605	81	70	62			240	1260	5	200	425
136	2230 – 2380	3	6900	605	84	73	64			240	1355	5	200	450
137	2380 – 2530	3	7350	605	87	76	66			240	1455	5	200	480
138	2530 – 2700	3	7800	632.5	90	78	68			260	1470	6	200	480
139	2700 – 2870	3	8300	632.5	92	81	70			260	1470	6	200	490
140	2870 – 3040	3	8700	632.5	95	84	73			260	1470	6	200	500
141	3040 – 3210	3	9300	660	97	84	76			280	1470	6	200	520
142	3210 – 3400	3	9900	660	100	87	78			280	1470	6	200	555
143	3400 – 3600	3	10500	660	102	90	78			280	1470	6	200	590
144	3600 – 3800	3	11100	687.5	105	92	81			300	1470	6	200	620
145	3800 – 4000	3	11700	687.5	107	95	84			300	1470	6	200	650
146	4000 – 4200	3	12300	687.5	111	97	87			300	1470	7	200	650
147	4200 – 4400	3	12900	715	114	100	87			300	1470	7	200	660
148	4400 – 4600	3	13500	715	117	102	90			300	1470	7	200	670
149	4600 – 4800	3	14100	715	120	105	92			300	1470	7	200	680
150	4800 – 5000	3	14700	742.5	122	107	95			300	1470	7	200	685
151	5000 – 5200	3	15400	742.5	124	111	97			300	1470	8	200	685
152	5200 – 5500	3	16100	742.5	127	111	97			300	1470	8	200	695
153	5500 – 5800	3	16900	742.5	130	114	100			300	1470	8	200	705
154	5800 – 6100	3	17800	742.5	132	117	102			300	1470	9	200	705
155	6100 – 6500	3	18800	742.5		120	107			300	1470	9	200	715
156	6500 – 6900	3	20000	770		124	111			300	1470	9	200	725
157	6900 – 7400	3	21500	770		127	114			300	1470	10	200	725
158	7400 – 7900	3	23000	770		132	117			300	1470	11	200	725
159	7900 – 8400	3	24500	770		137	122			300	1470	11	200	735
160	8400 – 8900	3	26000	770		142	127			300	1470	12	200	735
161	8900 – 9400	3	27500	770		147	132			300	1470	13	200	735
162	9400 – 10000	3	29000	770		152	132			300	1470	14	200	735
163	10000 – 10700	3	31000	770			137			300	1470	15	200	735
164	10700 – 11500	3	33000	770			142			300	1470	16	200	735
165	11500 – 12400	3	35500	770			147			300	1470	17	200	735
166	12400 – 13400	3	38500	770			152			300	1470	18	200	735
167	13400 – 14600	3	42000	770			157			300	1470	19	200	735
168	14600 – 16000	3	46000	770			162			300	1470	21	200	735

d_1 = chain diameter grade K1 (ordinary quality), see also D

d_2 = chain diameter grade K2 (special quality), see also D

d_3 = chain diameter grade K2 (extra special quality), see also D

1 see C.1

2 see F.3.2

(IACS UR A Table 1)

Section 19 Welded Joints

Preface

The content of this Section is to a large extent identical to that of the GL Rules for Welding in the Various Fields of Application (II-3-3), Section 1, G. Because of the re-issues of Chapter 3 referred to and this Chapter 1 at different times, some temporary divergences may arise and in such circumstances the more recent Rules are to take precedence.

A General

A.1 Information contained in manufacturing documents

A.1.1 The shapes and dimensions of welds and, where proof by calculation is supplied, the requirements applicable to welded joints (the weld quality grade, detail category) are to be stated in drawings and other manufacturing documents (parts lists, welding and inspection schedules). In special cases, e.g. where special materials are concerned, the documents have also to state the welding method, the welding consumables used, heat input and control, the weld build-up and any post-weld treatment which may be required.

A.1.2 Symbols and signs used to identify welded joints are to be explained if they depart from the symbols and definitions contained in the relevant standards (e.g. DIN standards). Where the weld preparation (together with approved methods of welding) conforms both to normal shipbuilding practice and to these Rules and recognized standards, where applicable, no special description is needed.

A.2 Materials, weldability

A.2.1 Only base materials of proven weldability (see Section 2) may be used for welded structures. Any approval conditions of the steel or of the procedure qualification tests and the steelmaker's recommendations are to be observed.

A.2.2 For normal strength hull structural steels grades A, B, D and E which have been tested by GL, weldability normally is considered to have been proven. The suitability of these base materials for high efficiency welding processes with high heat input is to be verified.

A.2.3 Higher strength hull structural steels grade AH / DH / EH / FH which have been approved by GL in accordance with the relevant requirements of Rules for Materials and Welding normally have had their weldability examined and, provided their handling is in accordance with normal shipbuilding practice, may be considered to be proven. The suitability of these base materials for high efficiency welding processes with high heat input is to be verified.

A.2.4 High strength (quenched and tempered) fine grain structural steels, low temperature steels, stainless and other (alloyed) structural steels require special approval by GL. Proof of weldability of the respective steel is to be presented in connection with the welding procedure and welding consumables.

A.2.5 Cast steel and forged parts require testing by GL. For castings intended to be used for welded shipbuilding structures the maximum permissible values of the chemical composition according to the GL Rules for Steel and Iron Materials (II-1-2), Section 4, B.4. and Table 4.1 have to be observed.

A.2.6 Aluminium alloys require testing by GL. Proof of their weldability is to be presented in connection with the welding procedure and welding consumables.

A.2.7 Welding consumables used are to be suitable for the parent metal to be welded and are to be approved by GL.

A.3 Manufacture and testing

A.3.1 The manufacture of welded structural components may only be carried out in workshops or plants that have been approved. The requirements that have to be observed in connection with the fabrication of welded joints are laid down in the GL Rules for Welding (II-3).

A.3.2 The weld quality grade of welded joints without proof by calculation (see A.1.1) depends on the significance of the welded joint for the total structure and on its location in the structural element (location to the main stress direction) and on its stressing. For details concerning the type, scope and manner of testing, see the GL Rules for Welding in the Various Fields of Application (II-3-3), Section 1, I. Where proof of fatigue strength is required, in addition the requirements of Section 20 apply.

B Design

B.1 General design principles

B.1.1 During the design stage welded joints are to be planned such as to be accessible during fabrication, to be located in the best possible position for welding and to permit the proper welding sequence to be followed.

B.1.2 Both the welded joints and the sequence of welding involved are to be so planned as to enable residual welding stresses to be kept to a minimum in order that no excessive deformation occurs. Welded joints should not be over dimensioned, see also B.3.3.3.

B.1.3 When planning welded joints, it is first to be established that the type and grade of weld envisaged, such as full root weld penetration in the case of HV or DHV (K) weld seams, can in fact be perfectly executed under the conditions set by the limitations of the manufacturing process involved. If this is not the case, a simpler type of weld seam is to be selected and its possibly lower load bearing capacity taken into account when dimensioning the component.

B.1.4 Highly stressed welded joints - which, therefore, are generally subject to examination - are to be so designed that the most suitable method of testing for faults can be used (radiography, ultrasonic, surface crack testing methods) in order that a reliable examination may be carried out.

B.1.5 Special characteristics peculiar to the material, such as the lower strength values of rolled material in the thickness direction (see B.2.5.1) or the softening of cold worked aluminium alloys as a result of welding, are factors which have to be taken into account when designing welded joints. Clad plates where the efficiency of the bond between the base and the clad material is proved may generally be treated as solid plates (up to medium plate thicknesses where mainly filled weld connections are used).

B.1.6 In cases where different types of material are paired and operate in sea water or any other electrolytic medium, for example welded joints made between unalloyed carbon steels and stainless steels in the wear-resistant cladding in rudder nozzles or in the cladding of rudder shafts, the resulting differences in potential greatly increase the susceptibility to corrosion and is therefore be given special attention. Where possible, such welds are to be positioned in locations less subject to the risk of corrosion (such as on the outside of tanks) or special protective counter-measures are to be taken (such as the provision of a protective coating or cathodic protection).

B.2 Design details

B.2.1 Stress flow, transitions

B.2.1.1 All welded joints on primary supporting members are to be designed to provide a stress profile as smooth as possible with no major internal or external notches, no discontinuities in rigidity and no obstructions to strains, see Section 3, E.

B.2.1.2 This applies in analogous manner to the welding of subordinate components on to primary supporting members whose exposed plate or flange edges should, as far as possible, be kept free from notch effects due to welded attachments. Regarding the inadmissibility of weldments to the upper edge of the sheer strake, see Section 6, C.3.4. This applies similarly to weldments to the upper edge of continuous hatchway side coamings.

B.2.1.3 Butt joints in long or extensive continuous structures such as bilge keels, fenders, crane rails, slop coamings, etc. attached to primary structural members are therefore to be welded over their entire cross-section.

B.2.1.4 Wherever possible, joints (especially site joints) in girders and sections are to not be located in areas of high bending stress. Joints at the knuckle of flanges are to be avoided.

B.2.1.5 The transition between differing component dimensions is to be smooth and gradual. Where the depth of web of girders or sections differs, the flanges or bulbs are to be bevelled and the web slit and expanded or pressed together to equalize the depths of the members. The length of the transition should be at least equal twice the difference in depth.

B.2.1.6 Where the plate thickness differs at joints perpendicularly to the direction of the main stress, differences in thickness greater than 3 mm are to be accommodated by bevelling the proud edge in the manner shown in Fig. 19.1 at a ratio of at least $1 : 3$ or according to the notch category. Differences in thickness of 3 mm or less may be accommodated within the weld.

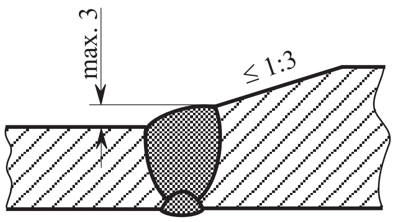


Fig. 19.1 Accommodation of differences of thickness

B.2.1.7 For the welding on of plates or other relatively thin-walled elements, steel castings and forgings should be appropriately tapered or provided with integrally cast or forged welding flanges in accordance with Fig. 19.2.

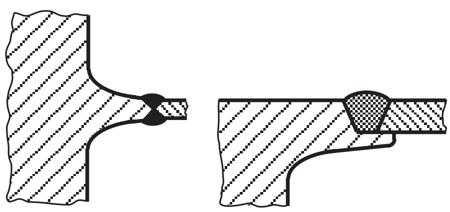


Fig. 19.2 Welding flanges on steel castings or forgings

B.2.1.8 For the connection of shaft brackets to the boss and shell plating, see B.4.3 and Section 13, D.2.; for the connection of horizontal coupling flanges to the rudder body, see 4.4. For the required thickened rudderstock collar required with build-up welds and for the connection of the coupling flange, see B.2.7 and Section 14, F.2.4. Rudderstock and coupling flange are to be connected by full penetration weld.

B.2.2 Local clustering of welds, minimum spacing

B.2.2.1 The local clustering of welds and short distances between welds are to be avoided. Adjacent welds should be separated from each other by a distance determined by the following formulae:

$50 + 4 \cdot t \quad [mm]$ between adjacent butt welds

$30 + 2 \cdot t \quad [mm]$ between adjacent fillet welds and between adjacent fillet and butt welds

t : plate thickness [mm]

The width of replaced or inserted plates (strips) should, however, be at least 300 mm or ten times the plate thickness, whichever is the greater.

B.2.2.2 Reinforcing plates, welding flanges, mountings and similar components socket-welded into plating should be of the following minimum size:

$D_{min} = 170 + 3 \cdot (t - 10)$ with $D_{min} \geq 170$ mm

D : diameter [mm] of round or length of side of angular weldments

t : plating thickness [mm]

The corner radii of angular socket weldments should be 5 t [mm] but at least 50 mm. Alternatively the "longitudinal seams" are to extend beyond the "transverse seams". Socket weldments are to be fully welded to the surrounding plating.

Regarding the increase of stress due to different thickness of plates see also Section 20, B.1.3.

B.2.3 Welding cut-outs

B.2.3.1 Welding cut-outs for the (later) execution of butt or fillet welds following the positioning of transverse members should be rounded (minimum radius 25 mm or twice the plate thickness, whichever is the greater) and should be shaped to provide a smooth transition on the adjoining surface as shown in Fig. 19.3 (especially necessary where the loading is mainly dynamic).

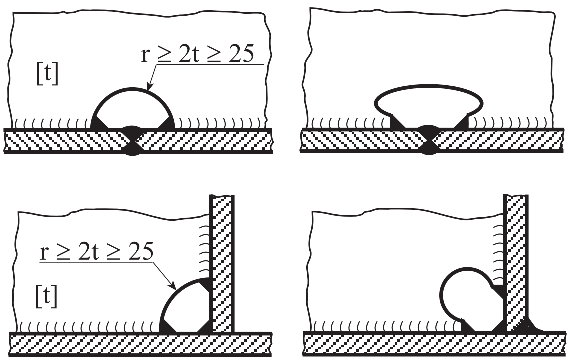


Fig. 19.3 Welding cut-outs

B.2.3.2 Where the welds are completed prior to the positioning of the crossing members, no welding cut-outs are needed. Any weld reinforcements present are to be machined off prior to the location of the crossing members or these members are to have suitable cut-outs.

B.2.4 Local reinforcements plates

B.2.4.1 Where platings (including girder plates and tube walls) are subjected locally to increased stresses, thicker plates should be used wherever possible in preference to doubling plates. Bearing bushes, hubs etc. have invariably to take the form of thicker sections welded into the plating, see B.2.2.2.

B.2.4.2 Where doublings cannot be avoided, the thickness of the doubling plates should not exceed twice the plating thickness. Doubling plates whose width is greater than approximately 30 x their thickness are to be plug welded to the underlying plating in accordance with B.3.3.11 at intervals not exceeding 30 times the thickness of the doubling plate.

B.2.4.3 Along their (longitudinal) edges, doubling plates are to be continuously fillet welded with a throat thickness "a" of 0.3 x the doubling plate thickness. At the ends of doubling plates, the throat thickness "a" at the end faces is to be increased to 0.5 x the doubling plate thickness but is not to exceed the plating thickness, see Fig. 19.4.

The welded transition at the end faces of the doubling plates to the plating should form with the latter an angle of 45 ° or less.

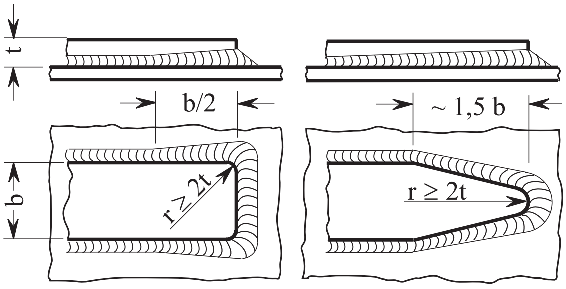


Fig. 19.4 Welding at the ends of doubling plates

B.2.4.4 Where proof of fatigue strength is required (see Section 20), the configuration of the end of the doubling plate has to conform to the selected detail category.

B.2.4.5 Doubling plates are not permitted in tanks for flammable liquids except collar plates and small doublings for fittings like tank heating fittings or fittings for ladders.

B.2.5 Intersecting members, stress in the thickness direction

B.2.5.1 Where, in the case of intersecting members, plates or other rolled products are stressed in the thickness direction by shrinking stresses due to the welding and / or applied loads, suitable measures are to be taken in the design and fabrication of the structures to prevent lamellar tearing (stratified fractures) due to the anisotropy of the rolled products.

B.2.5.2 Such measures include the use of suitable weld shapes with a minimum weld volume and a welding sequence designed to reduce transverse shrinkage. Other measures are the distribution of the stresses over a larger area of the plate surface by using a build-up weld or the joining together of several "fibres" of members stressed in the thickness direction as exemplified by the deck stringer/sheer strake joint shown in Fig. 19.12.

B.2.5.3 In case of very severe stresses in the thickness direction due, for example, to the aggregate effect of the shrinkage stresses of bulky single or double-bevel butt welds plus high applied loads, plates with guaranteed through thickness properties (extra high-purity material and guaranteed minimum reductions in area of tensile test specimens taken in thickness direction) are to be used.

See also the GL Rules for Steel and Iron Materials (II-1-2), Section 1 and also Supply Conditions 096 for Iron and Steel Products, "Plate, strip and universal steel with improved resistance to stress perpendicular to the product surface" issued by the German Iron and Steelmakers' Association.

B.2.6 Welding of cold formed sections, bending radii

B.2.6.1 Wherever possible, welding should be avoided at the cold formed sections with more than 5 % permanent elongation and in the adjacent areas of structural steels with a tendency towards strain ageing.

The elongation ε in the outer tensile-stressed zone is:

$$\varepsilon = \frac{100}{1 + 2 \cdot r/t} \quad [\%]$$

r : inner bending radius [mm]

t : plate thickness [mm]

B.2.6.2 Welding may be performed at the cold formed sections and adjacent areas of hull structural steels and comparable structural steels (e.g. those in quality groups S...J... and S...K... to DIN EN 10025) provided that the minimum bending radii are not less than those specified in Table 19.1.

Table 19.1 Minimum inner bending radius r

Plate thickness t [mm]	Minimum inner bending radius r [mm]
≤ 4	$1.0 \cdot t$
≤ 8	$1.5 \cdot t$
≤ 12	$2.0 \cdot t$
≤ 24	$3.0 \cdot t$
> 24	$5.0 \cdot t$

Note

The bending capacity of the material may necessitate a larger bending radius.

B.2.6.3 For other steels and other materials, where applicable, the necessary minimum bending radius is, in case of doubt, to be established by test. Proof of adequate toughness after welding may be stipulated for steels with a yield strength of more than 355 N/mm^2 and plate thicknesses of 30 mm and above which have undergone cold forming resulting in $2\ \%$ or more permanent elongation.

B.2.7 Build-up welds on rudderstocks and pintles

B.2.7.1 Wear resistance and/or corrosion resistant build-up welds on the bearing surfaces of rudderstocks, pintles etc. are to be applied to a thickened collar exceeding by at least 20 mm the diameter of the adjoining part of the shaft.

B.2.7.2 Where a thickened collar is impossible for design reasons, the build-up weld may be applied to the smooth shaft provided that relief-turning in accordance with B.2.7.3 is possible (leaving an adequate residual diameter).

B.2.7.3 After welding, the transition areas between the welded and non-welded portions of the shaft is to be relief-turned with large radii, as shown in Fig. 19.5, to remove any base material whose structure close to the concave groove has been altered by the welding operation and in order to effect the physical separation of geometrical and metallurgical "notches".

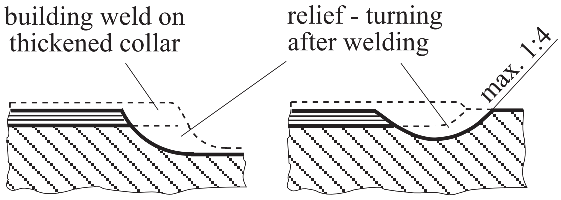


Fig. 19.5 Build-up welds applied to rudderstocks and pintles

B.3 Weld shapes and dimensions

B.3.1 Butt joints

B.3.1.1 Depending on the plate thickness, the welding method and the welding position, butt joints are to be of the square, V or double-V shape conforming to the relevant standards (e.g. EN 22553/ ISO 2533, ISO 9692 -1, -2, -3 or -4). Where other weld shapes are applied, these are to be specially described in the drawings. Weld shapes for special welding processes such as single-side or electrogas welding has to have been tested and approved in the context of a welding procedure test.

B.3.1.2 As a matter of principle, the rear sides of butt joints are to be grooved and welded with at least one capping pass. Exceptions to this rule, as in the case of submerged-arc welding or the welding processes mentioned in B.3.1.1, require to be tested and approved in connection with a welding procedure test. The effective weld thickness is to be deemed to be the plate thickness, or, where the plate thicknesses differ, the lesser plate thickness. Where proof of fatigue strength is required (see Section 20), the detail category depends on the execution (quality) of the weld.

B.3.1.3 Where the aforementioned conditions cannot be met, e.g. where the welds are accessible from one side only, the joints are to be executed as lesser bevelled welds with an open root and an attached or an integrally machined or cast, permanent weld pool support (backing) as shown in Fig. 19.6.

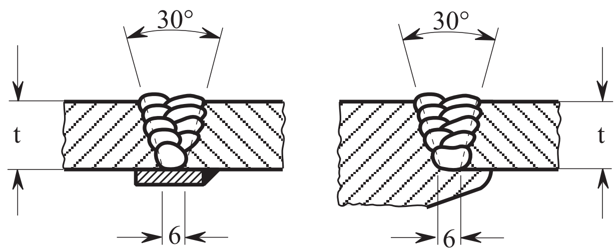


Fig. 19.6 Single-side welds with permanent weld pool supports (backings)

B.3.1.4 The weld shapes illustrated in Fig. 19.7 are to be used for clad plates. These weld shapes are to be used in analogous manner for joining clad plates to (unalloyed and low alloyed) hull structural steels.

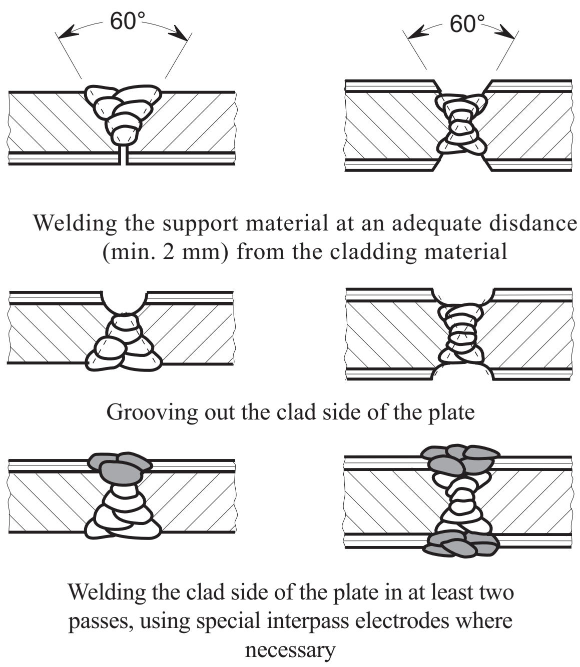


Fig. 19.7 Weld shapes for welding of clad plates

B.3.2 Corner, T and double-T (cruciform) joints

B.3.2.1 Corner, T and double-T (cruciform) joints with complete union of the abutting plates are to be made as single or double-bevel welds with a minimum root face and adequate air gap, as shown in Fig. 19.8, and with grooving of the root and capping from the opposite side.

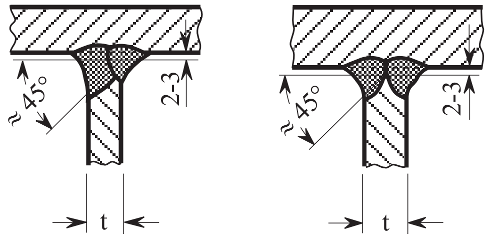


Fig. 19.8 Single and double-bevel welds with full root penetration

The effective weld thickness is to be assumed as the thickness of the abutting plate. Where proof of fatigue strength is required (see Section 20), the detail category depends on the execution (quality) of the weld.

B.3.2.2 Corner, T and double-T (cruciform) joints with a defined incomplete root penetration, as shown in Fig. 19.9, are to be made as single or double-bevel welds, as described in B.3.2.1, with a back-up weld but without grooving of the root.

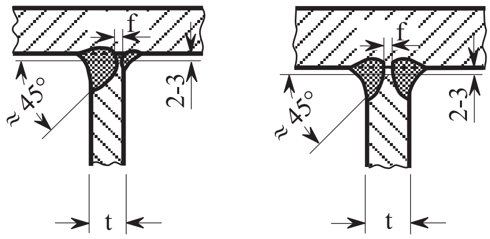


Fig. 19.9 Single and double-bevel welds with defined incomplete root penetration

The effective weld thickness may be assumed as the thickness of the abutting plate t, where f is the incomplete root penetration of 0.2 t with a maximum of 3 mm, which is to be balanced by equally sized double fillet welds on each side. Where proof of fatigue strength is required (see Section 20), these welds are to be assigned to type D1.

B.3.2.3 Corner, T and double-T (cruciform) joints with both an unwelded root face c and a defined incomplete root penetration f are to be made in accordance with Fig. 19.10.

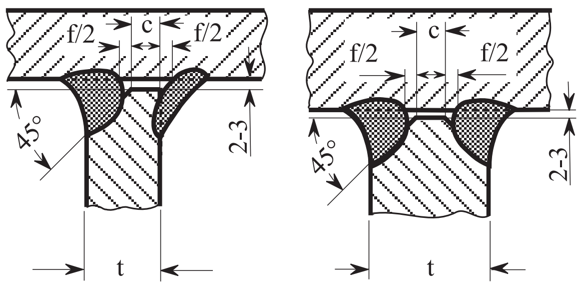


Fig. 19.10 Single and double-bevel welds with unwelded root face and defined in complete root penetration

The effective weld thickness is to be assumed as the thickness of the abutting plate t minus (c + f), where f is to be assigned a value of 0.2 t subject to a maximum of 3 mm. Where proof of fatigue strength is required (see Section 20), these welds are to be assigned to types D2 or D3.

B.3.2.4 Corner, T and double-T (cruciform) joints which are accessible from one side only may be made in accordance with Fig. 19.11 in a manner analogous to the butt joints referred to in B.3.1.3 using a weld pool support (backing), or as single-side, single bevel welds in a manner similar to those prescribed in B.3.2.2.

The effective weld thickness Is to be determined by analogy with B.3.1.3 or B.3.2.2, as appropriate. Wherever possible, these joints should not be used where proof of fatigue strength is required (see Section 20).

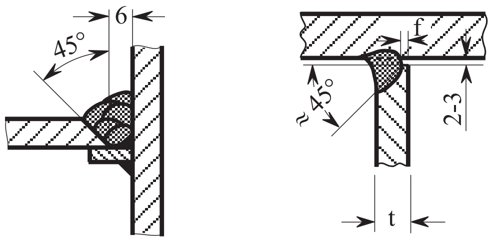


Fig. 19.11 Single-side welded T joints

B.3.2.5 Where corner joints are flush, the weld shapes are to be as shown in Fig. 19.12 with bevelling of at least 30 ° of the vertically drawn plates to avoid the danger of lamellar tearing. A similar procedure is to be followed in the case of fitted T joints (uniting three plates) where the abutting plate is to be socketed between the aligned plates.

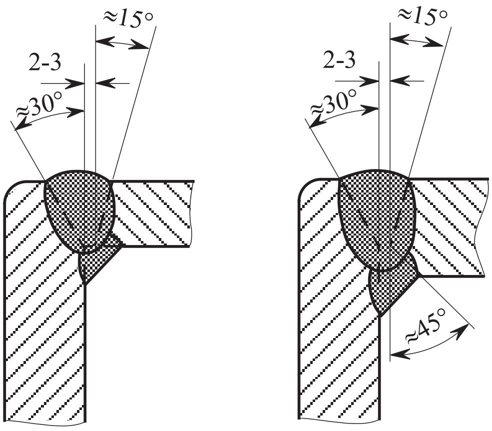


Fig. 19.12 Flush fitted corner joints

B.3.2.6 Where, in the case of T joints, the direction of the main stress lies in the plane of the horizontal plates (e.g. the plating) shown in Fig. 19.13 and where the connection of the perpendicular (web) plates is of secondary importance, welds uniting three plates may be made in accordance with Fig. 19.13 (with the exception of those subjected mainly to dynamic loads). For the root passes of the three plate weld sufficient penetration is to be achieved. Sufficient penetration has to be verified in way of the welding procedure test.

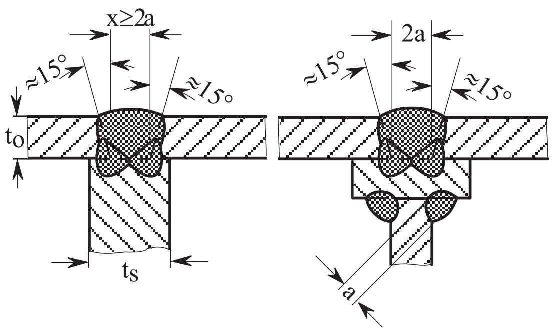


Fig. 19.13 Welding together three plates

The effective thickness of the weld connecting the horizontal plates is to be determined in accordance with B.3.2.2. The requisite "a" dimension is determined by the joint uniting the vertical (web) plates and is, where necessary, to be determined in accordance with Table 19.3 or by calculation as for fillet welds.

The following table shows reference values for the design of three plate connections at rudders, steering nozzle, etc.

plating thickness t_o	**[mm]**	≤ 10	12	14	16	18	≥ 20
minimum weld gap x	**[mm]**	6	7	8	10	11	12
minimum web thickness t_s	**[mm]**	10	12	14	16	18	20

B.3.3 Fillet weld connections

B.3.3.1 In principle fillet welds are to be of the double fillet weld type. Exceptions to this rule (as in the case of closed box girders and mainly shear stresses parallel to the weld) are subject to approval in each individual case. The throat thickness "a" of the weld (the height of the inscribed isosceles triangle) is to be determined in accordance with Table 19.3 or by calculation according to C. The leg length of a fillet weld is to be not less than 1.4 x the throat thickness "a". For fillet welds at doubling plates, see B.2.4.3; for the welding of the deck stringer to the sheer strake, see Section 7, A.2.1, and for bracket joints, see C.2.7.

B.3.3.2 The relative fillet weld throat thicknesses specified in Table 19.3 relate to normal strength and higher strength hull structural steels and comparable structural steels. They may also be generally applied to high-strength structural steels and non-ferrous metals provided that the "tensile shear strength" of the weld metal used is at least equal to the tensile strength of the base material. Failing this, the "a" dimension is to be increased accordingly and the necessary increment is to be established during the welding procedure test (see the GL Rules for Welding in the Various Fields of Application (II-3-3), Section 1, F.). Alternatively proof by calculation taking account of the properties of the weld metal may be presented.

Note

In the case of higher-strength aluminium alloys (e.g. AlMg4,5Mn0,7), such an increment may be necessary for cruciform joints subject to tensile stresses, as experience shows that in the welding procedure tests the tensile-shear strength of fillet welds (made with matching filler metal) often fails to attain the tensile strength of the base material. See also the GL Rules for Welding in the Various Fields of Application (II-3-3), Section 1, F.

B.3.3.3 The throat thickness of fillet welds is not to exceed 0.7 x the lesser thickness of the parts to be connected (generally the web thickness). The minimum throat thickness a_{min} is defined by the following formula:

$$a_{min} = \sqrt{\frac{t_1 + t_2}{3}} \quad [mm] \qquad \text{with } a_{min} \geq 3 \text{ mm}$$

t_1 : lesser (e.g. the web) plate thickness [mm]

t_2 : greater (e.g. the flange) plate thickness [mm]

B.3.3.4 It is desirable that the fillet weld section is to be flat faced with smooth transitions to the base material. Where proof of fatigue strength is required (see Section 20), machining of the weld (grinding to remove notches) may be required depending on the notch category. The weld should penetrate at least close to the theoretical root point.

B.3.3.5 Where mechanical welding processes are used which ensure deeper penetration extending well beyond the theoretical root point and where such penetration is uniformly and dependably maintained under production conditions, approval may be given for this deeper penetration to be allowed for in determining the throat thickness. The effective dimension:

$$a_{deep} = a + \frac{2 \cdot e_{min}}{3} \quad [mm]$$

Is to be ascertained in accordance with Fig. 19.14 and by applying the term "e_{min}" to be established for each welding process by a welding procedure test. The throat thickness is not to be less than the minimum throat thickness related to the theoretical root point.

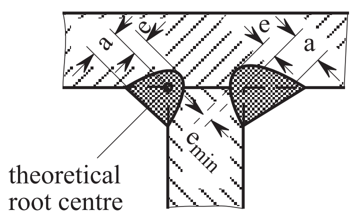


Fig. 19.14 Fillet welds with increased penetration

B.3.3.6 When welding on top of shop primers which are particularly liable to cause porosity, an increase of the "a" dimension by up to 1 mm may be stipulated depending on the welding process used. This is specially applicable where minimum fillet weld throat thicknesses are employed. The size of the increase is to be decided on a case by case basis considering the nature and severity of the stressing following the test results of the shop primer in accordance with the GL Rules for Welding in the Various Fields of Application (II-3-3), Section 3, F. This applies in analogous manner to welding processes where provision has to be made for inadequate root penetration.

B.3.3.7 Strengthened filled welds continuous on both sides are to be used in areas subjected to severe dynamic loads (e.g. for connecting the longitudinal and transverse girders of the engine base to top plates close to foundation bolts, see Section 8, D.4.2.5 and Table 19.3), unless single or double-bevel welds are stipulated in these locations. In these areas the "a" dimension is to be equal 0.7 x the lesser thickness of the parts to be welded.

B.3.3.8 Intermittent fillet welds in accordance with Table 19.3 may be located opposite one another (chain intermittent welds, possibly with scallops) or may be staggered, see Fig. 19.15. In case of small sections other types of scallops may be accepted.

In water and cargo tanks, in the bottom area of fuel oil tanks and of spaces where condensed or sprayed water may accumulate and in hollow components (e.g. rudders) threatened by corrosion, only continuous or intermittent fillet welds with scallops are to be used. This applies accordingly also to areas, structures or spaces exposed to extreme environmental conditions or which are exposed to corrosive cargo.

There are to be no scallops in areas where the plating is subjected to severe local stresses (e.g. in the bottom section of the fore ship) and continuous welds are to be preferred where the loading is mainly dynamic.

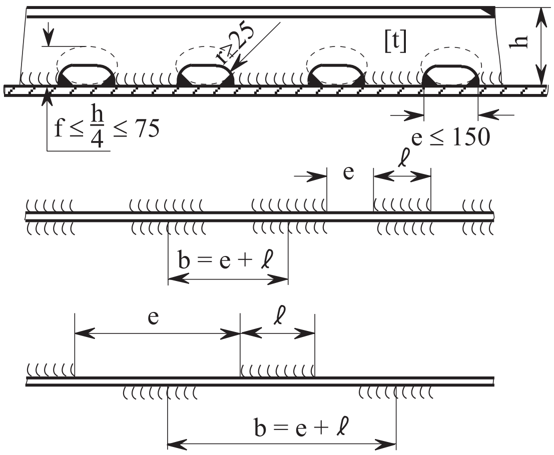


Fig. 19.15 Scallop, chain and staggered welds

B.3.3.9 The throat thickness a_u of intermittent fillet welds is to be determined according to the selected pitch ratio b / ℓ by the following formula:

$$a_u = 1.1 \cdot a \cdot \left(\frac{b}{\ell}\right) \quad [\text{mm}]$$

a : required fillet weld throat thickness [mm] for a continuous weld according to Table 19.3 or determined by calculation

b : pitch [mm], defined as:

$$b = e + \ell$$

e : interval between the welds [mm]

ℓ : length of fillet weld [mm]

The pitch ratio b / ℓ should not exceed 5. The maximum unwelded length ($b - \ell$ with scallop and chain welds, or $b / 2 - \ell$ with staggered welds) should not exceed 25 x times the lesser thickness of the parts to be welded. The length of scallops should, however, not exceed 150 mm.

B.3.3.10 Lap joints should be avoided wherever possible and are not to be used for heavily loaded components. In the case of components subject to low loads lap joints may be accepted provided that, wherever possible, they are orientated parallel to the direction of the main stress. The width of the lap is to be $1.5\ t + 15$ mm (t = thickness of the thinner plate). Except where another value is determined by calculation, the fillet weld throat thickness "a" is to be equal 0.4 x the lesser plate thickness, subject to the requirement that it is not to be less than the minimum throat thickness required by B.3.3.3. The fillet weld is to be continuous on both sides and is to meet at the ends.

B.3.3.11 In the case of plug welding, the plugs should, wherever possible, take the form of elongated holes lying in the direction of the main stress. The distance between the holes and the length of the holes may be determined by analogy with the pitch "b" and the fillet weld length "ℓ" in the intermittent welds covered by B.3.3.8. The fillet weld throat thickness "a_u" may be established in accordance with B.3.3.9. The width of the holes is to be equal to at least twice the thickness of the plate and is not to be less than 15 mm. The ends of the holes are to be semi-circular. Plates or sections placed underneath should at least equal the perforated plate in thickness and should project on both sides to a distance of 1.5 x the plate thickness subject to a maximum of 20 mm. Wherever possible only the necessary fillet welds are to be welded, while the remaining void is packed with a suitable filler. Lug joint welding is not allowed.

B.4 Welded joints of particular components

B.4.1 Welds at the ends of girders and stiffeners

B.4.1.1 As shown in Fig. 19.16, the web at the end of intermittently welded girders or stiffeners is to be continuously welded to the plating or the flange plate, as applicable, over a distance at least equal to the depth "h" of the girder or stiffener subject to a maximum of 300 mm. Regarding the strengthening of the welds at the ends, extending normally over 0.15 of the span, see Table 19.3.

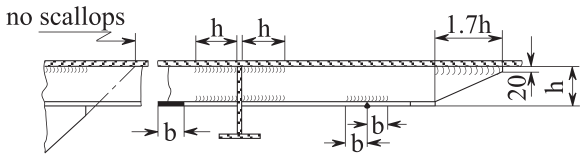


Fig. 19.16 Welds at the ends of girders and stiffeners

B.4.1.2 The areas of bracket plates should be continuously welded over a distance at least equal to the length of the bracket plate. Scallops are to be located only beyond a line imagined as an extension of the free edge of the bracket plate.

B.4.1.3 Wherever possible, the free ends of stiffeners are to abut against the transverse plating or the webs of sections and girders so as to avoid stress concentrations in the plating. Failing this, the ends of the stiffeners are to be sniped and continuously welded over a distance of at least $1.7\ h$ subject to a maximum of 300 mm.

B.4.1.4 Where butt joints occur in flange plates, the flange is to be continuously welded to the web on both sides of the joint over a distance at least equal to the width of the flange.

B.4.2 Joints between section ends and plates

B.4.2.1 Welded joints connecting section ends and plates may be made in the same plane or lapped.

Where no design calculations have been carried out or stipulated for the welded connections, the joints may be made analogously to those shown in Fig. 19.17.

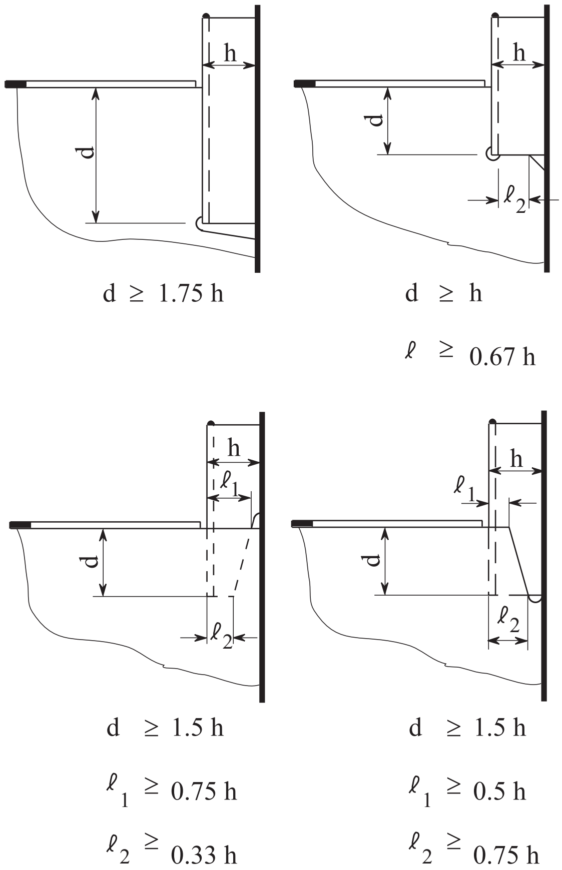


Fig. 19.17 Joints uniting section ends and plates

B.4.2.2 Where the joint lies in the plane of the plate, it may conveniently take the form of a single-bevel butt weld with fillet. Where the joint between the plate and the section end overlaps, the fillet weld is to be continuous on both sides and is to meet at the ends. The necessary "a" dimension is to be calculated in accordance with C.2.6. The fillet weld throat thickness is not to be less than the minimum specified in B.3.3.3.

B.4.3 Welded shaft bracket joints

B.4.3.1 Unless cast in one piece or provided with integrally cast welding flanges analogous to those prescribed in B.2.1.7 (see Fig. 19.18), strut barrel and struts are to be connected to each other and to the shell plating in the manner shown in Fig. 19.19.

B.4.3.2 In the case of single-strut shaft brackets no welding is to be performed on the arm at or close to the position of constraint. Such components are to be provided with integrally forged or cast welding flanges.

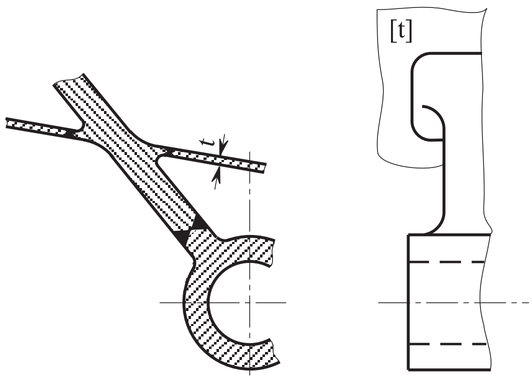
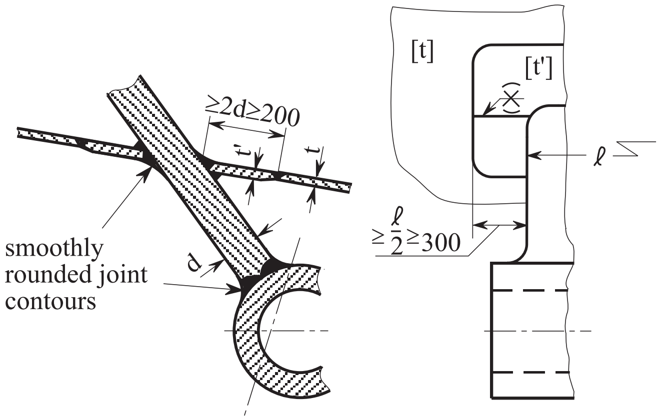


Fig. 19.18 Shaft bracket with integrally cast welding flanges



t = plating thickness in accordance with Section 6, F. in [mm]

t' $= \frac{d}{3} + 5$ [mm] where $d < 50$mm

t' $= 3\sqrt{d}$ [mm] where $d \geq 50$mm

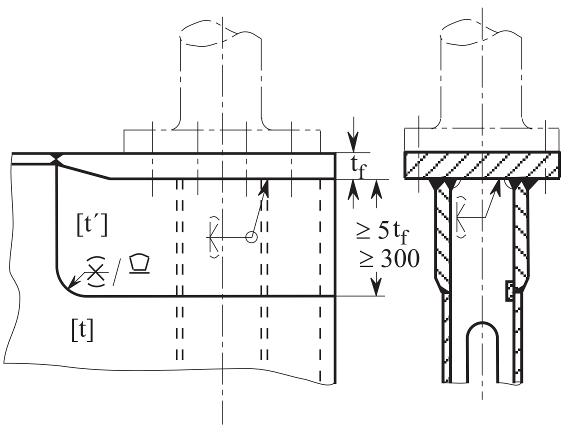
For shaft brackets of elliptically shaped cross section d may be substituted by 2/3 d in the above formulae.

Fig. 19.19 Shaft bracket without integrally cast welding flanges

B.4.4 Rudder coupling flanges

B.4.4.1 Unless forged or cast steel flanges with integrally forged or cast welding flanges in conformity with B.2.1.7 are used, horizontal rudder coupling flanges are to be joined to the rudder body by plates of graduated thickness and full penetration single or double-bevel welds as prescribed in B.3.2.1, see Fig. 19.20. See also Section 14, F.1.4 and Section 14, F.2.4.

B.4.4.2 Allowance is to be made for the reduced strength of the coupling flange in the thickness direction see B.1.5 and B.2.5. In case of doubt, proof by calculation of the adequacy of the welded connection is to be produced.



t : plate thickness [mm] in according to Section 14, G.3.1

t_f : actual flange thickness in [mm]

t' $= \frac{t_f}{3} + 5$ [mm] where $t_f < 50$ mm

t' $= 3\sqrt{t_f}$ [mm] where $t_f \geq 50$ mm

Fig. 19.20 Horizontal rudder coupling flanges

B.4.4.3 The welded joint between the rudder stock (with thickened collar, see B.2.1.8) and the flange is to be made in accordance with Fig. 19.21.

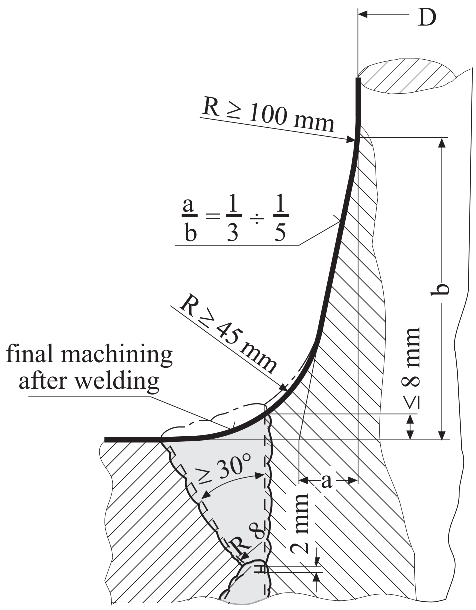


Fig. 19.21 Welded joint between rudder stock and coupling flange

C Stress Analysis

C.1 General analysis of fillet weld stresses

C.1.1 Definition of stresses

For calculation purposes, the following stresses in a fillet weld are defined as (see also Fig. 19.22):

σ_v : equivalent stress $[\mathrm{N/mm^2}]$, defined as:

$$\sigma_v = \sqrt{\sigma_\perp^2 + \tau_\perp^2 + \tau_{II}^2}$$

$\sigma_\perp$: normal stresses $[\mathrm{N/mm^2}]$ acting vertically to the direction of the weld seam

$\tau_\perp$: shear stress $[\mathrm{N/mm^2}]$ acting vertically to the direction of the weld seam

τ_{II} : shear stress $[\mathrm{N/mm^2}]$ acting in the direction of the weld seam

Normal stresses acting in the direction of the weld seam need not be considered.

For calculation purposes the weld seam area is $a \cdot \ell$.

Due to equilibrium conditions the following applies to the flank area vertical to the shaded weld seam area:

$$\tau_\perp = \sigma_\perp$$

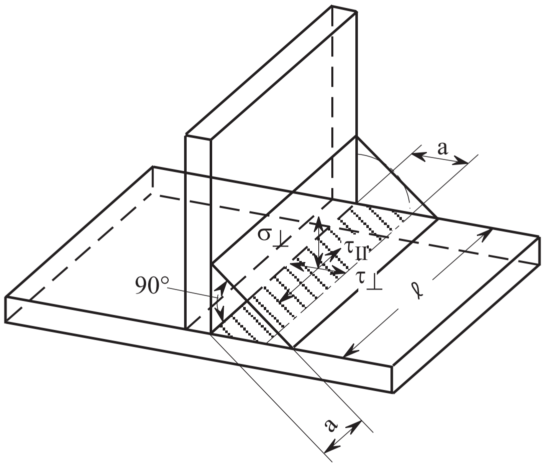


Fig. 19.22 Stresses in a fillet weld

C.1.2 Definitions

a : throat thickness [mm]

ℓ : length [mm] of fillet weld

P : single force [N]

M : bending moment [Nm] at the position considered

Q : shear force [N] at the point considered

S : first moment [cm^3] of the cross sectional area of the flange connected by the weld to the web in relation to the neutral beam axis

I : moment of inertia [cm^4] of the girder section

W : section modulus [cm^2] of the connected section

C.2 Determination of stresses

C.2.1 Fillet welds stressed by normal and shear forces

Flank and frontal welds are regarded as being equal for the purposes of stress analysis. In view of this, normal and shear stresses are to be determined by the following formulae:

$$\sigma = \tau = \frac{P}{\sum a \cdot \ell} \quad [N/mm^2]$$

- Equivalent stress [N/mm^2], defined as:

$$\sigma_v = \sqrt{\tau_\perp^2 + \tau_{II}^2}$$

- Shear stresses [N/mm^2] in frontal fillet welds as shown in Fig. 19.23, defined as:

$$\tau_\perp = \frac{P_1}{2 \cdot a \cdot (\ell_1 + \ell_2)}$$

$$\tau_{II} = \frac{P_2}{2 \cdot a \cdot (\ell_1 + \ell_2)} \pm \frac{P_2 \cdot e}{2 \cdot a \cdot F_t}$$

- Shear stresses [N/mm^2] in flank fillet welds as shown in Fig. 19.23, defined as:

$$\tau_\perp = \frac{P_2}{2 \cdot a \cdot (\ell_1 + \ell_2)}$$

$$\tau_{II} = \frac{P_1}{2 \cdot a \cdot (\ell_1 + \ell_2)} \pm \frac{P_2 \cdot e}{2 \cdot a \cdot F_t}$$

- Shear stresses $[\mathrm{N} / \mathrm{mm}^2]$ in joint as shown in Fig. 19.24, defined as:

$$\tau_{\perp} = \frac{P_2}{2 \cdot \ell \cdot a} + \frac{3 \cdot P_1 \cdot e}{\ell^2 \cdot a}$$

$$\tau_{||} = \frac{P_1}{2 \cdot \ell \cdot a}$$

ℓ_1, ℓ_2 : lengths [mm] as defined in Fig. 19.23

e : distances [mm] as defined in Fig. 19.23 and Fig. 19.24

F_t : area $[\mathrm{mm}^2]$, defined as:

$$F_t = (\ell_1 + a) \cdot (\ell_2 + a)$$

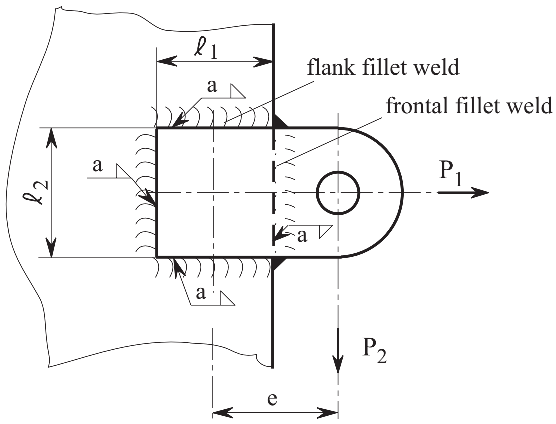


Fig. 19.23 Weld joint of an overlapped lifting eye

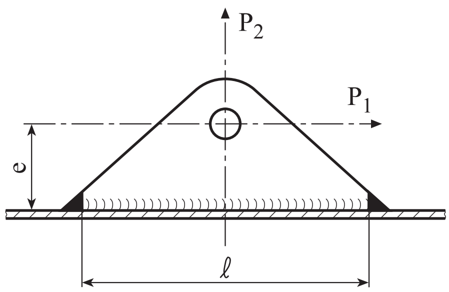


Fig. 19.24 Weld joint of a vertically mounted lifting eye

C.2.2 Fillet weld joints stressed by bending moments and shear forces

The stresses at the fixing point of a girder are calculated as follows (in Fig. 19.25 a cantilever beam is given as an example):

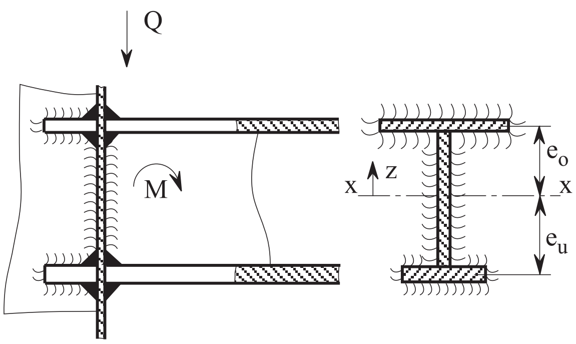


Fig. 19.25 Fixing point of a cantilever beam

- Equivalent stress $[N/mm^2]$, defined as:

$$\sigma_v = \sqrt{\sigma_\perp^2 + \tau_{||}^2}$$

- Normal stress due to bending moment $[N/mm^2]$, defined as:

$$\sigma_\perp(z) = \frac{M}{I_s} \cdot z \quad [N/mm^2]$$

$$\sigma_{\perp,max} = \frac{M}{I_s} \cdot e_u \qquad \text{if } e_u > e_0$$

$$\sigma_{\perp,max} = \frac{M}{I_s} \cdot e_0 \qquad \text{if } e_u < e_0$$

- Shear stress due to shear force $[N/mm^2]$, defined as:

$$\tau_{||}(z) = \frac{Q \cdot S_s(z)}{10 \cdot I_s \cdot \sum a}$$

$$\tau_{||,max} = \frac{Q \cdot S_{s,max}}{20 \cdot I_s \cdot a}$$

I_s : moment of inertia $[cm^4]$ of the welded joint related to the x-axis

$S_s(z)$: the first moment $[cm^3]$ of the connected weld section at the point under consideration

z : distance $[cm]$ from the neutral axis

It has to be proved that neither $\sigma_{\perp,max}$ in the region of the flange nor $\tau_{||,max}$ in the region of the neutral axis nor the equivalent stress σ_v exceed the permitted limits given in C.2.8 at any given point. The equivalent stress σ_v should always be calculated at the web-flange connection.

C.2.3 Fillet weld joints stressed by bending and torsional moments and shear forces

Regarding the normal and shear stresses resulting from bending, see C.2.2. Torsional τ_T stresses resulting from the torsional moment M_T are to be determined by the following formula:

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

M_T : torsional moment $[Nm]$

A_m : sectional area $[mm^2]$ enclosed by the weld seam

The equivalent stress σ_v composed of all three components (bending, shear and torsion) is calculated by means of the following formulae:

$$\sigma_v = \sqrt{\sigma_\perp^2 + \tau_{||}^2 + \tau_T^2} \quad [N/mm^2] \qquad \text{where } \tau_{||} \text{ and } \tau_T \text{ have not the same direction}$$

$$\sigma_v = \sqrt{\sigma_\perp^2 + (\tau_{||} + \tau_T)^2} \quad [N/mm^2] \qquad \text{where } \tau_{||} \text{ and } \tau_T \text{ have the same direction}$$

C.2.4 Continuous fillet weld joints between web and flange of bending girders

The stresses are to be calculated in way of maximum shear forces. Stresses in the weld's longitudinal direction need not be considered.

In the case of continuous double fillet weld connections the shear stress $\tau_{||}$ and the required fillet weld thickness a_{req} are to be determined by the following formulae:

$$\tau_{II} = \frac{Q \cdot S}{20 \cdot I \cdot a} \quad [N/mm^2]$$

$$a_{req} = \frac{Q \cdot S}{20 \cdot I \cdot \tau_p} \quad [mm]$$

C.2.5 Intermittent fillet weld joints between web and flange of bending girders

In the case of intermittent fillet weld joints the shear stress τ_{II} and the required fillet weld thickness a_{req} are to be determined by the following formulae:

$$\tau_{II} = \frac{Q \cdot S \cdot \alpha}{20 \cdot I \cdot a} \cdot \left(\frac{b}{\ell}\right) \quad [N/mm^2]$$

$$a_{req} = \frac{Q \cdot S \cdot 1.1}{20 \cdot I \cdot \tau_p} \cdot \left(\frac{b}{\ell}\right) \quad [mm]$$

b : pitch of intermittent fillets welds $[mm]$

α : stress concentration factor which takes into account increases in shear stress at the ends of the fillet weld seam "ℓ", defined as:

$$\alpha = 1.1$$

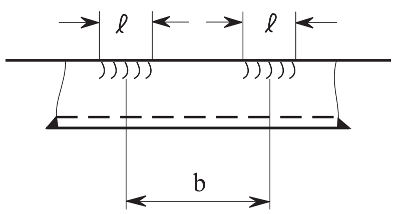


Fig. 19.26 Intermittent fillet weld joint

C.2.6 Fillet weld connections on overlapped profile joints

C.2.6.1 In the case of fillet weld connections on overlapped profile joints the equivalent stress σ_v and the shear stresses τ_{II} and $\tau_{\perp}$ are to be determined by the following formulae:

$$\sigma_v = \sqrt{\tau_{\perp}^2 + \tau_{II}^2}$$

$$\tau_{\perp} = \frac{Q}{2 \cdot a \cdot d} \quad [N/mm^2]$$

$$\tau_{II} = \frac{M \cdot 10^3}{2 \cdot a \cdot c \cdot d} \quad [N/mm^2]$$

d : distance $[mm]$, as defined Fig. 19.27

c : distance $[mm]$, as defined Fig. 19.27

$$c = r + \frac{3 \cdot \ell_1 - \ell_2}{4} \quad [mm]$$

r : radius $[mm]$, as defined Fig. 19.27

ℓ_1, ℓ_2 : distances $[mm]$, as defined Fig. 19.27

As the influence of the shear force can generally be neglected, the required fillet weld thickness a_{req} may be determined by the following formula:

$$a_{req} = \frac{W \cdot 10^3}{1.5 \cdot c \cdot d} \quad [mm]$$

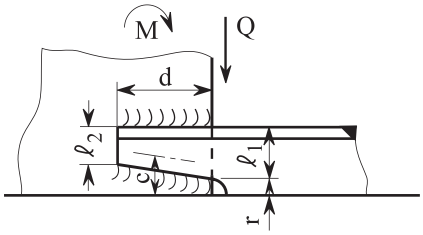


Fig. 19.27 Profile joined by means of two flank fillet joints

C.2.6.2 In the case of profiles joined by means of two flank and two frontal fillet welds (all round welding as shown in Fig. 19.28) the equivalent stress σ_v, the shear stresses $\tau_{||}$ and $\tau_\perp$ and the required fillet weld thickness a_{req} are to be determined by the following formulae:

$$\sigma_v = \sqrt{\tau_\perp^2 + \tau_{||}^2} \quad [N/mm^2]$$

$$\tau_\perp = \frac{Q}{a \cdot (2 \cdot d + \ell_1 + \ell_2)} \quad [N/mm^2]$$

$$\tau_{||} = \frac{M \cdot 10^3}{a \cdot c \cdot (2 \cdot d + \ell_1 + \ell_2)} \quad [N/mm^2]$$

$$a_{req} = \frac{W \cdot 10^3}{1.5 \cdot c \cdot d \cdot \left(1 + \frac{\ell_1 + \ell_2}{2 \cdot d}\right)} \quad [mm]$$

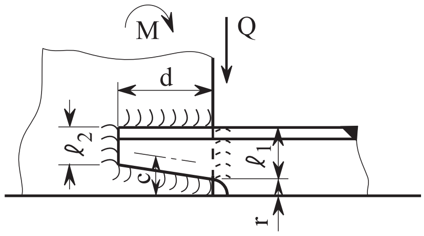


Fig. 19.28 Profile joined by means of two flank and two frontal fillet welds (all round welding)

C.2.7 Bracket joints

Where profiles are joined to brackets as shown in Fig. 19.29, the average shear stress τ and the required fillet weld thickness a_{req} are to be determined by the following formulae:

$$\tau = \frac{3 \cdot M \cdot 10^3}{4 \cdot a \cdot d^2} + \frac{Q}{2 \cdot a \cdot d} \quad [N/mm^2]$$

$$a_{req} = \frac{W \cdot 10^3}{d^2} \quad [mm]$$

d : length $[mm]$ of overlap

(The shear force Q has been neglected.)

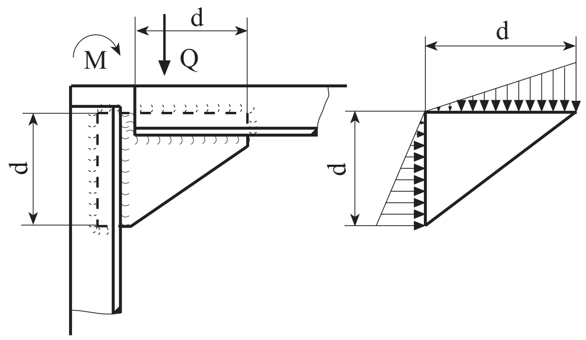


Fig. 19.29 Bracket joint with idealized stress distribution resulting from moment M and shear force Q

C.2.8 Permissible stresses

The permissible stresses for various materials under mainly static loading conditions are given in Table 19.2. The values listed for high strength steels, austenitic stainless steels and aluminium alloys are based on the assumption that the strength values of the weld metal used are at least as high as those of the parent metal. If this is not the case, the "a"-value calculated is to be increased accordingly (see also B.3.3.2).

Table 19.2 Permissible stresses in fillet weld seams

Material		R_{eH} or $R_{p0,2}$ [N / mm²]	Permissible stresses for: equivalent stress σ_{vp} and shear stress τ_p [N / mm²]
normal strength hull structural steel	GL – A / B / D / E	235	115
higher strength structural steel	GL – A / D / E / F 32	315	145
	GL – A / D / E / F 36	355	160
	GL – A / D / E / F 40	390	175
high strength steels	S 460	460	200
	S 690	685	290
austenitic and austenitic-ferritic stainless steels	1.4306 / 304 L	180	110
	1.4404 / 316 L	190	
	1.4435 / 316 L	190	
	1.4438 / 317 L	195	
	1.4541 / 321	205	
	1.4571 / 316 Ti	215	
	1.4406 / 316 LN	280	130
	1.4429 / 316 LN	295	
	1.4439 / 317 LN	285	
	1.4462 / 318 LN	480	205
aluminium alloys	AlMg3 / 5754	80 [1]	35
	AlMg4,5Mn0,7 / 5083	125 [1]	56
	AlMgSi / 6060	65 [2]	30
	AlSi1MgMn / 6082	110 [2]	45

[1] Plates, soft condition
[2] Sections, cold hardened

Table 19.3 Fillet weld connections

Structural parts to be connected	Basic thickness of fillet welds a / t_0 [1] for double continuous fillet welds [2]	Intermittent fillet welds permissible [3]
Bottom structures		
transverse and longitudinal girders to each other	0.35	x
• to shell and inner bottom	0.20	x
centre girder to flat keel and inner bottom	0.40	
transverse and longitudinal girders and stiffeners including shell plating in way of bottom strengthening forward	0.30	
machinery space		
transverse and longitudinal girders to each other	0.35	
• to shell and inner bottom	0.30	
inner bottom to shell	0.40	
sea chests: water side	0.50	
sea chests: inside	0.30	
Machinery foundation		
longitudinal and transverse girders to each other and to the shell	0.40	
• to inner bottom and face plates	0.40	
• to top plates	0.50 [4]	
• in way of foundation bolts	0.70 [4]	
• to brackets and stiffeners	0.30	
longitudinal girders of thrust bearing to inner bottom	0.40	
Decks		
• to shell (general)	0.40	
deckstringer to sheerstrake (see also Section 7, B.2)	0.50	
Frames, stiffeners, beams etc.		
general	0.15	x
in peak tanks	0.30	x
bilge keel to shell	0.15	
Transverses, longitudinal and transverse girders		
general	0.15	x
within 0.15 of span from supports	0.25	
cantilevers	0.40	
pillars to decks	0.40	
Bulkheads, tank boundaries, walls of superstructures and deckhouses		
• to decks, shell and walls	0.40	
Hatch coamings		
• to deck (see also Section 17, C.1.6)	0.40	
• to longitudinal stiffeners	0.30	

Hatch covers		
general	0.15	x [5]
watertight or oiltight fillet welds	0.30	
Rudder		
plating to webs	0.25	x
Stem		
plating to webs	0.25	x

1 t_0 = Thickness of the thinner plate.

2 In way of large shear forces larger throat thicknesses may be required on the bases of calculations according to C.

3 For intermittent welding in spaces liable to corrosion B.3.3.8 is to be observed.

4 For plate thicknesses exceeding 15 mm single or double bevel butt joints with, full penetration or with defined incomplete root penetration according to Fig. 19.9 to be applied.

5 excepting hatch covers above holds provided for ballast water.

Section 20 Fatigue Strength

Preface

The proof of sufficient fatigue strength, i. e. the strength against crack initiation under dynamic loads during operation, is useful for judging and reducing the probability of crack initiation of structural members during the design stage.

Due to the randomness of the load process, the spreading of material properties and fabrication factors and to effects of ageing, crack initiation cannot be completely excluded during later operation. Therefore among other things periodical surveys are necessary.

A General

A.1 Definitions

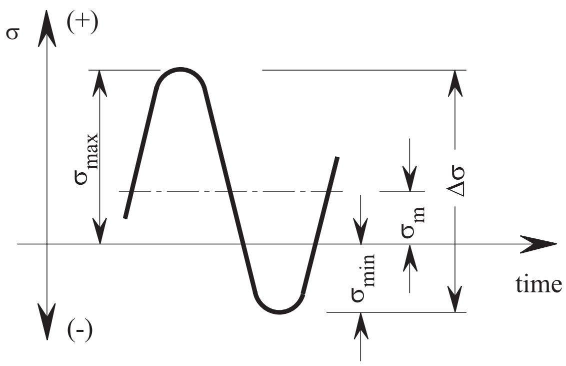


Fig. 20.1 Dynamic load cycle

$\Delta\sigma$: applied stress range $[N / mm^2]$ (see also Fig. 20.1), defined as:

$$\Delta\sigma = \sigma_{max} - \sigma_{min}$$

σ_{max} : maximum upper stress $[N / mm^2]$ of a stress cycle

σ_{min} : maximum lower stress $[N / mm^2]$ of a stress cycle

$\Delta\sigma_{max}$: applied peak stress $[N / mm^2]$ range within a stress range spectrum

σ_m : mean stress $[N/mm^2]$, defined as:

$$\sigma_m = (\sigma_{max} + \sigma_{min}) / 2$$

$\Delta\sigma_p$: permissible stress range $[N / mm^2]$

$\Delta\tau$: Corresponding range $[N / mm^2]$ for shear stress

n : number of applied stress cycles

N : number of endured stress cycles according to S-N curve (= endured stress cycles under constant amplitude loading)

$\Delta\sigma_R$: fatigue strength reference value of S-N curve at $2 \cdot 10^6$ cycles of stress range $[N / mm^2]$ (= FAT class according to Table 20.3)

f_m : correction factor for material effect

f_R : correction factor for mean stress effect

f_w : correction factor for weld shape effect

f_i : correction factor for importance of structural element

f_t : correction factor for thickness effect

f_s : additional correction factor for structural stress analysis

f_n : factor considering stress spectrum and number of cycles for calculation of permissible stress range

$\Delta\sigma_{Rc}$: corrected fatigue strength reference value of S-N curve at $2 \cdot 10^6$ stress cycles $[N / mm^2]$

D : cumulative damage ratio

A.2 Scope

A.2.1 A fatigue strength analysis is to be performed for structures which are predominantly subjected to cyclic loads. Items of equipment, e.g. hatch cover resting pads or equipment holders, are thereby also to be considered. The notched details i. e. the welded joints as well as notches at free plate edges are to be considered individually. The fatigue strength assessment is to be carried out either on the basis of a permissible peak stress range for standard stress spectra, see B.2.1 or on the basis of a cumulative damage ratio, see B.2.2.

A.2.2 No fatigue strength analysis is required if the peak stress range due to dynamic loads in the seaway (stress spectrum A according to A.2.4) and/or due to changing draught or loading conditions, respectively, fulfils the following conditions:

- peak stress range only due to seaway-induced dynamic loads:

$$\Delta\sigma_{max} \le 2.5 \cdot \Delta\sigma_R \quad [N / mm^2]$$

- sum of the peak stress ranges due to seaway-induced dynamic loads and due to changes of draught or loading condition, respectively:

$$\Delta\sigma_{max} \le 4.0 \cdot \Delta\sigma_R \quad [N / mm^2]$$

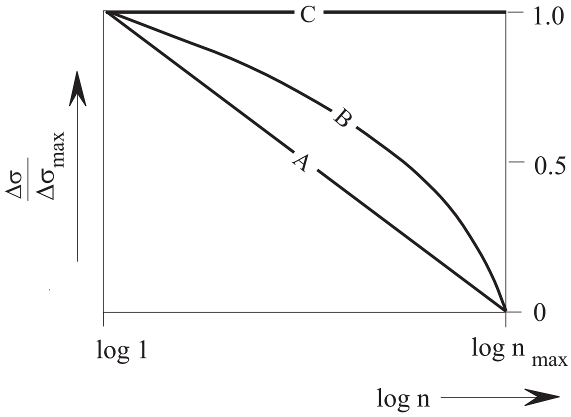
Note

For welded steel structures of FAT class 80 or higher a fatigue strength analysis is required only in case of extraordinary high dynamic stresses.

A.2.3 The rules are applicable to constructions made of normal and higher-strength hull structural steels according to Section 2, B as well as aluminium alloys. Other materials such as cast steel can be treated in an analogous manner by using appropriate design S-N curves.

Low cycle fatigue problems in connection with extensive cyclic yielding have to be specially considered. When applying the following rules, the calculated nominal stress range should not exceed 1.5 times the yield strength. In special cases the fatigue strength analysis may be performed by considering the local elasto-plastic stresses.

A.2.4 The stress ranges $\Delta\sigma$ which are to be expected during the service life of the ship or structural component, respectively, may be described by a stress range spectrum (long-term distribution of stress range) Fig. 20.2 shows three standard stress range spectra A, B and C, which differ from each other in regard to the distribution of stress range $\Delta\sigma$ as a function of the number of load cycles.



A : straight-line spectrum (typical stress range spectrum of seaway-induced stress ranges)

B : parabolic spectrum (approximated normal distribution of stress range $\Delta\sigma$ acc. DIN 15018)

C : rectangular spectrum (constant stress range within the whole spectrum; typical spectrum of engine- or propeller-excited stress ranges)

Fig. 20.2 Standard stress range spectra A, B and C

In case of only seaway-induced stresses, for a design lifetime of about 20 years normally the stress range spectrum A is to be assumed with a number of cycles $n_{max} = 5.0 \cdot 10^7$.

For design lifetime of 30 years the number of cycles $n_{max} = 7.5 \cdot 10^7$ is to be assumed.

The maximum and minimum stresses result from the maximum and minimum relevant seaway-induced load effects. The different load-effects for the calculation of $\Delta\sigma_{max}$ are, in general, to be superimposed conservatively. Table 20.1 shows examples for the individual loads which have to be considered in normal cases.

Under extreme seaway conditions stress ranges exceeding $\Delta\sigma_{max}$ occur (see Section 5, D). These stress ranges, which load cycles are to be generally assumed with $n < 10^4$, can be neglected regarding the fatigue life, when the stress ranges $\Delta\sigma_{max}$ derived from loads according to Table 20.1 are assigned to the spectrum A.

For ships of unconventional hull shape and for ships for which a special mission profile applies, a stress range spectrum deviating from spectrum A may be applied which may be evaluated by the spectral method.

Other significant fluctuating stresses, e.g. in longitudinals due to deflections of supporting transverses (see Section 3, B.3.8.2 on this), in longitudinal and transverse structures due to torsional deformations (see for this also Section 5, E.8) as well as additional stresses due to the application of non-symmetrical sections, have to be considered, see Section 3, B.3.7.

A.2.5 Additional stress cycles resulting from changing mean stresses, e.g. due to changing loading conditions or draught, need generally not be considered as long as the seaway-induced stress ranges are determined for the loading condition being most critical with respect to fatigue strength and the maximum change in mean stress is less than the maximum seaway-induced stress range.

Larger changes in mean stress are to be included in the stress range spectrum by conservative super positioning of the largest stress ranges (e.g. in accordance with the "rain flow counting method"). If nothing else is specified, 10^3 load cycles have to be assumed for changes in loading condition or draught.

A.2.6 The fatigue strength analysis is, depending on the detail considered, based on one of the following types of stress:

- For notches of free plate edges the notch stress σ_k, determined for linear-elastic material behaviour, is relevant, which can normally be calculated from a nominal stress σ_n and a theoretical stress concentration factor K_t. Values for K_t are given in Section 3, Fig. 3.13 and Section 3 for different types of cut-outs. The fatigue strength is determined by the FAT class $(\Delta\sigma_R)$ according to Table 20.3, type E2 and E3.

- For welded joints the fatigue strength analysis is normally based on the nominal stress σ_n at the structural detail considered and on an appropriate detail classification as given in Table 20.3, which defines the FAT class $(\Delta\sigma_R)$.
- For those welded joints, for which the detail classification is not possible or additional stresses occur, which are not or not adequately considered by the detail classification, the fatigue strength analysis may be performed on the basis of the structural stress σ_S in accordance with C.

Table 20.1 Maximum and minimum value for seaway induced cyclic loads

Load		Maximum load	Minimum load
Vertical bending moments (Section 5, D.1) [1]		$M_{SW} + M_{ST} + f_Q \cdot M_{WVhog}$	$M_{SW} + M_{ST} + f_Q \cdot M_{WVsag}$
Vertical bending moments and horizontal wave bending moments [1] (Section 5, D.1)		$M_{SW} + M_{ST}$ $+ f_Q \cdot (0.6 \cdot M_{WVhog} + M_{WH})$	$M_{SW} + M_{ST}$ $+ f_Q \cdot (0.6 \cdot M_{WVsag} - M_{WH})$
Vertical bending moments, horizontal wave bending moments and torsional moments [1] (Section 5, D.1)		$f_F \cdot \{M_{SW} + M_{ST}$ $+ f_Q \cdot [(0.43 + C) \cdot M_{WVhog}$ $+ M_{WH} + M_{WT}]\}$	$f_F \cdot \{M_{SW} + M_{ST}$ $+ f_Q \cdot [(0.43 + C \cdot (0.5 - C)) \cdot M_{WVhog}$ $+ C \cdot (0.43 + C) M_{WVsag} - M_{WH} - M_{WT}]\}$
		$C = \left(\frac{x}{\mathbf{L}} - 0.5\right)^2$	
Loads on weather decks [2] (Section 4, B.1)		p_D	0
Loads on ship's sides [2, 4] (Section 4, B.2)			
• below **T**		$10 \cdot (\mathbf{T} - z) + p_0 \cdot c_F \cdot \left(1 + \frac{z}{\mathbf{T}}\right)$	$10 \cdot (\mathbf{T} - z) - p_0 \cdot c_F \cdot \left(1 + \frac{z}{\mathbf{T}}\right)$ but ≥ 0
• above **T**		$p_0 \cdot c_F \cdot \frac{20}{10 + z - \mathbf{T}}$	0
Loads on ship's bottom [2, 4] (Section 4, B.5)		$10 \cdot \mathbf{T} + p_0 \cdot c_F$	$10 \cdot \mathbf{T} - p_0 \cdot c_F$
Liquid pressure in completely filled tanks (Section 4, D.1)	upright [4]	$9.81 \cdot h_1 \cdot \rho \cdot (1 + a_v) + 100 \cdot p_v$	$9.81 \cdot h_1 \cdot \rho \cdot (1 - a_v) + 100 \cdot p_v$
	heeled	$9.81 \cdot \rho \cdot [h_1 \cdot \cos\varphi$ $+ (0.3 \cdot b + y) \cdot \sin\varphi] + 100 \cdot p_v$	$9.81 \cdot \rho \cdot [h_1 \cdot \cos\varphi + (0.3 \cdot b - y)$ $\cdot \sin\varphi] + 100 \cdot p_v$ but $\geq 100 \cdot p_v$
Loads due to cargo [5] (Section 4, C.1 and Section 4, E.1)		$p \cdot (1 + a_v)$ $p \cdot a_x \cdot 0.7$ $p \cdot a_y \cdot 0.7$	$p \cdot (1 - a_v)$ $-p \cdot a_x \cdot 0.7$ $-p \cdot a_y \cdot 0.7$
Loads due to friction forces [3] (Section 17, B.5.5.5)		P_h	$-P_h$

Loads due to rudder forces [3] (Section 14, D)	C_R Q_R	$-C_R$ $-Q_R$

1 Maximum and minimum load are to be so determined that the largest applied stress range $\Delta\sigma$ as per Fig. 20.1 at conservative mean stress is obtained having due regard to the sign (plus, minus). For f_F, f_Q see Section 5, D.2.

2 With probability factor f for calculation of p_0 according to Section 4, A.3, however:

$f = 1.0$ for stiffeners if no other cyclic load components are considered

3 In general, the largest load is to be taken in connection with the load spectrum B without considering further cyclic loads.

For hatch cover supports the following load spectra are to be used:

- spectrum A for non-metallic, frictionless material on steel contact
- spectrum B for steel on steel contact

4 Assumption of conservative superpositioning of sea and tank pressures within $0.2 < x / L \le 0.7$: Where appropriate, proof is to be furnished for T_{min}

5 Probability factor $f_Q = 1.0$ used for determination of a_0 and further calculation of a_x and a_y according to Section 4, E.1.

A.3 Quality requirements (fabrication tolerances)

A.3.1 The detail classification of the different welded joints as given in Table 20.3 is based on the assumption that the fabrication of the structural detail or welded joint, respectively, corresponds in regard to external defects at least to quality group B according to DIN EN ISO 5817 and in regard to internal defects at least to quality group C. Further information about the tolerances can also be found in the GL Rules for Design, Fabrication and Inspection of Welded Joints (II-3-2).

A.3.2 Relevant information have to be included in the manufacturing document for fabrication. If it is not possible to comply with the tolerances given in the standards, this has to be accounted for when designing the structural details or welded joints, respectively. In special cases an improved manufacture as stated in A.3.1 may be required, e.g. stricter tolerances or improved weld shapes, see also B.3.2.4.

A.3.3 The following stress increase factors k_m for considering significant influence of axial and angular misalignment are already included in the fatigue strength reference values $\Delta\sigma_R$ (Table 20.3):

$k_m = 1.15$ butt welds (corresponding type A1, A2, A11)

$k_m = 1.30$ butt welds (corresponding type A3 – A10)

$k_m = 1.45$ cruciform joints (corresponding type D1 – D5)

$k_m = 1.25$ T-joints (corresponding type D1 – D3)

$k_m = 1.25$ fillet welds on one plate surface (corresponding type C7, C8)

Other additional stresses need to be considered separately.

B Fatigue Strength Analysis for Free Plate Edges and for Welded Joints using Detail Classification

B.1 Definition of nominal stress and detail classification for welded joints

B.1.1 Corresponding to their notch effect, welded joints are normally classified into detail categories considering particulars in geometry and fabrication, including subsequent quality control, and definition of nominal stress. Table 20.3 shows the detail classification based on recommendations of the International Institute of Welding (IIW) giving the FAT class ($\Delta\sigma_R$) for structures made of steel or aluminium alloys (Al).

In Table 20.4 $\Delta\sigma_R$-values for steel are given for some intersections of longitudinal frames of different shape and webs, which can be used for the assessment of the longitudinal stresses.

It has to be noted that some influence parameters cannot be considered by the detail classification and that a large scatter of fatigue strength has therefore to be expected.

B.1.2 Details which are not contained in Table 20.3 may be classified either on the basis of local stresses in accordance with C or, else, by reference to published experimental work or by carrying out special fatigue tests, assuming a sufficiently high confidence level (see B.3.1) and taking into account the correction factors as given in C.4.

Details contained in Table 20.3, produced by improved manufacturing technology, may be classified by carrying out special fatigue tests as described above. Such classification of details is to be agreed upon with GL case by case.

B.1.3 Regarding the definition of nominal stress, the arrows in Table 20.3 indicate the location and direction of the stress for which the stress range is to be calculated. The potential crack location is also shown in Table 20.3. Depending on this crack location, the nominal stress range has to be determined by using either the cross sectional area of the parent metal or the weld throat thickness, respectively. Bending stresses in plate and shell structures have to be incorporated into the nominal stress, taking the nominal bending stress acting at the location of crack initiation.

Note

The factor K_s for the stress increase at transverse butt welds between plates of different thickness (see type $A5$ in Table 20.3) can be estimated in a first approximation as follows:

$$K_s = \frac{t_2}{t_1}$$

t_1 : *smaller plate thickness*

t_2 : *larger plate thickness*

Additional stress concentrations which are not characteristic of the FAT class itself, e.g. due to cut-outs in the neighbourhood of the detail, have also to be incorporated into the nominal stress.

B.1.4 In the case of combined normal and shear stress the relevant stress range is to be taken as the range of the principal stress at the potential crack location which acts approximately perpendicular (within $\pm 45°$) to the crack front as shown in Table 20.3 as long as it is larger than the individual stress components.

B.1.5 Where solely shear stresses are acting the largest principal stress $\sigma_1 = \tau$ may be used in combination with the relevant FAT class.

B.2 Permissible stress range for standard stress range spectra or calculation of the cumulative damage ratio

B.2.1 For standard stress range spectra according to Fig. 20.2, the permissible peak stress range can be calculated as follows:

$$\Delta\sigma_p = f_n \cdot \Delta\sigma_{Rc}$$

$\Delta\sigma_{Rc}$: FAT class or fatigue strength reference value, respectively, corrected according to B.3.2

f_n : factor according to Table 20.2

The peak stress range of the spectrum is not to exceed the permissible value, i.e.

$$\Delta\sigma_{max} \le \Delta\sigma_p$$

B.2.2 If the fatigue strength analysis is based on the calculation of the cumulative damage ratio, the stress range spectrum expected during the envisaged service life is to be established (see A.2.4) and the cumulative damage ratio D is to be calculated as follows:

$$D = \sum_{i=1}^{I} \left(n_i / N_i\right)$$

I : total number of blocks of the stress range spectrum for summation (normally $I \geq 20$)

n_i : number of stress cycles in block i

N_i : number of endured stress cycles determined from the corrected design S-N curve (see B.3) taking $\Delta\sigma = \Delta\sigma_i$

$\Delta\sigma_i$: stress range of block i

To achieve an acceptable high fatigue life, the cumulative damage ratio should not exceed $D = 1$.

If the expected stress range spectrum can be superimposed by two or more standard stress spectra according to A.2.4, the partial damage ratios D_i due to the individual stress range spectra can be derived from Table 20.2. In this case a linear relationship between number of load cycles and cumulative damage ratio may be assumed. The numbers of load cycles given in Table 20.2 apply for a cumulative damage ratio of $D = 1$.

Table 20.2 Factor f_n for the determination of the permissible stress range for standard stress range spectra

Stress range spectrum	Welded Joints					Plates Edges														
	($m_o = 3$)					Type E1 ($m_o = 5$)					Type E2, E2a ($m_o = 4$)					Type E3 ($m_o = 3.5$)				
	n_{max} =					n_{max} =					n_{max} =					n_{max} =				
	10^3	10^5	$5\cdot10^7$	10^8	$3\cdot10^8$	10^3	10^5	$5\cdot10^7$	10^8	$3\cdot10^8$	10^3	10^5	$5\cdot10^7$	10^8	$3\cdot10^8$	10^3	10^5	$5\cdot10^7$	10^8	$3\cdot10^8$
A		(17.2)	3.53	3.02	2.39		(8.1)	3.63	3.32	2.89		(8.63) (9.20)[3]	3.66	3.28	2.76		(10,3) (12.2)[2]	3.65	3.19	2.62
B		(9.2)	1.67	1.43	1.15	(9.5)	5.0	1.95	1.78	1.55	(10.30) (11.20)[3]	5.50 5.90 [3]	1.86	1.65	1.40		6.6 7.5 [2]	1.78	1.55	1.28
C	(12.6)	2.71	0.424 0.543[1]	0.369 0.526[1]	0.296 0.501[1]	(4.57)	1.82	0.606 0.673[1]	0.561 0.653[1]	0.500 0.621[1]	(4.57)	1.82	0.532 0.621[1]	0.482 0.602[1]	0.411 0.573[1]	(4.57)	1.82	0.483 0.587[1]	0.430 0.569[1]	0.358 0.541[1]

For definition of type E1 to type E3 see Table 20.3

For definition of m_0 see B.3.1.2

The values given in parentheses may be applied for interpolation.

For interpolation between any pair of values (n_{max1}; f_{n1}) and (n_{max2}; f_{n2}), the following formula may be applied in the case of stress spectrum A or B:

$$\log f_n = \log f_{n1} + \log\left(n_{max} / n_{max\,1}\right) \cdot \frac{\log\left(f_{n2} / f_{n1}\right)}{\log\left(n_{max\,2} / n_{max\,1}\right)}$$

For the stress spectrum C intermediate values may be calculated according to B.3.1.2 by taking $N = n_{max}$ and $f_n = \Delta\sigma / \Delta\sigma_R$

1 f_n for non-corrosive environment, see also B.3.1.4.

2 for $\Delta\sigma_R = 100 \text{ N / mm}^2$

3 for $\Delta\sigma_R = 140 \text{ N / mm}^2$

B.3 Design S-N curves

B.3.1 Description of the design S-N curves

B.3.1.1 The design S-N curves for the calculation of the cumulative damage ratio according to B.2.2 are shown in Fig. 20.3 for welded joints at steel and in Fig. 20.4 for notches at plate edges of steel plates. For aluminium alloys (Al) corresponding S-N curves apply with reduced reference values of the S-N curves (FAT classes) according to Table 20.3. The S-N curves represent the lower limit of the scatter band of 95 % of all test results available (corresponding to 97.5 % survival probability) considering further detrimental effects in large structures.

To account for different influence factors, the design S-N curves have to be corrected according to B.3.2.

B.3.1.2 The S-N curves represent section-wise linear relationships between $\log(\Delta\sigma)$ and $\log(N)$:

$$\log(N) = 7.0 + m \cdot Q$$

Q : coefficient, defined as:

$$Q = \log\left(\Delta\sigma_R / \Delta\sigma\right) - 0.69897 / m_0$$

m : slope exponent of S-N curve, see B.3.1.3 and B.3.1.4

m_0 : inverse slope in the range $N \le 1 \cdot 10^7$, defined as:

$m_0 = 3$ for welded joints

$m_0 = 3.5 \div 5$ for free plate edges (see Fig. 20.4)

The S-N curve for FAT class 160 forms the upper limit for the S-N curves of free edges of steel plates with detail categories 100 – 150 in the range of low stress cycles, see Fig. 20.4. The same applies accordingly to FAT classes 32 – 40 of aluminium alloys with an upper limit of FAT 71, see type E1 in Table 20.3.

B.3.1.3 For structures subjected to variable stress ranges, the S-N curves shown by the solid lines in Fig. 20.3 and Fig. 20.4 have to be applied (S-N curves of type "M"), i.e.

$m = m_0$ for $N \le 10^7$ $(Q \le 0)$

$m = 2 \cdot m_0 - 1$ for $N > 10^7$ $(Q > 0)$

B.3.1.4 For stress ranges of constant magnitude (stress range spectrum C) in non-corrosive environment from $N = 1 \cdot 10^7$ the S-N curves of type "O" in Fig. 20.3 and Fig. 20.4 can be used, thus:

$m = m_0$ for $N \le 10^7$ $(Q \le 0)$

$m = 22$ for $N > 10^7$ $(Q > 0)$

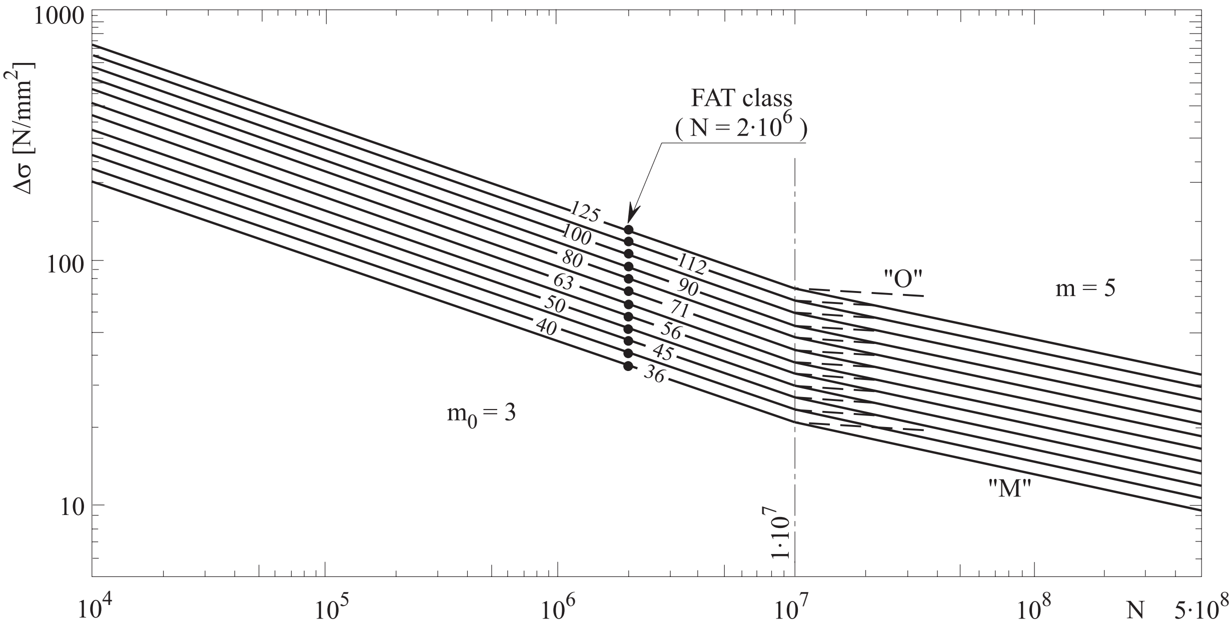


Fig. 20.3 S-N curves for welded joints at steel

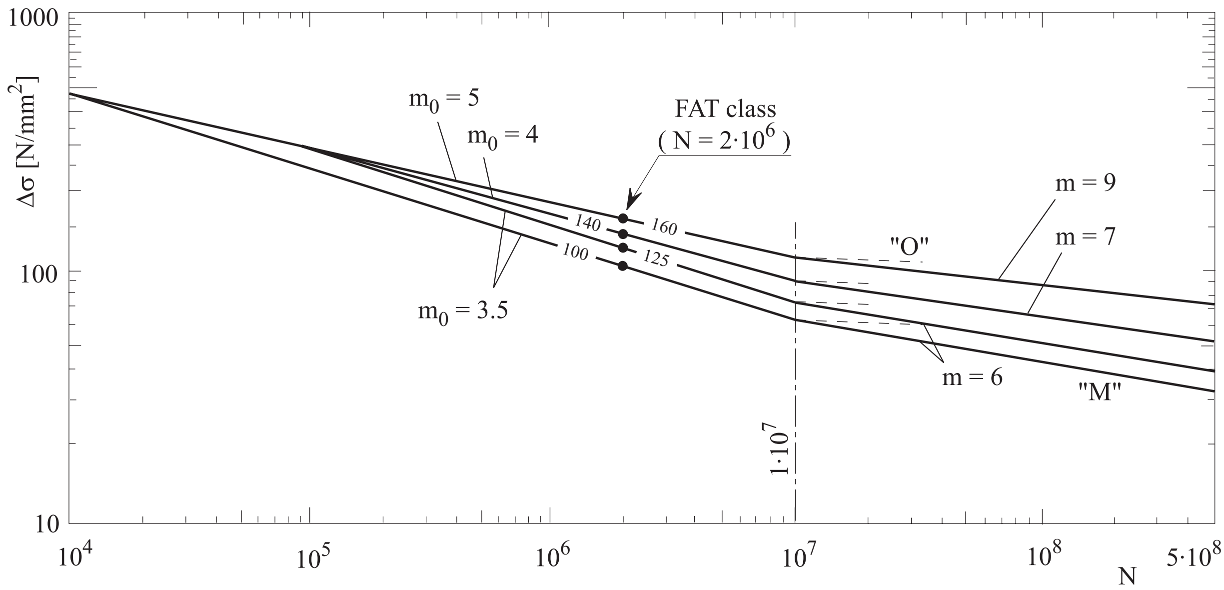


Fig. 20.4 S-N curves for notches at plate edges of steel plates

B.3.2 Correction of the reference value of the design S-N curve

B.3.2.1 A correction of the reference value of the S-N curve (FAT class) is required to account for additional influence factors on fatigue strength as follows:

$$\Delta\sigma_{Rc} = f_m \cdot f_R \cdot f_w \cdot f_i \cdot f_t \cdot \Delta\sigma_R$$

f_m, f_R, f_w, f_i, f_t : factors according to B.3.2.2 – B.3.2.6

For the description of the corrected design S-N curve, the formulae given in B.3.1.2 may be used by replacing $\Delta\sigma_R$ by $\Delta\sigma_{Rc}$.

B.3.2.2 Material effect (f_m)

For welded joints it is generally assumed that the fatigue strength is independent of steel strength, i.e.:

$$f_m = 1.0$$

For free edges at steel plates the effect of the material's yield strength is accounted for as follows:

$$f_m = 1 + \frac{R_{eH} - 235}{1200}$$

For aluminium alloys, $f_m = 1$ generally applies.

B.3.2.3 Effect of mean stress (f_R)

The correction factor f_R is to be determined by the following formulae:

$f_R = 1.0$ for $\sigma_m \geq \frac{\Delta\sigma_{max}}{2}$ (range of tensile pulsating stresses)

$f_R = 1 + c \cdot \left(1 - \frac{2 \cdot \sigma_m}{\Delta\sigma_{max}}\right)$ for $-\frac{\Delta\sigma_{max}}{2} \leq \sigma_m \leq \frac{\Delta\sigma_{max}}{2}$ (range of alternating stresses)

$f_R = 1 + 2 \cdot c$ for $\sigma_m \leq -\frac{\Delta\sigma_{max}}{2}$ (range of compressive pulsating stresses)

c : coefficient, defined as:

$c = 0$ for welded joints subjected to constant stress cycles (stress range spectrum C)

$c = 0.15$ for welded joints subjected to variable stress cycles (corresponding to stress range spectrum A or B)

$c = 0.30$ for unwelded base material

B.3.2.4 Effect of weld shape (f_w)

In normal cases:

$$f_w = 1.0$$

A factor $f_w > 1.0$ applies for welds treated e.g. by grinding. Grinding removes surface defects such as slag inclusions, porosity and crack-like undercuts, to achieve a smooth transition from the weld to the base material. Final grinding is to be performed transversely to the weld direction. The depth should be about 0.5 mm larger than the depth of visible undercuts.

For ground weld toes of fillet and K-butt welds machined by:

$f_w = 1.15$ for disc grinder

$f_w = 1.30$ for burr grinder

Premise for this is that root and internal failures can be excluded. Application of toe grinding to improve fatigue strength is limited to following details of Table 20.3:

- butt welds of type A2, A3 and A5 if they are ground from both sides
- non-load-carrying attachments of type C1, C2, C5 and C6 if they are completed with a full penetration weld
- transverse stiffeners of type C7
- doubling plates of type C9 if the weld throat thickness according to Section 19 was increased by 30 %
- cruciform and T-joints of type D1 with full penetration welds

The corrected FAT class that can be reached by toe grinding is limited for all types of welded connections of steel to $f_w \cdot \Delta\sigma_R = 100\ N/mm^2$ and of aluminium to $f_w \cdot \Delta\sigma_R = 40\ N/mm^2$.

For butt welds ground flush the corresponding reference value of the S-N curve (FAT class) has to be chosen, e.g. type A1, A10 or A12 in Table 20.3.

For endings of stiffeners or brackets, e.g. type C2 in Table 20.3, which have a full penetration weld and are completely ground flush to achieve a notch-free transition, the following factor applies:

$$f_w = 1.4$$

The assessment of a local post-weld treatment of the weld surface and the weld toe by other methods e.g. ultrasonic impact treatment has to be agreed on in each case.

B.3.2.5 Influence of importance of structural element (f_i)

The following applies:

$f_i = 1.0$	in general
$f_i = 0.9$	for secondary structural elements failure of which may cause failure of larger structural areas
$f_i = 0.9 + 5 / r \leq 1.0$	for notches at plate edges taking into account the radius of rounding

r : notch radius [mm]; for elliptical roundings the mean value of the two main half axes may be taken.

B.3.2.6 Plate thickness effect

In order to account for the plate thickness effect, application of the reduction factor f_t is required by GL for butt welds oriented transversely to the direction of applied stress for plate thicknesses $t > 25$ mm.

$$f_t = \left(\frac{25}{t}\right)^n$$

n : exponent, defined as:

$n = 0.17$	as welded
$n = 0.10$	toe-ground

For all other weld connections consideration of the thickness effect may be required subject to agreement with GL.

C Fatigue Strength Analysis for Welded Joints Based on Local Stresses

C.1 Alternatively to the procedure described in the preceding paragraphs, the fatigue strength analysis for welded joints may be performed on the basis of local stresses. For common plate and shell structures in ships the assessment based on the so-called structural (or hot-spot) stress σ_s is normally sufficient.

The structural stress is defined as the stress being extrapolated to the weld toe excluding the local stress concentration in the local vicinity of the weld, see Fig. 20.5.

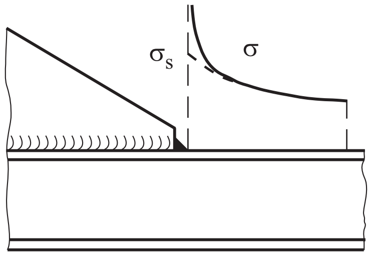


Fig. 20.5 Structural stress

C.2 The structural stress can be determined by measurements or numerically e.g. by the finite element method using shell or volumetric models under the assumption of linear stress distribution over the plate thickness. Normally the stress is extrapolated linearly to the weld toe over two reference points which are located 0.5 and 1.5 x plate thickness away from the weld toe. In some cases the structural stress can be calculated from the nominal stress σ_n and a structural stress concentration factor K_s, which has been derived from parametric investigations using the methods mentioned. Parametric equations should be used with due consideration of their inherent limitations and accuracy.

C.3 For the fatigue strength analysis based on structural stress, the S-N curves shown in Fig. 20.3 apply with the following reference values:

$\Delta\sigma_R = 100$ (resp. 40 for Al)	for the butt welds types A1 – A6 and for K-butt welds with fillet welded ends, e.g. type D1 in Table 20.3, and for fillet welds which carry no load or only part of the load of the attached plate, type C1 – C9 in Table 20.3
$\Delta\sigma_R = 90$ (resp. 36 for Al)	for fillet welds, which carry the total load of the attached plate, e.g. type D2 in Table 20.3

In special cases, where e.g. the structural stresses are obtained by non-linear extrapolation to the weld toe and where they contain a high bending portion, increased reference values of up to 15 % can be allowed.

C.4 The reference value $\Delta\sigma_{Rc}$ of the corrected S-N curve is to be determined according to B.3.2, taking into account the following additional correction factor which describes influencing parameters not included in the calculation model such as e.g. misalignment:

$$f_s = \frac{1}{k'_m - \frac{\Delta\sigma_{s,b}}{\Delta\sigma_{s,max}} \cdot (k'_m - 1)}$$

$\Delta\sigma_{s,max}$: applied peak stress range within a stress range spectrum

$\Delta\sigma_{s,b}$: bending portion of $\Delta\sigma_{s,max}$

k'_m : effective stress increase factor due to misalignments under axial loading, defined as:

$$k'_m = k_m - 0.05$$

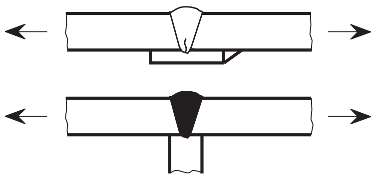
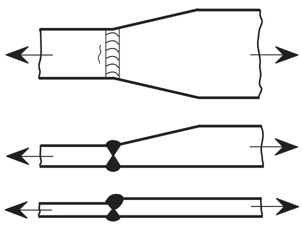
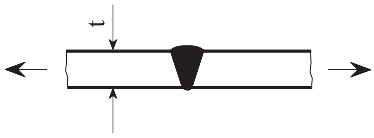
k_m : stress increase factor due to misalignments under axial loading, at least k_m according A.3.3

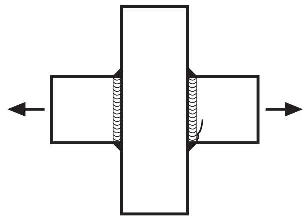
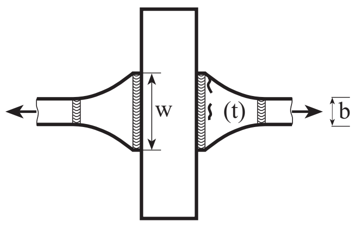
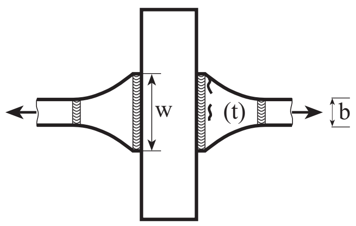
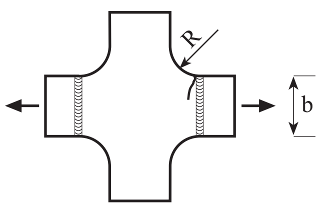
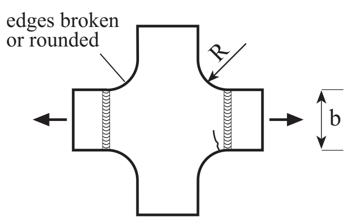
The permissible stress range or cumulative damage ratio, respectively, has to be determined according to B.2.

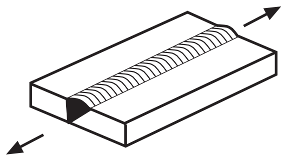
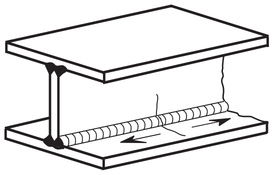
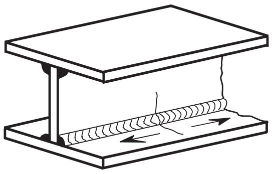
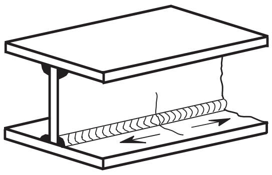
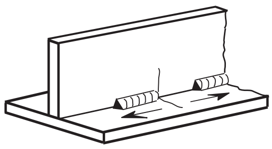
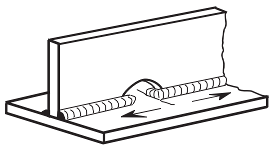
C.5 In addition to the assessment of the structural stress at the weld toe, the fatigue strength with regard to root failure has to be considered by analogous application of the respective FAT class, e.g. type D3 of Table 20.3.

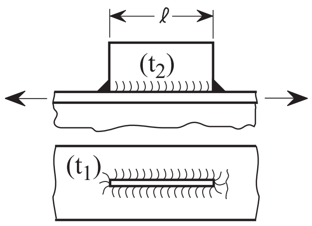
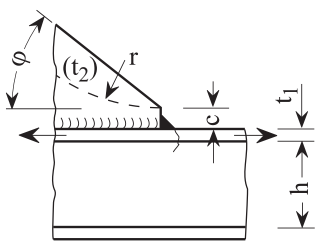
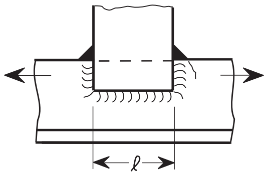
In this case the relevant stress is the stress in the weld cross section caused by the axial stress in the plate perpendicular to the weld. It is to be converted at a ratio of t / (2 · a).

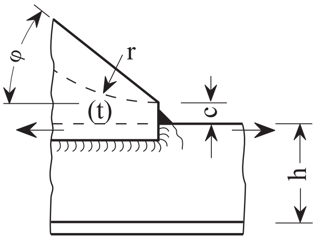
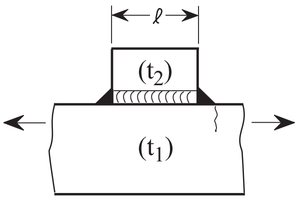
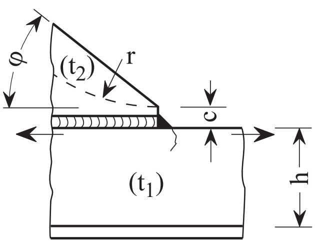
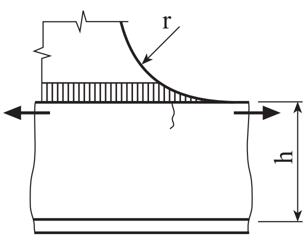
Table 20.3 Catalogue of details

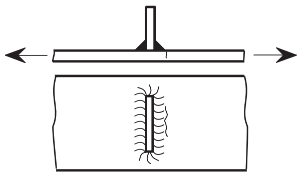
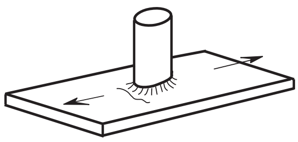
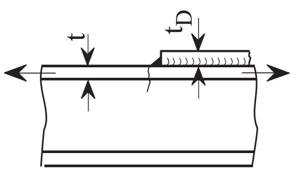
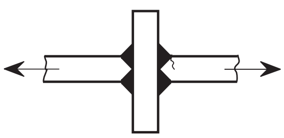
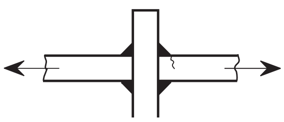
Type No.	Joint configuration showing mode of fatigue cracking and stress σ considered	Description of joint	FAT class $\Delta\sigma_R$ Steel	FAT class $\Delta\sigma_R$ Al
Butt welds, transverse loaded (A)				
A1		Transverse butt weld ground flush to plate, 100 % NDT (Non-Destructive Testing)	112	45
A2		Transverse butt weld made in shop in flat position, max. weld reinforcement 1 mm + 0.1 x weld width, smooth transitions, NDT	90	36
A3		Transverse butt weld not satisfying conditions for joint type No. A2, NDT	80	32
A4		Transverse butt weld on backing strip or three-plate connection with unloaded branch	71	25
		Butt weld, welded on ceramic backing, root crack	80	28
A5		Transverse butt welds between plates of different widths or thickness, NDT		
		as for joint type No. A2: slope 1 : 5	90	32
		slope 1 : 3	80	28
		slope 1 : 2	71	25
		as for joint type No. A3: slope 1 : 5	80	25
		slope 1 : 3	71	22
		slope 1 : 2	63	20
		For the third sketched case the slope results from the ratio of the difference in plate thicknesses to the breadth of the welded seam. Additional bending stress due to thickness change to be considered, see also B.1.3.		
A6		Transverse butt welds welded from one side without backing bar, full penetration root:		
		• controlled by NDT	71	28
		• not controlled by NDT	36	12
		For tubular profiles $\Delta\sigma_R$ may be lifted to the next higher FAT class.		
		Laser (t ≤ 8 mm) and laser hybrid (t ≤ 12 mm) butt welds	80	28

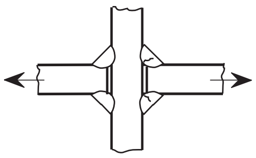
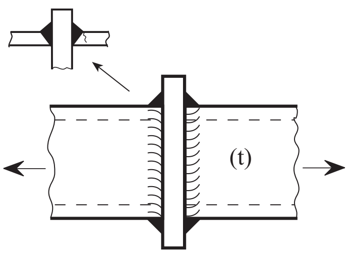
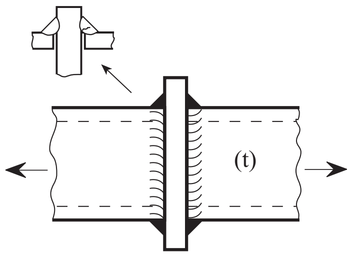
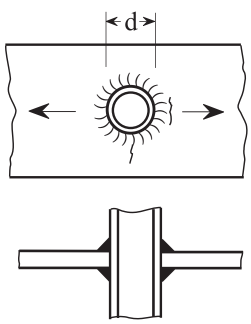
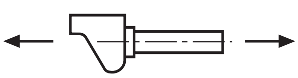
A7		Partial penetration butt weld; the stress is to be related to the weld throat sectional area, weld overfill not to be taken into account	36	36
A8		Full penetration butt weld at crossing flanges Welded from both sides	50	18
A9		Full penetration butt weld at crossing flanges Welded from both sides Cutting edges in the quality according to type E2 or E3 Connection length $w \geq 2 \cdot b$ Nominal stress $\sigma_{nominal} = \frac{F}{b \cdot t}$	63	22
A10		Full penetration butt weld at crossing flanges Welded from both sides, NDT, weld ends ground, butt weld ground flush to surface Cutting edges in the quality according to type E2 or E3 with $\Delta\sigma_R = 125$ Connection length $w \geq 2 \cdot b$ Nominal stress $\sigma_{nominal} = \frac{F}{b \cdot t}$	80	32
A11		Full penetration butt weld at crossing flanges Welded from both sides made in shop at flat position, radius transition with $R \geq b$ Weld reinforcement ≤ 1 mm + 0.1 x weld width, smooth transitions, NDT, weld ends ground Cutting edges in the quality according to type E2 or E3 with $\Delta\sigma_R = 125$	90	36
A12		Full penetration butt weld at crossing flanges, radius transition with $R \geq b$ Welded from both sides, no misalignment, 100 % NDT, weld ends ground, butt weld ground flush to surface Cutting edges broken or rounded according to type E2	100	40

Longitudinal load-carrying weld				
B1		Longitudinal butt welds both sides ground flush parallel to load direction without start / stop positions, NDT with start / stop positions	 125 125 90	 50 50 36
B2		Continuous automatic longitudinal fully penetrated K-butt without stop / start positions (based on stress range in flange adjacent to weld)	125	50
B3		Continuous automatic longitudinal fillet weld penetrated K-butt weld without stop / start positions (based on stress range in flange adjacent to weld)	100	40
B4		Continuous manual longitudinal fillet or butt weld (based on stress range in flange adjacent to weld)	90	36
B5		Intermittent longitudinal fillet weld (based on stress range in flange at weld ends) In presence of shear τ in the web, the FAT class has to be reduced by the factor (1 – $\Delta\tau$ / $\Delta\sigma$), but not below 36 (steel) or 14 (Al).	80	32
B6		Longitudinal butt weld, fillet weld or intermittent fillet weld with cut outs (based on stress range in flange at weld ends) If cut out is higher than 40 % of web height In presence of shear τ in the web, the FAT class has to be reduced by the factor (1 – $\Delta\tau$ / $\Delta\sigma$), but not below 36 (steel) or 14 (Al). ***Note*** *For Ω-shaped scallops, an assessment based on local stresses in recommended.*	71 63	28 25

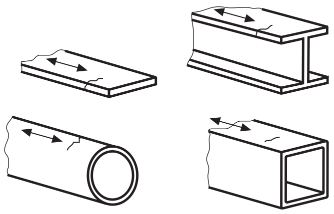
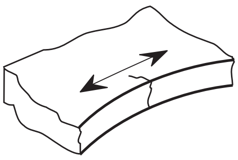
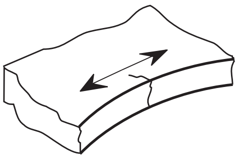
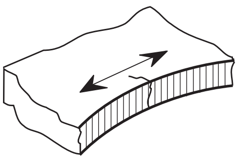
Non-load-carrying attachments				
C1		Longitudinal gusset welded on beam flange, bulb or plate: $\ell \le 50$ mm 50 mm $< \ell \le$ 150 mm 150 mm $< \ell \le$ 300 mm $\ell >$ 300 mm For $t_2 \le 0.5\ t_1$, $\Delta\sigma_R$ may be increased by one class, but not over 80 (steel) or 28 (Al); not valid for bulb profiles. When welding close to edges of plates or profiles (distance less than 10 mm) and/or the structural element is subjected to bending, $\Delta\sigma_R$ is to be decreased by one class.	 80 71 63 56	 28 25 20 18
C2		Gusset with smooth transition (sniped end or radius) welded on beam flange, bulb or plate; $c \le 2 \cdot t_2$, max. 25 mm $t \ge 0.5$ h r < 0.5 h or $\varphi \le 20$ ° $\varphi > 20$ ° see joint type C1 For $t_2 \le 0.5\ t_1$, $\Delta\sigma_R$ may be increased by one class; not valid for bulb profiles. When welding close to the edges of plates or profiles (distance less than 10 mm), $\Delta\sigma_R$ is to be decreased by one class.	 71 63	 25 20
C3		Fillet welded non-load-carrying lap joint welded to longitudinally stressed component. • flat bar • to bulb section • to angle section For $\ell >$ 150 mm, $\Delta\sigma_R$ has to be decreased by one class, while for $\ell \le$ 50 mm, $\Delta\sigma_R$ may be increased by one class. If the component is subjected to bending, $\Delta\sigma_R$ has to be reduced by one class.	 56 56 50	 20 20 18

C4		Fillet welded lap joint with smooth transition (sniped end with $\varphi \leq 20°$ or radius) welded to longitudinally stressed component. • flat bar • to bulb section • to angle section $c \leq 2 \cdot t$, max. 25 mm	 56 56 50	 20 20 18
C5		Longitudinal flat side gusset welded on plate or beam flange edge • $\ell \leq 50$ mm • 50 mm < $\ell \leq 150$ mm • 150 mm < $\ell \leq 300$ mm • $\ell > 300$ mm For $t_2 \leq 0.7 \cdot t_1$, $\Delta\sigma_R$ may be increased by one class, but not over 56 (steel) or 20 (Al). If the plate or beam flange is subjected to in-plane bending, $\Delta\sigma_R$ has to be decreased by one class.	 56 50 45 40	 20 18 16 14
C6		Longitudinal flat side gusset welded on plate edge or beam flange edge, with smooth transition (sniped end or radius); $c \leq 2 \cdot t_2$, max. 25 mm $r \geq 0.5 \cdot h$ $r < 0.5 \cdot h$ or $\varphi \leq 20°$ $\varphi > 20°$ see joint type C5 For $t_2 \leq 0.7 \cdot t_1$, $\Delta\sigma_R$ may be increased by one class.	 50 45	 18 16
C6a		Longitudinal flat side gusset welded on plate edge or beam flange edge, with smooth transition radius $r / h > 1 / 3$ or $r \geq 150$ mm $1 / 6 < r / h < 1 / 3$ $r / h < 1 / 6$	 90 71 50	 36 28 22

		Smooth transition radius formed by grinding the full penetration weld area in order to achieve a notch-free transition area. Final grinding is to be performed parallel to stress direction.		
C7		Transverse stiffener with fillet welds (applicable for short and long stiffeners)	80	28
C8		Non-loaded stud welding on a plate or bulb profile ***Note*** *For an adequate workmanship on bulb profile a centric connection is required.* *For load carrying studs an additional assessment acc. to detail D7 is required.*	80	28
C9		End of long doubling plate on beam, welded ends (based on stress range in flange at weld toe)		
		$t_D \le 0.8 \cdot t$	56	20
		$0.8 \cdot t < tD \le 1.5 \cdot t$	50	18
		$t_D > 1.5 \cdot t$	45	16
		The following features increase $\Delta\sigma_R$ by one class accordingly: • reinforced ends according to Section 19, Fig. 19.4 • weld toe angle $\le 30\ °$ • length of doubling ≤ 300 mm For length of doubling ≤ 150 mm, $\Delta\sigma_R$ may be increased by two classes.		
Cruciform joints and T-joints				
D1		Cruciform or tee-joint K-butt welds with full penetration or with defined incomplete root penetration according to Section 19, Fig. 19.9.		
		cruciform joint	71	25
		tee-joint	80	28
D2		Cruciform or tee-joint with transverse fillet welds, toe failure (root failure particularly for throat thickness $a < 0.7 \cdot t$, see joint type D3)		

		cruciform joint tee-joint	63 71	22 25
D3		Welded metal in transverse load-carrying fillet welds at cruciform or tee-joint, root failure (based on stress range in weld throat), see also joint type No. D2 $a \geq t / 3$ $a < t / 3$ ***Note*** *Crack initiation at weld root*	 36 40	 12 14
D4		Full penetration weld at the connection between a hollow section (e.g. pillar) and a plate, for tubular section for rectangular hollow section For $t \leq 8$ mm, $\Delta\sigma_R$ has to be decreased by one class.	 56 50	 20 18
D5		Fillet weld at the connection between a hollow section (e.g. pillar) and a plate, for tubular section for rectangular hollow section The stress is to be related to the weld sectional area. For $t \leq 8$ mm, $\Delta\sigma_R$ has to be decreased by one class.	 45 40	 16 14
D6		Continuous butt or fillet weld connecting a pipe penetrating through a plate $d \leq 50$ mm $d > 50$ mm ***Note*** *For large diameters an assessment based on local stress is recommended.*	 71 63	 25 22
D7		Axially loaded stud welding on a bulb profile ***Note*** *For an adequate workmanship a centric connection is required*	45	16

Unwelded base material

E1		Rolled or extruded plates and sections as well as seamless pipes, no surface or rolling defects	160 ($m_0 = 5$)	71 ($m_0 = 5$)
E2a		Plate edge sheared or machine-cut by any thermal process with surface free of cracks and notches, cutting edges chamfered or rounded by means of smooth grinding, groove direction parallel to the loading direction. Stress increase due to geometry of cut-outs to be considered by means of direct numerical calculation of the appertaining maximum notch stress range.	150 ($m_0 = 4$)	—
E2		Plate edge sheared or machine-cut by any thermal process with surface free of cracks and notches, cutting edges broken or rounded. Stress increase due to geometry of cut-outs to be considered. [1]	140 ($m_0 = 4$)	40 ($m_0 = 4$)
E3		Plate edge not meeting the requirements of type E2, but free from cracks and severe notches. Machine cut or sheared edge: Manually thermally cut: Stress increase due to geometry of cut-outs to be considered. [1]	 125 ($m_0 = 3.5$) 100 ($m_0 = 3.5$)	 36 ($m_0 = 3.5$) 32 ($m_0 = 3.5$)

1 Stress concentrations caused by an opening to be considered as follows:

$\Delta\sigma_{max} = K_t \cdot \Delta\sigma_N$

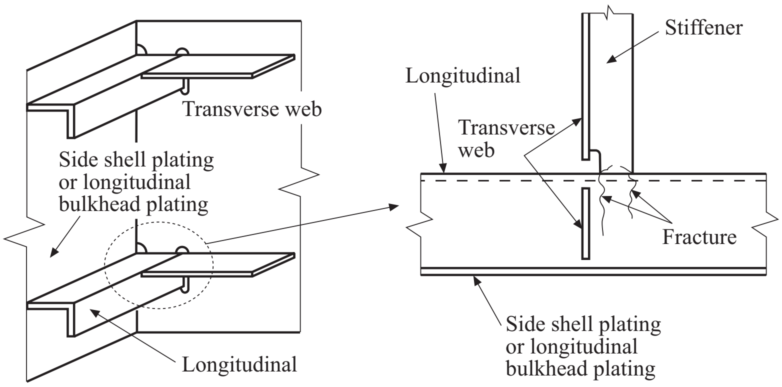
K_t : Notch factor according to Section 3, F

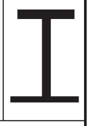
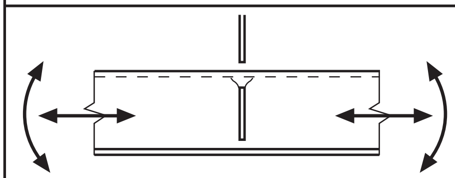
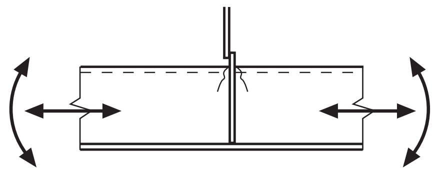
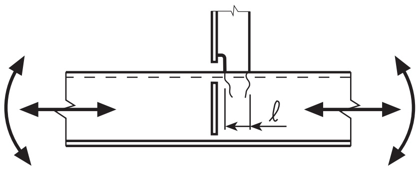
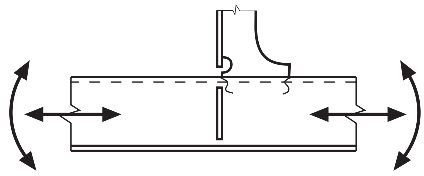
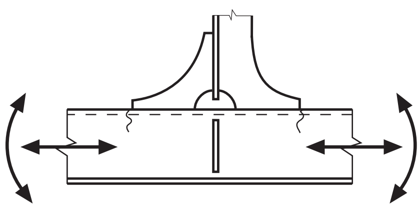
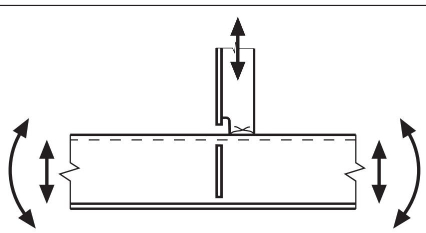
$\Delta\sigma_N$: Nominal stress range related to net section

alternatively direct determination of $\Delta\sigma_{max}$ from FE-calculation, especially in case of hatch openings or multiple arrangement of openings.

Partly based on Recommendations on Fatigue of Welded Components, reproduced from IIW document XIII-2151-07 / XV-1254-07, by kind permission of the International Institute of Welding.

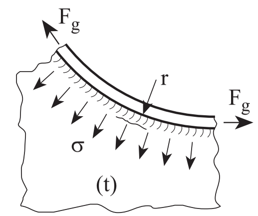
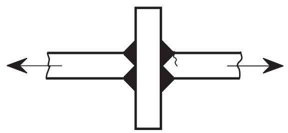
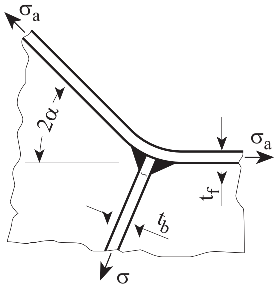
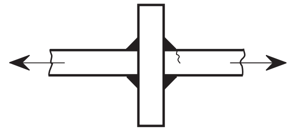
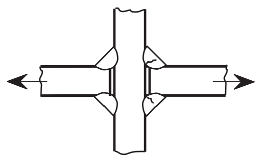
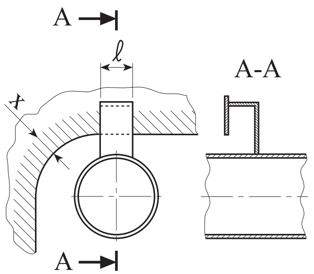
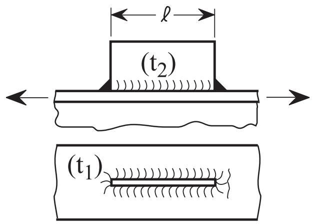
Table 20.4 Various intersections

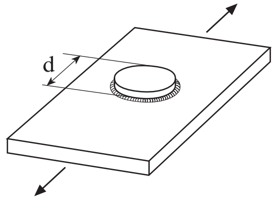
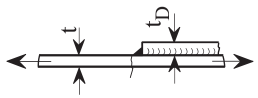
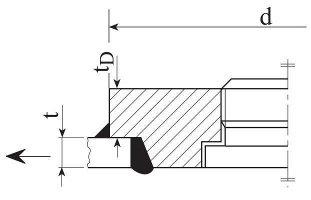
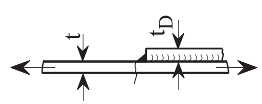
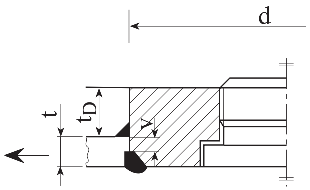
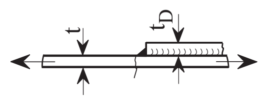
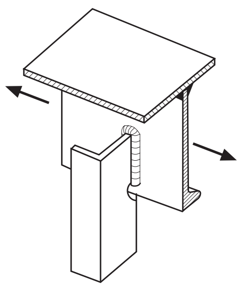
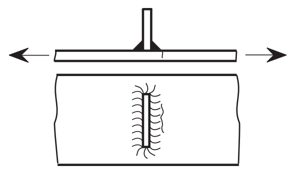


Joint configuration Loads Locations being at risk for cracks	Description of joint	FAT class $\Delta\sigma_R$ steel			
			 [1]	 [1]	
	None watertight intersection without heel stiffener. For predominant longitudinal load only.	80	80	80	80
	Watertight intersection without heel stiffener (without cyclic load on the transverse member, see Section 9, B.4.1) For predominant longitudinal load only	71	71	71	71
 2	With heel stiffener direct connection $\ell \leq 150$ direct connection $\ell > 150$ overlapping connection $\ell \leq 150$ overlapping connection $\ell > 150$	 45 40 50 45	 56 50 50 45	 56 50 45 40	 63 56
 2	With heel stiffener and integrated bracket	45	56	56	63
	With heel stiffener and integrated bracket and with backing bracket direct connection overlapping connection	 50 56	 63 56	 63 50	 71
	With heel stiffener but considering the load transferred to the stiffener (see Section 9, B.4.9) crack initiation at weld toe crack initiation at weld root Stress increase due to eccentricity and shape of cut out has to be observed	 80 	 71 40	 71 40	 71 40

[1] Additional stresses due to asymmetric sections have to be observed, see Section 3,L.
[2] To be increased by one class, when longitudinal loads only

Table 20.5 Examples of details

Structure or equipment detail	Description of structure or equipment detail	Type No.	Joint configuration showing mode of fatigue cracking and stress σ considered	Description of joint	FAT class $\Delta\sigma_R$ Steel
 	Unstiffened flange to web joint, to be assessed according to type D1, D2 or D3, depending on the type of joint. The stress in the web is calculated using the force F_g in the flange as follows: $\sigma = \frac{F_g}{r \cdot t}$ Furthermore, the stress in longitudinal weld direction has to be assessed according to type B2 - B4. In case of additional shear or bending, also the highest principle stress may become relevant in the web, see B.1.4.	D1		Cruciform or tee-joint K-butt welds with full penetration or with defined incomplete root penetration according to Section 19, Fig. 19.9. cruciform joint tee-joint	 71 80
 	Joint at stiffened knuckle of a flange, to be assessed according to type D1, D2 or D3, depending on the type of joint. The stress in the stiffener at the knuckle can normally be calculated as follows: $\sigma = \sigma_a \frac{t_f}{t_b} 2 \sin \alpha$	D2		Cruciform or tee-joint with transverse fillet welds, toe failure (root failure particuarly for throat thickness a < 0,7 · t, see joint type D3) cruciform joint tee-joint	 63 71
		D3		Welded metal in transverse load-carrying fillet welds at cruciform or tee-joint, root failure (based on stress range in weld throat), see also joint type No. D2	36
 	Holder welded in way of an opening and arranged parallel to the edge of the opening. not valid for hatch corner	C1	 	$\ell \le 150$ mm In way of the rounded corner of an opening with the radius r a minimum distance x from the edge to be kept (hatched area): x [mm] = 15 + 0.175 · r [mm] 100 mm ≤ r ≤ 400 mm In case of an elliptical rounding the mean value ot both semiaxes to be applied	71

Structure or equipment detail	Description of structure or equipment detail	Type No.	Joint configuration showing mode of fatigue cracking and stress σ considered	Description of joint	FAT class $\Delta\sigma_R$ steel
	Circular doubler plate with max. 150 mm diameter.	C9		$t_D \leq 0.8\ t$ $0.8\ t < t_D \leq 1.5\ t$ $t_D > 1.5\ t$	71 63 56
	Drain plugs with full penetration butt weld $d \leq 150$ mm Assesment corresponding to doubling plate.	C9		$t_D \leq 0.8\ t$ $0.8\ t < t_D \leq 1.5\ t$ $t_D > 1.5\ t$ For $d > 150$ mm $\Delta\sigma_R$ has to be decreased by one class	71 63 56
	Drain plugs with partial penetration butt weld and a defined root gap $d \leq 150$ mm For $v < 0.4\ t$ or $v < 0.4\ t_D$	C9		$0.2\ t < t_D \leq 0.8\ t$ $0.8\ t < t_D \leq 1.5\ t$ $1.5\ t < t_D < 2.0\ t$ For $d > 150$ mm $\Delta\sigma_R$ has to be decreased by one class	50 45 40
	For $v \geq 0.4\ t$ and $v \geq 0.4\ t_D$	A7		Partial penetration butt weld; the stress is to be related to the weld throat sectional area, weld overfill not to be taken into account	36
	The detail category is also valid for not fully circumferential welded holders For stiffeners loaded in bending $\Delta\sigma_R$ to be downgraded by one class	C7		Transverse stiffener with fillet welds (applicable for short and long stiffeners)	80

Section 21 Hull Outfit

A General

A.1 References

A.1.1 Paragraphs of this section are based on the following international convention(s) and / or code(s):

IACS UR S26 Rev.4

IACS UR S27 Rev.5

ICLL containing all amendments up to 1st July 2010

At the end of each relevant paragraph, the corresponding paragraphs of the international convention(s) and / or code(s) are given in brackets.

B Partition Bulkheads

B.1 Partition bulkheads between engine and boiler rooms

B.1.1 General

Unless these bulkheads are watertight or tank bulkheads according to Section 11 or Section 12, the scantlings according to B.1.2 are sufficient.

B.1.2 Scantlings

B.1.2.1 The thickness of watertight parts of the partition bulkheads is not to be less than 6 mm. The thickness of the remaining parts may be 5 mm.

B.1.2.2 Platforms and decks below the boilers are to be made watertight; they are to be not less than 6.0 mm in thickness, and are to be well supported.

B.1.2.3 Stiffeners spaced 900 mm apart are to be fitted. The section modulus of the stiffeners is not to be less than:

$$W = 12 \cdot \ell \quad [cm^3]$$

ℓ : unsupported span [m] of stiffener

Where the stiffener spacing deviates from 900 mm, the section modulus W is to be corrected in direct proportion.

B.2 Moveable grain bulkheads

B.2.1 General

Movable grain bulkheads may consist of moveable 'tween deck covers or just by moveable bulkheads.

B.2.2 Sealing system

B.2.2.1 A detailed drawing of the sealing system is to be submitted for approval.

B.2.2.2 Sufficient tightness regarding grain leakage is to be ensured.

B.2.2.3 A GL type approval of a moveable bulkhead sealing system is acceptable in lieu of ship specific examination.

C Ceiling

C.1 Bottom ceiling

C.1.1 Where in the holds of general cargo ships a tight bottom ceiling is fitted from board to board, the thickness of a wooden ceiling is not to be less than 60 mm.

C.1.2 On single bottoms ceilings are to be removable for inspection of bottom plating at any time.

C.1.3 Ceilings on double bottoms are to be laid on battens not less than 12.5 mm thick providing a clear space for drainage of water or leakage oil. The ceiling may be laid directly on the inner bottom plating, if embedded in preservation and sealing compound.

C.1.4 The manholes are to be protected by a steel coaming welded around each manhole, fitted with a cover of wood or steel, or by other suitable means.

D Side Scuttles, Windows and Skylights

D.1 General

D.1.1 Side scuttles and windows, together with their glasses, deadlights and storm covers, if fitted, are to be of an approved design and substantial construction. Non-metallic frames are not acceptable.

Deadlights are fitted to the inside of windows and side scuttles, while storm covers are fitted to the outside of windows, where accessible, and may be hinged or portable.

(ICLL Annex I, II, 23(1))

D.1.2 Side scuttles are defined as being round or oval openings with an area not exceeding $0.16 m^2$. Round or oval openings having areas exceeding $0.16\ m^2$ are to be treated as windows.

(ICLL Annex I, II, 23(2))

D.1.3 Windows are defined as being rectangular openings generally, having a radius at each corner relative to the window size and round or oval openings with an area exceeding $0.16\ m^2$.

(ICLL Annex I, II, 23(3))

D.1.4 Side scuttles to the following spaces are to be fitted with hinged inside deadlights:

- spaces below freeboard deck
- spaces within the first tier of enclosed superstructures
- first tier deckhouses on the freeboard deck protecting openings leading below or considered buoyant in stability calculations

Deadlights are to be capable of being closed and secured watertight if fitted below the freeboard deck and weathertight if fitted above.

(ICLL Annex I, II, 23(4))

D.1.5 Side scuttles are not to be fitted in such a position that their sills are below a line drawn parallel to the freeboard deck at side and having its lowest point 2.5 % of the breadth (B), or 500 mm, which ever is the greatest distance, above the Summer Load Line (or Timber Summer Load Line if assigned), see Fig. 21.1.

(ICLL Annex I, II, 23(5))

D.1.6 If the required damage stability calculations indicate that the side scuttles would become immersed at any intermediate stage of flooding or the final equilibrium waterline, they are to be of the non-opening type.

(ICLL Annex I, II, 23(6))

D.1.7 Windows are not to be fitted in the following locations:

- below the freeboard deck
- in the first tier end bulkheads or sides of enclosed superstructures
- in first tier deckhouses that are considered buoyant in the stability calculations

(ICLL Annex I, II, 23(7))

D.1.8 Side scuttles and windows at the side shell in the second tier are to be provided with hinged inside deadlights capable of being closed and secured weathertight if the superstructure protects direct access to an opening leading below or is considered buoyant in the stability calculations.

(ICLL Annex I, II, 23(8))

D.1.9 Side scuttles and windows in side bulkheads set inboard from the side shell in the second tier which protect direct access below to spaces listed in D.1.4 are to be provided with either hinged inside deadlights or, where they are accessible, permanently attached external storm covers which are capable of being closed and secured weathertight.

(ICLL Annex I, II, 23(9))

D.1.10 Cabin bulkheads and doors in the second tier and above separating side scuttles and windows from a direct access leading below or the second tier considered buoyant in the stability calculations may be accepted in place of deadlights or storm covers fitted to the side scuttles and windows.

(ICLL Annex I, II, 23(10))

D.1.11 Deckhouses situated on a raised quarter deck or on the deck of a superstructure of less than standard height may be regarded as being in the second tier as far as the requirements for deadlights are concerned, provided that the height of the raised quarter deck or superstructure is equal to or greater than the standard quarter deck height.

(ICLL Annex I, II, 23(11))

D.1.12 Fixed or opening skylights are to have a glass thickness appropriate to their size and position as required for side scuttles and windows. Skylight glasses in any position are to be protected from mechanical damage and, where fitted in position 1 or 2, are to be provided with permanently attached deadlights or storm covers.

(ICLL Annex I, II, 23(12))

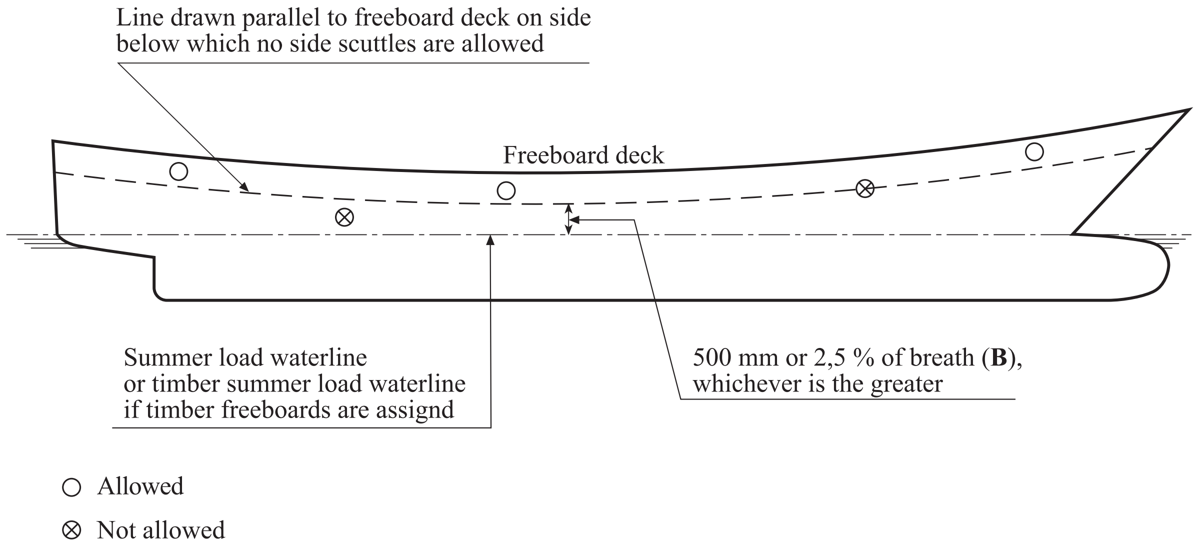


Fig. 21.1 Arrangement of side scuttles

D.1.13 Additional requirements for passenger vessels given in Section 26 have to be observed.

D.1.14 Additional requirements for oil tankers given in Section 24 have to be observed.

D.2 Design Load

D.2.1 The design load is to be determined according to Section 4 and Section 16.

D.2.2 For ships with a length $\mathbf{L_c}$ equal to or greater than 100 m, loads in accordance with ISO 5779 and 5780 standard have to be calculated additionally. The greater value has to be considered up to the third tier.

D.2.3 Deviations and special cases are subject to separate approval.

D.3 Frames

D.3.1 The design has to be in accordance with ISO standards 1751 and 3903 or any other recognised, equivalent national or international standard.

D.3.2 Variations from respective standards may require additional proof of sufficient strength by direct calculation or tests. This is to be observed for bridge windows in exposed areas (e.g. within forward quarter of ships length) in each case.

D.4 Glass panes

D.4.1 Glass panes have to be made of thermally toughened safety glass (TSG), or laminated safety glass. In case of chemically toughened glass, the depth of chemical toughening is not be less than 30 μm. The glass batches are to be qualified by testing in accordance with EN 1288-3. The ISO standards 614, 1095 and 21005 are to be observed.

D.4.2 The glass thickness for windows and side scuttles has to be determined in accordance with ISO 21005 or any other equivalent national or international standard, considering the design loads given in D.2. For sizes deviating from the standards, the formulas given in ISO 21005 may be used.

D.4.3 Heated glass panes have to be in accordance with ISO 3434.

D.4.4 An equivalent thickness t_s of laminated toughened safety glass is to be determined from the following formula:

$$t_s = \sqrt{t_1^2 + t_2^2 + \ldots + t_n^2}$$

t_1, t_2,... t_n : thicknesses of laminate layers

D.5 Tests

Windows and side scuttles have to be tested in accordance with the respective ISO standards 1751 and 3903.

Windows in ship safety relevant areas (i.e. wheelhouse and others as may be defined) and window sizes not covered by ISO standards are to be tested at four times design pressure.

For test requirements for passenger ships see Section 26, E.

E Side Shell Fittings, Scuppers and Freeing Ports

E.1 Side shell fittings and scuppers

E.1.1 General

E.1.1.1 Scuppers led through the shell from enclosed superstructures used for the carriage of cargo shall be permitted only where the edge of the freeboard deck is not immersed when the ship heels 5 ° either way. In other cases the drainage shall be led inboard in accordance with the requirements of the International Convention for the Safety of Life at Sea in force.

(ICLL Annex I, II, 22(2))

E.1.1.2 In manned machinery spaces, and auxiliary sea inlets and discharges in connection with the operation of machinery may be controlled locally. The controls shall be readily accessible and shall be provided with indicators showing whether the valves are open or closed.

(ICLL Annex I, II, 22(3))

E.1.1.3 Scuppers and discharge pipes originating at any level and penetrating the shell either more than 450 mm below the freeboard deck or less than 600 mm above the summer load line shall be provided with a non-return valve at the shell. This valve, unless required by E.1.2.1, may be omitted if the piping is of substantial thickness (see E.1.3 below).

(ICLL Annex I, II, 22(4))

E.1.1.4 Scuppers leading from superstructures or deckhouses not fitted with doors complying with the requirements of R. shall be led overboard.

(ICLL Annex I, II, 22(5))

E.1.1.5 All shell fittings and the valves required by this regulation shall be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable. All pipes to which this regulation refers shall be of steel or other equivalent material to the satisfaction of the Administration.

(ICLL Annex I, II, 22(6))

E.1.1.6 Requirements for seawater valves related to operating the power plant shall be observed see the GL Rules for Machinery Installations (I-1-2), Section 11

E.1.1.7 Scuppers and sanitary discharges should not be fitted above the lowest ballast waterline in way of lifeboat launching positions or means for preventing any discharge of water into the lifeboats are to be provided for. The location of scuppers and sanitary discharges is also to be taken into account when arranging gangways and pilot lifts.

E.1.2 Valves

E.1.2.1 Discharges led through the shell either from spaces below the freeboard deck or from within superstructures and deckhouses on the freeboard deck fitted with doors complying with the requirements of R. shall, except as provided in E.1.1.1, be fitted with efficient and accessible means for preventing water from passing inboard. Normally each separate discharge shall have one automatic non-return valve with a positive means of closing it from a position above the freeboard deck. Where the inboard end of the discharge pipe is located at least $0.01\ \mathbf{L}$ above the summer load line, the discharge may have two automatic non-return valves without positive means of closing. Where that vertical distance exceeds $0.02\ \mathbf{L}$, a single automatic non-return valve without positive means of closing may be accepted. The means for operating the positive action valve shall be readily accessible and provided with an indicator showing whether the valve is open or closed.

(ICLL Annex I, II, 22(1a))

E.1.2.2 One automatic non-return valve and one sluice valve controlled from above the freeboard deck instead of one automatic non-return valve with a positive means of closing from a position above the freeboard deck, is acceptable.

(ICLL Annex I, II, 22(1b))

E.1.2.3 Where two automatic non-return valves are required, the inboard valve shall always be accessible for examination under service conditions (i.e., the inboard valve shall be above the level of the tropical load line). If this is not practicable, the inboard valve need not be located above the tropical load line, provided that a locally controlled sluice valve is fitted between the two automatic non-return valves.

(ICLL Annex I, II, 22(1c))

E.1.2.4 Where sanitary discharges and scuppers lead overboard through the shell in way of machinery spaces, a locally operated positive closing valve at the shell, together with a non-return valve inboard, is acceptable. The controls of the valves shall be in a easily accessible position.

(ICLL Annex I, II, 22(1d))

E.1.2.5 The position of the inboard end of discharges shall be related to the Summer Timber Load Line when a timber freeboard is assigned.

(ICLL Annex I, II, 22(1e))

E.1.2.6 The requirements for non-return valves are applicable only to those discharges which remain open during the normal operation of a ship. For discharges which are to be kept closed at sea, a single screw down valve operated from the deck is acceptable.

(ICLL Annex I, II, 22(1f))

E.1.2.7 Table 21.1 provides the acceptable arrangements of scuppers, inlets and discharges.

(ICLL Annex I, II, 22(1g))

E.1.3 Scuppers and discharge pipes

E.1.3.1 For scuppers and discharge pipes where substantial thickness is not required:

- for pipes having an external diameter equal to or less than 155 mm, the thickness shall not be less than 4.5 mm;
- for pipes having an external diameter equal to or more than 230 mm, the thickness shall not be less than 6 mm.

Intermediate sizes shall be determined by linear interpolation.

(ICLL Annex I, II, 22(7a))

E.1.3.2 For scuppers and discharge pipes, where substantial thickness is required:

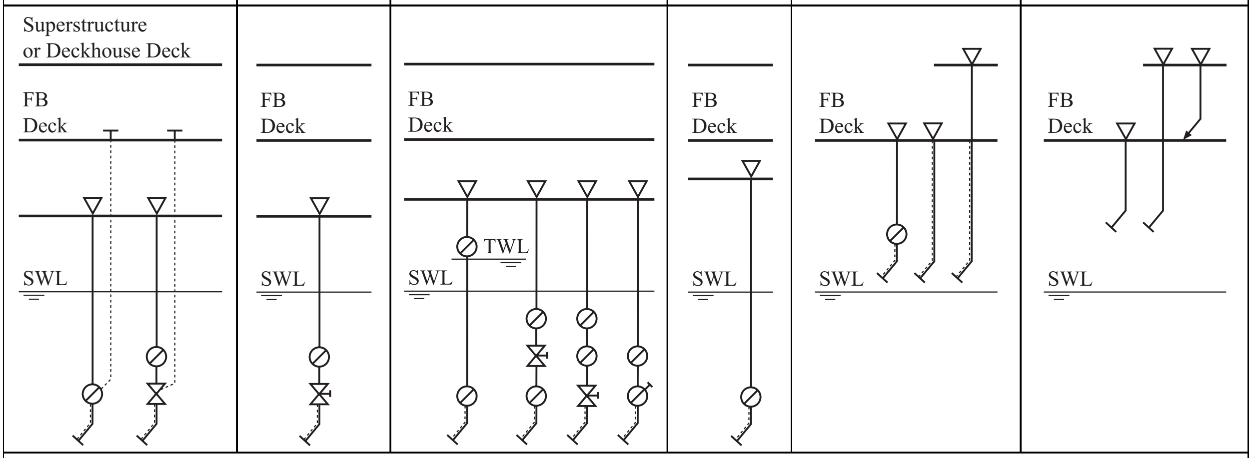
- for pipes having an external diameter equal to or less than 80 mm, the thickness shall not be less than 7 mm
- for pipes having an external diameter of 180 mm, the thickness shall not be less than 10 mm
- for pipes having an external diameter equal to or more than 220 mm, the thickness shall not be less than 12.5 mm.

Intermediate sizes shall be determined by linear interpolation.

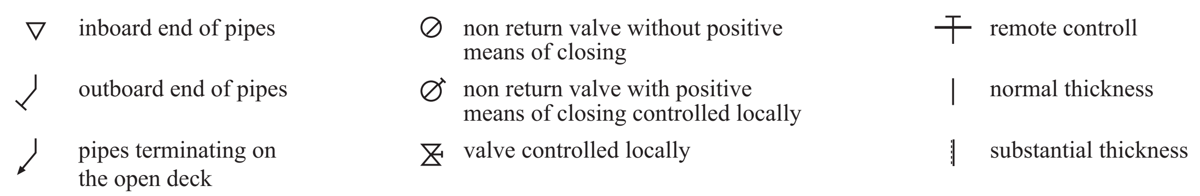
(ICLL Annex I, II, 22(7b))

Table 21.1 Arrangement of side shell fittings

Discharges coming from enclosed spaces below the freeboard deck or on the freeboard deck				Discharges coming from other spaces	
General requirement acc. to H.1 where inboard end ≤ 0.01L above SWL	Discharges through machinery space	Alternatives (see H.1) where inboard end		outboard end > 450 mm below FB deck or ≤ 60 mm above SWL see H.1	otherwise see H.1
		> 0.01L above SWL	> 0,02L above SWL		



Symbols:



E.2 Freeing ports

E.2.1 Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of water and for draining them.

(ICLL Annex I, II, 24(1a))

E.2.2 Except as provided in E.2.3 and E.2.8 the minimum freeing port area A [m^2] on each side of the ship for each well on the freeboard deck is to be determined by the following formulae in cases where the sheer in way of the well is standard or greater than standard.

The minimum area for each well on superstructure decks is to be one half of the area obtained by the formulae:

$A = 0.7 + 0.035 \cdot \ell$ for $\ell \le 20$ m

$A = 0.07 \cdot \ell$ for $\ell > 20$ m

ℓ : length of bulwark [m], with:

$\ell \leq 0.7 \cdot \mathbf{L}$

If the bulwark is more than 1.2 m in average height the required area is to be increased by 0.004 m^2 per metre of length of well for each 0.1 m difference in height.

If the bulwark is less than 0.9 m in average height, the required area may be decreased accordingly.

(ICLL Annex I, II, 24(1b))

E.2.3 In ships with no sheer the area calculated according to E.2.2 is to be increased by 50 %. Where the sheer is less than the standard the percentage is to be obtained by linear interpolation.

(ICLL Annex I, II, 24(1c))

E.2.4 On a flush deck ship with a deckhouse amidships having a breadth at least 80 % of the beam of the ship and the passageways along the side of the ship not exceeding 1.5 m in width, two wells are formed. Each is to be given the required freeing port area based upon the length of each well.

(ICLL Annex I, II, 24(1d))

E.2.5 Where a screen bulkhead is fitted completely across the ship at the forward end of a midship deckhouse, the exposed deck is divided into two wells and there is no limitation on the breadth of the deckhouse.

(ICLL Annex I, II, 24(1e))

E.2.6 Wells on raised quarterdecks are to be treated as being on freeboard decks.

(ICLL Annex I, II, 24(1f))

E.2.7 Gutter bars greater than 300 mm in height fitted around the weather decks of tankers in way of cargo manifolds and cargo piping are to be treated as bulwarks. Freeing ports are to be arranged in accordance with this regulation. Closures attached to the freeing ports for use during loading and discharge operations are to be arranged in such a way that jamming cannot occur while at sea.

(ICLL Annex I, II, 24(1g))

E.2.8 Where a ship is fitted with a trunk on the freeboard deck, which will not be taken into account when calculating the freeboard, or where continuous or substantially continuous hatchway side coamings are fitted between detached superstructures the minimum area of the freeing port openings is to be determined from Table 21.2.

(ICLL Annex I, II, 24(2))

Table 21.2 Minimum area of freeing ports

Breath of hatchway or trunk in relation to B [%]	Area of freeing ports in relation to the total area of the bulwark [%] [1] (each side separately)
40 or less	20
75 or more	10

[1] The area of freeing ports at intermediate breaths is to be obtained by linear interpolation

E.2.9 The effectiveness of the freeing area in bulwarks required by E.2.1 – E.2.7 depends on the free flow area across the deck of a ship.

The free flow area on deck is the net area of gaps between hatchways, and between hatchways and superstructures and deckhouses up to the actual height of the bulwark.

The freeing port area in bulwarks is to be assessed in relation to the net free flow area as follows:

1. If the free flow area is not less than the freeing area calculated from E.2.8 as if the hatchway coamings were continuous, then the minimum freeing port area calculated from E.2.1 – E.2.7 is to be deemed sufficient.
2. If the free flow area is equal to, or less than the area calculated from E.2.1 – E.2.7, the minimum freeing area in the bulwarks is to be determined from E.2.8.
3. If the free flow area is smaller than calculated from E.2.8, but greater than calculated from E.2.1 – E.2.7, the minimum freeing area in the bulwark is to be determined from the following formula:

$$F = F_1 + F_2 - f_p \quad [m^2]$$

F_1 : minimum freeing area calculated from E.2.1 – E.2.7

F_2 : minimum freeing area calculated from E.2.8

f_p : total net area of passages and gaps between hatch ends and superstructures or deckhouses up to the actual height of bulwark

(ICLL Annex I, II, 24(3))

E.2.10 In ships having superstructures on the freeboard deck or superstructure decks, which are open at either or both ends to wells formed by bulwarks on the open decks, adequate provision for freeing the open spaces within the superstructures is to be provided.

The minimum freeing port area on each side of the ship for the open superstructure (A_s) and for the open well (A_w), are to be calculated in accordance with the following procedure:

1. Determine the total well length (ℓ_t) equal to the sum of the length of the open deck enclosed by bulwarks (ℓ_w) and the length of the common space within the open superstructure (ℓ_s).
2. To determine A_s:
   1. calculate the freeing port area (A) required for an open well of length ℓ_t in accordance with E.2.2 with standard height bulwark assumed;
   2. multiply by a factor of 1.5 to correct for the absence of sheer, if applicable, in accordance with E.2.3;
   3. multiply by the factor (b_o / ℓ_t) to adjust the freeing port area for the breadth (b_o) of the openings in the end bulkhead of the enclosed superstructure;
   4. to adjust the freeing port area for that part of the entire length of the well which is enclosed by the open superstructure, multiply by the factor:

$$1 - \left(\frac{\ell_W}{\ell_t}\right)^2$$

   5. to adjust the freeing port area for the distance of the well deck above the freeboard deck, for decks located more than $0.5 \cdot h_s$ above the freeboard deck, multiply by the factor:

$$0.5 \cdot \left(\frac{h_s}{h_W}\right)$$

h_w : distance of the well deck above the freeboard deck

h_s : one standard superstructure height

3. To determine A_w:
   1. the freeing port area for the open well (A_w) is to be calculated in accordance with 2.1, using ℓ_w to calculate a nominal freeing port area (A'), and then adjusted for the actual height of the bulwark (h_b) by the application of one of the following area corrections, whichever is applicable:

$$A_c = 0.004 \cdot \ell_W \cdot \left(\left(h_b - 0.9\right)/0.10\right) \quad [m^2]$$ for bulwarks with $h_b < 0.9$ m

$A_c = 0$ for bulwarks with $0.9 \le h_b \le 1.2$ m

$A_c = 0.004 \cdot \ell_W \cdot ((h_b - 1.2)/0.10)$ [m²] for bulwarks with $h_b > 1.2$ m

2. the corrected freeing port area ($A_W = A' + A_c$) is then to be adjusted for absence of sheer, if applicable, and height above freeboard deck as in 2.1 and 2.5, using h_s and h_W.

4. The resulting freeing port areas for the open superstructure (A_s) and for the open well (A_W) is to be provided along each side of the open space covered by the open superstructure and each side of the open well, respectively.

5. The above relationships are summarised by the following equations, assuming ℓ_t, the sum of ℓ_w and ℓ_s, is greater than 20 m:

freeing port area A_w for the open well:

$$A_W = (0.07 \cdot \ell_W + A_c) \cdot (\text{sheer correction}) \cdot \left(0.5 \cdot \frac{h_s}{h_W}\right) \quad [m^2]$$

freeing port area A_s for the open superstructure:

$$A_W = 0.07 \cdot \ell_t \cdot (\text{sheer correction}) \cdot \left(\frac{b_0}{\ell_t} \cdot \left(1 - 2 \cdot \frac{\ell_W}{\ell_t}\right)\right) \cdot \left(0.5 \cdot \frac{h_s}{h_W}\right) \quad [m^2]$$

where ℓ_t is 20 m or less, the basic freeing port area is $A = 0.7 + 0.035 \cdot \ell_t$ in accordance with E.2.2.

(ICLL Annex I, II, 24(4))

E.2.11 The lower edges of the freeing ports are to be as near to the deck as practicable. Two thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve. One third of the freeing port area required is to be evenly spread along the remaining length of the well. With zero or little sheer on the exposed freeboard deck or an exposed superstructure deck the freeing port area is to be evenly spread along the length of the well.

(ICLL Annex I, II, 24(5))

E.2.12 All such openings in the bulwarks are to be protected by rails or bars spaced approximately 230mm apart. If shutters are fitted to freeing ports, ample clearance is to be provided to prevent jamming. Hinges are to have pins or bearings of non-corrodible material.

(ICLL Annex I, II, 24(6))

E.2.13 On ships with continuous longitudinal hatch coamings, where water may accumulate between the transverse coamings, freeing ports are to be provided at both sides, with a minimum section area A_q of:

$$A_q = 0.07 \cdot b_Q \quad [m^2]$$

In case of partial closed structures the area A_q may be reduced by the ratio of clear opening of the transverse hatch coaming and the total area of enclosed space.

b_Q : breadth of transverse box girder [m]

F Air Pipes, Overflow Pipes, Sounding Pipes

F.1 Each tank is to be fitted with air pipes, overflow pipes and sounding pipes. The air pipes are to be led to above the exposed deck. The arrangement is to be such as to allow complete filling of the tank. For the arrangement and scantlings of pipes see the Machinery Installations (I-1-2), Section 11, R. The height from the deck of the point where the sea water may have access is to be at least 760 mm on the freeboard deck and 450 mm on a superstructure deck.

F.2 Suitable closing appliances are to be provided for air pipes, overflow pipes and sounding pipes, see also the Machinery Installations (I-1-2), Section 11, R.. Where deck cargo is carried, the closing appliances are to be readily accessible at all times. In ships for which flooding calculations are to be made, the ends of the air pipes are to be above the damage waterline in the flooded condition. Where they immerge at intermediate stages of flooding, these conditions are to be examined separately.

F.3 Closely under the inner bottom or the tank top, holes are to be cut into floor plates and side girders as well as into beams, girders, etc., to give the air free access to the air pipes.

Besides, all floor plates and side girders are to be provided with limbers to permit the water or oil to reach the pump suctions.

F.4 Sounding pipes are to be extended to directly above the tank bottom. The shell plating is to be strengthened by thicker plates or doubling plates under the sounding pipes.

F.5 Special strength requirements for fore deck fittings

F.5.1 General

The following strength requirements are to be observed to resist green sea forces for the items given below, located within the forward quarter length:

- air pipes, ventilator pipes and their closing devices

Exempted from these requirements are air pipes, ventilator pipes and their closing devices of the cargo venting systems and the inert gas systems of tankers.

(IACS UR S27.1.1)

F.5.2 Application

For ships that are contracted for construction on or after 1st January 2004 on the exposed deck over the forward $0.25\,\mathbf{L}$, applicable to:

- all ship types of seagoing service of length $80\ \mathrm{m}$ or more, where the height of the exposed deck in way of the item is less than $0.1\,\mathbf{L}$ or $22\ \mathrm{m}$ above the summer load waterline, whichever is the lesser

(IACS UR S27.2.1)

F.5.3 Applied loading for air pipes, ventilator pipes and their closing devices

F.5.3.1 The pressures p acting on air pipes, ventilator pipes and their closing devices may be calculated from:

$$p = 0.5 \cdot \rho \cdot V^2 \cdot C_d \cdot C_s \cdot C_p \quad [\mathrm{kN/m^2}]$$

ρ : density $[\mathrm{t/m^3}]$ of sea water, defined as:

$\rho = 1.025$

V : velocity $[\mathrm{m/sec}]$ of water over the fore deck, defined as:

$V = 13.5$

C_d : shape coefficient, defined as:

$C_d = 0.5$	for pipes
$C_d = 0.8$	for an air pipe or ventilator head of cylindrical form with its axis in the vertical direction
$C_d = 1.3$	for air pipes or ventilator heads

C_s : slamming coefficient, defined as:

$C_s = 3.2$

C_p : protection coefficient, defined as:

$C_p = 0.7$	for pipes and ventilator heads located immediately behind a breakwater or forecastle
$C_p = 1.0$	elsewhere and immediately behind a bulwark

(IACS UR S27.4.1.1)

F.5.3.2 Forces acting in the horizontal direction on the pipe and its closing device may be calculated from F.5.3.1 using the largest projected area of each component.

(IACS UR S27.4.1.2)

F.5.4 Strength requirements for air pipes, ventilator pipes and their closing devices

F.5.4.1 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 $0.8 \cdot R_{eH}$. Irrespective of corrosion protection, a corrosion addition to the net section of 2.0 mm is then to be applied.

(IACS UR S27.5.1.2)

F.5.4.2 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 21.3. 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 21.2 but need not extend over the joint flange for the head. Bracket toes at the deck are to be suitably supported.

(IACS UR S27.5.1.3)

F.5.4.3 For other configurations, loads, according to F.5.3 are to be applied, and means of support determined in order to comply with the requirements of F.5.4.1. 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 the Machinery Installations (I-1-2), Section 11, Table 11.20a.

(IACS UR S27.5.1.4)

F.5.4.4 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 21.4. Brackets, where required are to be as specified in F.5.4.2.

(IACS UR S27.5.1.5)

F.5.4.5 For ventilators of height greater than 900 mm, brackets or alternative means of support are to be specially considered. Pipe thickness is not to be taken less than as indicated in the Machinery Installations (I-1-2), Section 11, Table 11.20a.

(IACS UR S27.5.1.6)

F.5.4.6 All component part and connections of the air pipe or ventilator are to be capable of withstanding the loads defined in F.5.3.

(IACS UR S27.5.1.7)

F.5.4.7 Rotating type mushroom ventilator heads are unsuitable for application in the areas defined in F.5.2.

(IACS UR S27.5.1.8)

Table 21.3 760 mm air pipe thickness and brackets standards

Nominal pipe diameter [mm]	Minimum fitted [1] gross thickness [mm]	Maximum projected area of head [cm^2]	Height [2] of brackets [mm]
65A	6.0	-	480
80A	6.3	-	460
100A	7.0	-	390
125A	7.8	-	300
150A	8.5	-	300
175A	8.5	-	300
200A	8.5 [3]	1900	300 [3]
250A	8.5 [3]	2500	300 [3]
300A	8.5 [3]	3200	300 [3]
350A	8.5 [3]	3800	300 [3]
400A	8.5 [3]	4500	300 [3]

[1] See IACS Unified Interpretation LL 36c

[3] Brackets are required where the as fitted (gross) thickness is less than 10.5 mm, or where the tabulated projected head area is exceeded

[2] Brackets *see* F.5.4.3 *need* not extend over the joint flange for the head

Note:

For other ventilator heights, the relevant requirements of F.5.4 are to be applied

(IACS UR S27 Table 1

Table 21.4 900 mm air pipe thickness and brackets standards

Nominal pipe diameter [mm]	Minimum fitted [1] gross thickness [mm]	Maximum projected area of head [cm^2]	Height of brackets [mm]
80A	6.3	-	460
100A	7.0	-	380
150A	8.5	-	300
200A	8.5	550	-
250A	8.5	880	-
300A	8.5	1200	-
350A	8.5	2000	-
400A	8.5	2700	-
450A	8.5	3300	-
500A	8.5	4000	-

Note:

For other ventilator heights, the relevant requirements of F.5.4 are to be applied

(IACS UR S27 Table 2)

G Ventilators

G.1 General

G.1.1 Ventilators in position 1 or 2 to spaces below freeboard deck or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck. Ventilators in position 1 are to have coamings of a height of at least 900 mm above the deck; in position the coamings are to be of at least 760 mm above the deck. Where the coaming of any ventilator exceeds 900 mm in height it is to be specially supported.

(ICLL Annex I, II, 19(1))

G.1.2 Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the freeboard deck.

(ICLL Annex I, II, 19(2))

G.1.3 Ventilators in position 1 the coamings of which extend to more than 4.5 m above the deck, and in position 2 the coamings of which extend to more than 2.3 m above the deck, need not be fitted with closing arrangements unless specially required by the Administration.

(ICLL Annex I, II, 19(3))

G.1.4 Except as provided in G.3, ventilator openings are to be provided with weathertight closing appliances of steel or other equivalent material. In ships of not more than 100 m in length the closing appliances are to be permanently attached; where not so provided in other ships, they are to be conveniently stowed near the ventilators to which they are to be fitted.

(ICLL Annex I, II, 19(4))

G.1.5 In exposed locations, the height of coamings may be increased to the satisfaction of the administration.

(ICLL Annex I, II, 19(5))

G.1.6 Ventilators of cargo holds are not to have any connection with other spaces.

G.1.7 The thickness of the coaming plates is to be 7.5 mm where the clear opening sectional area of the ventilator coaming is 300 cm^2 or less, and 10 mm where the clear opening sectional area exceeds 1600 cm^2. Intermediate values are to be determined by direct interpolation. A thickness of 6 mm will generally be sufficient within not permanently closed superstructures.

G.1.8 The thickness of ventilator posts is to be at least equal to the thickness of coaming as per G.1.7.

G.1.9 The wall thickness of ventilator posts of a clear sectional area exceeding 1600 cm^2 is to be increased according to the expected loads.

G.1.10 Generally, the coamings and posts are to pass through the deck and are to be welded to the deck plating from above and below. Where coamings or posts are welded onto the deck plating, fillet welds subject of Section 19, B.3.3 are to be adopted for welding inside and outside.

G.1.11 Coamings and posts particularly exposed to wash of sea are to be efficiently connected with the ship's structure.

G.1.12 Where the thickness of the deck plating is less than 10 mm, a doubling plate or insert plate of 10 mm thickness is to be fitted. Their side lengths are to be equal to twice the length or breadth of the coaming.

G.1.13 Where beams are pierced by ventilator coamings, carlings of adequate scantlings are to be fitted between the beams in order to maintain the strength of the deck.

G.2 Weathertight closing appliances

G.2.1 Inlet and exhaust openings of ventilation systems are to be provided with easily accessible closing appliances, which can be closed weathertight against wash of the sea. In ships of less than 100 m in length, the closing appliances are to be permanently attached. In ships exceeding 100 m in length, they may be conveniently stowed near the opening to which they belong.

G.2.2 For ventilator posts which exceed 4.5 m in height above the freeboard deck or raised quarter-deck and above exposed superstructure decks forward of 0 25 **L** from **F.P.** and for ventilator posts exceeding 2.3 m in height above exposed superstructure decks abaft 0.25 **L** from **F.P.** closing appliances are required in special cases only.

G.2.3 For the case of fire draught-tight fire dampers are to be fitted.

G.2.4 Weathertight closing appliances for all ventilators are to be of steel or other equivalent materials. Wood plugs and canvas covers are not acceptable in these positions.

G.2.5 Closing appliances are to be examined and tested for weathertightness by water jet (from a 12.5 mm dia. nozzle and a minimum hydrostatic pressure of 2.0 bar from a distance of 1.5 m).

G.2.6 For special strength requirements for fore deck fittings, see F.5.

G.3 Machinery space- and emergency generator room ventilation

G.3.1 For special requirements for machinery space ventilation see the GL Rules for Ventilation (I-1-21), Section 1, E.5.

G.3.2 For special requirements for emergency generator room ventilation see the GL Rules for Ventilation (I-1-21), Section 1, E.11.

H Stowage of Containers

H.1 General

H.1.1 All parts for container stowing and lashing equipment are to comply with the Stowage and Lashing of Containers (I-1-20). All parts which are intended to be welded to the ship's hull or hatch covers are to be made of materials complying with and tested in accordance with the Rules II – Materials and Welding.

H.1.2 All equipment on deck and in the holds essential for maintaining the safety of the ship and which are to be accessible at sea, e.g. fire fighting equipment, sounding pipes etc., should not be made inaccessible by containers or their stowing and lashing equipment.

H.1.3 For transmitting the forces from the container stowing and lashing equipment into the ship's hull adequate welding connections and local reinforcements of structural members are to be provided (see also H.2 and H.3).

H.1.4 The hatchway coamings are to be strengthened in way of the connections of transverse and longitudinal struts of cell guide systems.

The cell guide systems are not permitted to be connected to projecting deck plating edges in way of the hatchways. Any flame cutting or welding should be avoided, particularly at the deck roundings in the hatchway corners.

H.1.5 Where inner bottom, decks, or hatch covers are loaded with containers, adequate substructures, e.g. carlings, half height girders etc., are to be provided and the plate thickness is to be increased where required. For welded-in parts, see Section 19, B.2.

H.2 Load assumptions

H.2.1 The scantlings of the local ship structures and of the container substructures are to be determined on the basis of the Container Stowage and Lashing Plan.

H.2.2 For determining scantlings the following design forces are to be used which are assumed to act simultaneously in the centre of gravity of a stack:

$0.5 \cdot g \cdot G \quad [kN]$ for ship's transverse (y-)direction

$(1 + a_v) \cdot g \cdot G \quad [kN]$ for ship's vertical (z-)direction

g : gravitational acceleration $[m / s^2]$, defined as:

$g = 9.81$

G : stack mass $[t]$

a_v : acceleration addition as defined in Section 4, A.3

H.3 Permissible stresses

H.3.1 For hatchway covers in position 1 and 2 loaded with containers, the permissible stresses according to Section 17, B.3.1 are to be observed.

H.3.2 The stresses in local ship structures and in substructures for containers as well as for cell guide systems and lashing devices in the hatch covers of cargo decks are not to exceed the following values:

$$\sigma_b = \frac{\sigma_y}{1.5}$$ for bending stresses

$$\tau = \frac{\sigma_y}{2.3}$$ for shear stresses

$$\sigma_v = \sqrt{\sigma_b^2 + \tau^2} = \frac{\sigma_y}{1.3}$$ for equivalent stresses

H.3.3 For dimensioning the double bottom in case of single point loads due to $20' - \text{or } 40'$ - containers, see Section 8, C.2.

H.3.4 Where other structural members of the hull, e.g. frames, deck beams, bulkheads, hatchway coamings, bulwark stays etc. are subjected to loads from containers, cell guide systems and container lashing devices, these members are to be strengthened wherever necessary so that the actual stresses will not exceed those upon which the formulae in the respective Sections are based.

I Lashing Arrangements

Lashing eyes and holes are to be arranged in such a way as to not unduly weaken the structural members of the hull. In particular where lashings are attached to frames, they are to be so arranged that the bending moment in the frames is not unduly increased. Where necessary, the frame is to be strengthened.

J Car Decks

J.1 General

J.1.1 These Rules apply to movable as well as to removable car decks not forming part of the ship's structure.

J.1.2 The following information should be included in the plans to be submitted for approval:

- scantlings of the car decks
- masses of the car decks
- number and masses of cars intended to be stowed on the decks
- wheel loads and distance of wheels
- connection of the car decks to the hull structure
- moving and lifting gear of the car decks

J.1.3 Car decks in accordance with these requirements may be made of hull structural steel or of the following materials:

- structural steel R St 37-2 (Fe 360 B) and St 52-3 (Fe 510 D1)
- seawater resisting aluminium alloys

J.2 Design loads

J.2.1 For determining the deck scantlings, the following loads are to be used:

- A uniformly distributed load resulting from the mass of the deck and maximum number of cars to be carried. This load is not to be taken less than $2.5\ \mathrm{kN/m^2}$.
- The wheel load P considering the following situations:

  Where all wheels of one axle are standing on a deck girder or a deck beam, the axle load is to be evenly distributed on all wheels.

  Where not all of the wheels of one axle are standing on a deck girder or a deck beam, the following wheel loads are to be used:

  $P = 0.5$ x axle load for 2 wheels per axle

  $P = 0.3$ x axle load for 4 wheels per axle

  $P = 0.2$ x axle load for 6 wheels per axle

J.2.2 For determining the scantlings of the suspensions, the increased wheel load in case of four and six wheels per axle according to J.2.1 need not be considered.

J.3 Plating

J.3.1 The thickness of the plating is to be determined according to the formulae according to Section 7, B.2. Where aluminium alloy is used, the thickness is to be determined according to Section 2, D.1.

J.3.2 The thickness of plywood is to be determined taking into account a safety factor of 6 against the minimum ultimate strength of the material.

Where plywood plates, supported on two sides only, are subjected to single loads, 1.45 times the unsupported span may be taken as effective width of the plating.

J.4 Permissible stresses

J.4.1 In steel stiffeners and girders as well as in the steel structural elements of the suspensions, subjected to loads according to J.2 including the acceleration factor a_v according to Section 4, A.3 the following permissible stresses are to be observed:

$\sigma = \frac{140}{k} \quad [N/mm^2]$ for normal and bending stresses (tension and compression)

$\tau = \frac{90}{k} \quad [N/mm^2]$ for shear stresses

$\sigma_v = \sqrt{\sigma^2 + 3\tau^2} \le \frac{180}{k} \quad [N/mm^2]$ for equivalent stresses

k : material factor according to Section 2, A.2:

$k = 0.72$ for Fe 510 D1 (St 52-3)

$k = 1.00$ for Fe 360 B (R St 37-2)

J.4.2 Where aluminium alloys are used, the permissible stresses may be derived from multiplying the permissible stresses specified for ordinary hull structural steel by the factor $1 / k_{A\ell}$

$k_{A\ell}$: material factor for aluminium according to Section 2, D.1

J.5 Permissible deflection

J.5.1 The deflection of girders subjected to loads stipulated under J.2 is not to exceed:

$$f = \frac{\ell}{200}$$

ℓ : unsupported span of girder

J.5.2 An adequate safety distance should be maintained between the girders of a loaded deck and the top of cars towed on the deck below.

K Life Saving Appliances

K.1 It is assumed that for the arrangement and operation of lifeboats and other life-saving appliances the regulations of SOLAS 74 or those of the competent Authority are complied with.

K.2 The design appraisal and testing of life boats with their launching appliances and of other life saving appliances are not part of Classification.

However, approval of the hull structure in way of the launching appliances taking into account the forces from the above appliances is part of classification.

Note

For ships subject to the requirements of BG Verkehr Dienststelle Schiffssicherheit (BG Verkehr Ship Safety Division) and for ships for which GL has been authorized by the competent Administration to issue the safety construction - or safety equipment certificates - as well as in all cases where GL has been requested to approve the launching appliances, the GL Guidelines for Life-Saving Launching Appliances (VI-2-1) apply.

L Signal and Radar Masts

L.1 General

L.1.1 Drawings of masts, mast substructures and hull connections are to be submitted for approval.

L.1.2 Loose component parts are to comply with the Loading Gear on Seagoing Ships and Offshore Installations (VI-2-2). They are to be tested and certified by GL.

L.1.3 Other masts than covered by L.2 and L.3 as well as special designs, shall as regards dimensions and construction in each case be individually agreed with GL.

L.2 Single tubular masts

The following requirements apply to tubular or equivalent rectangular sections made of steel with an ultimate tensile strength of $400\ \text{N/mm}^2$, which are designed to carry only signals (navigation lanterns, flag and day signals).

L.2.1 Stayed masts

L.2.1.1 Stayed masts may be constructed as simply supported masts (rocker masts) or may be supported by one or more decks (constrained masts).

L.2.1.2 The diameter of stayed steel masts in the uppermost housing is to be at least $20\ \text{mm}$ for each 1m length of hounding. The length of the mast top above the hound is not to exceed $\ell_w / 3$ (ℓ_w denotes the hounding $[\text{m}]$).

L.2.1.3 Masts according to L.2.1.2 may be gradually tapered towards the hound to $75\ \%$ of the diameter at the uppermost housing. The plate thickness is not to be less than $1/70$ of the diameter or at least 4mm, see L.4.1.

L.2.1.4 Wire ropes for shrouds are to be thickly galvanized. It is recommended to use wire ropes composed of a minimum number of thick wires, as for instance a rope construction 6×7 with a tensile breaking strength of $1570\ \text{N / mm}^2$.

L.2.1.5 Where masts are stayed forward and aft by one shroud on each side of the ship, steel wire ropes are to be used with a tensile breaking strength of $1\ 570\ \text{N / mm}^2$ according to Table 21.5.

Table 21.5 Ropes and shackles of stayed steel masts

height of hound above the hauling of the shrounds	**[m]**	6	8	10	12	14	16
Rope diammeter	**[mm]**	14	16	18	20	22	24
Nominal size of shackl, rigging srew and rope socket		2.5	3	4	5	6	8

L.2.1.6 Where steel wire ropes according to Table 21.5 are used, the following conditions apply:

$$b \geq 0.3 \cdot h$$

$$0.15 \leq a \leq b$$

a : the distance of the hauling points of the shrouds from the transverse section through the hound

b : the distance of the hauling points of the shrouds from the longitudinal section through the hound

Alternative arrangements of stayings are to be of equivalent stiffness.

L.2.2 Unstayed masts

L.2.2.1 Unstayed masts may be completely constrained in the uppermost deck or be supported by two or more decks. (In general, the fastenings of masts to the hull of a ship should extend over at least one deck height.)

L.2.2.2 The scantlings for unstayed steel masts are given in the Table 21.6 with the following definitions:

ℓ_m : length of mast from uppermost support to the top

D : diameter of mast at uppermost support

t : plate thichness of steel mast

Table 21.6 Dimensions of unstayed steel masts

ℓ_m	**[m]**	6	8	10	12	14
D × t	**[mm]**	160 × 4	220 × 4	290 × 4.5	360 × 5.5	430 × 5.5

L.2.2.3 The diameter of masts may be gradually tapered to $D / 2$ at the height of $0.75 \cdot \ell_m$.

L.3 Box girder and frame work masts

L.3.1 For dimensioning the dead loads, acceleration forces and wind loads are to be considered.

L.3.2 Where necessary, additional loads e.g. loads caused by the sea fastening of crane booms or tension wires are also to be considered.

L.3.3 The design loads for L.3.1 and L.3.2 as well as the allowable stresses can be taken from the Loading Gear on Seagoing Ships and Offshore Installations (VI-2-2).

L.3.4 Single tubular masts mounted on the top may be dimensioned according to L.2.

L.3.5 In case of thin walled box girder masts stiffeners and additional buckling stiffeners may be necessary.

L.4 Structural details

L.4.1 Steel masts closed all-round are to have a wall thickness of at least 4 mm.

For masts not closed all-round the minimum wall thickness is 6 mm.

For masts used as funnels a corrosion addition of at least 1 mm is required.

L.4.2 The ship's side foundations are to be dimensioned in accordance with the acting forces.

L.4.3 Doubling plates at mast feet are permissible only for the transmission of compressive forces since they are generally not suitable for the transmission of tensile forces or bending moments.

L.4.4 In case of tubular constructions all welded fastenings and connections are to be of full penetration weld type.

L.4.5 If necessary, slim tubes are to be additionally supported in order to avoid vibrations.

L.4.6 The dimensioning normally does not require a calculation of vibrations. However, in case of undue vibrations occurring during the ship's trial a respective calculation will be required.

L.4.7 For determining scantlings of masts made from aluminium or austenitic steel, the requirements given in Section 2, D and Section 2, E apply.

L.4.8 At masts solid steel ladders have to be fixed at least up to 1.50 m below top, if they have to be climbed for operational purposes. Above them, suitable handgrips are necessary.

L.4.9 If possible from the construction point of view, ladders should be at least 0.30 m wide.

The distance between the rungs is to be 0.30 m. The horizontal distance of the rung centre from fixed parts is not to be less than 0.15 m. The rungs are to be aligned and be made of square steel bars 20 / 20 edge up.

L.4.10 Platforms on masts which have to be used for operational reasons, are to have a rail of at least 0.90 m in height with one intermediate bar. Safe access from the mast ladders to the platform is to be provided.

L.4.11 On masts additional devices have to be installed consisting of foot, back, and hand rings enabling safe work in places of servicing and maintenance.

M Loading and Lifting Gear

The design appraisal and testing of loading and lifting gear on ships are not part of classification.

However, approval of the hull structure in way of loading and lifting gear taking into account the forces from the gear is part of classification.

Note

For ships subject to the requirements of BG Verkehr Dienststelle Schiffssicherheit (BG Verkehr Ship Safety Division), the GL Guidelines for the Construction and Survey of Lifting Appliances (VI-2-2) apply.

These Guidelines will be applied in all cases where GL is entrusted with the judgement of loading and lifting gears of ships.

N Protection of the Crew

N.1 The deckhouses used for accommodation of the crew are to be constructed to an acceptable level of strength.

N.2 Guard rails or bulwarks are to be fitted around all exposed decks. The height of the bulwarks or guard rails is to be at least 1 m from the deck, provided that where this height would interfere with the normal operation of the ship, a lesser height may be approved, if the Administration is satisfied that adequate protection is provided.

N.3 Guard rails fitted on superstructure and freeboard decks are to have at least three courses. The opening below the lowest course of the guard rails is not to exceed 230 mm. The other courses are not to be more than 380 mm apart. In the case of ships with rounded gunwales the guard rail supports are to be placed on the flat of the deck. In other locations, guard rails with at least two courses are to be fitted. Guard rails are to comply with the following provisions:

- fixed, removable or hinged stanchions are to be fitted about 1.5 m apart. Removable or hinged stanchions are to be capable of being locked in the upright position;
- at least every third stanchions is to be supported by a bracket or stay;
- where necessary for the normal operation of the ship, steel wire ropes may be accepted in lieu of guard rails. Wires are to be made taut by means of turnbuckles; and
- where necessary for the normal operation of the ship, chains fitted between two fixed stanchions and/or bulwarks are acceptable in lieu of guard rails.

N.4 Satisfactory means of safe passage required by O (in the form of guard rails, lifelines, gangways or underdeck passages, etc) is to be provided for the protection of the crew in getting to and from their quarters, the machinery spaces and any other spaces used in the essential operation of the ship.

N.5 Deck cargo carried on any ship is to be stowed that any opening which is in way of the cargo and which gives access to and from the crew's quarters, the machinery space and all other parts used in the essential operation of the ship can be closed and secured against water ingress. Protection for the crew in the form of guard rails or lifelines is to be provided above the deck cargo if there is no convenient passage on or below the deck of the ship.

N.6 Guard-rails are to be constructed in accordance with DIN 81702 or equivalent standards.

Equivalent constructions of sufficient strength and safety can be accepted, e.g. IMO unified interpretation LL.3/Circ.208.

N.7 Guard rail stanchions are not to be welded to the shell plating.

N.8 The use of doubling plates below guard-rail stanchions is permitted, if the dimensions are according to Fig. 21.2 and the fatigue requirements in Section 20 are fulfilled (see respective detail in Table 20.5).

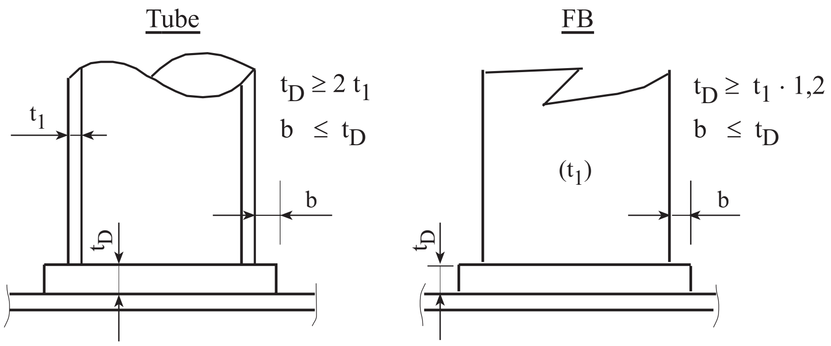


Fig. 21.2 Plates below guard-rail stanchions

N.9 In the case of ships with rounded gunwales the guard-rail supports are to be placed on the flat part of the deck.

O Means for Safe Passage of Crew

O.1 The safe passage of crew is to be provided by at least one of the means mentioned below:

O.1.1 A well lighted and ventilated underdeck passageway (with a clear opening of at least 0.8 m wide and 2 m high), as close as practicable to the freeboard deck, connecting and providing access to the location in question.

O.1.2 A permanent and efficiently constructed gangway, fitted at or above the level of the superstructure deck, on or as nears as practicable to the centre line of the ship, providing a continuous platform at least 0.6 m in width and a non-slip surface and with guard rails extending on each side throughout its length. Guard rails are to be at least 1 m high with three courses and constructed as required in N.8. A foot-stop is to be provided.

O.1.3 A permanent walkway at least 0.6 m in width, fitted at freeboard deck level and consisting of two rows of guard rails with stanchions space not more than 3 m. The number of courses of rails and their spacing are to be in accordance with N.8. On type "B" ships, hatchway coamings not less than 0.6 m in height may be accepted as forming one side of the walkway, provided that two rows of guard rails are fitted between the hatchways.

O.1.4 A wire rope lifeline not less than 10 mm in diameter, supported by stanchions not more than 10 m apart, or a single hand rail or wirer rope attached to hatch coamings, continued and supported between hatchways.

O.1.5 A permanent gangway that is:

- located at or above the level of the superstructure deck;
- located on or near as practicable to the centre line of the ship;
- located so as not to hinder easy access across the working areas of the deck;
- providing a continuous platform at least 1 m in width;
- constructed of fire resistant and non-slip material;
- fitted with guard rails extending on each side throughout its length; guard rails are to be at least 1 m high with courses as required by N.8 and supported by stanchions spaced not more than 1.5 m apart;
- provided with a food-stop on each side;
- having openings, with ladders where appropriate, to and from the deck. Openings are not to be more than 40 m apart;
- having shelters set in way of the gangway at intervals not exceeding 45 m if the length of the exposed deck to be traversed exceeds 70 m. Every such shelter is to be capable of accommodating at least on person and be so constructed as to afford weather protection on the forward, port and starboard sides.

O.2 Permitted transverse locations for arrangements in Q.1.3 and Q.1.4 above, where appropriate:

- at or near the centre line of the ship; or fitted on hatchways at or near the centre line of the ship;
- fitted on each side of the ship;
- fitted on one side of the ship, provision being made for fitting on either side:
- fitted on one side of the ship only;
- fitted on each side of the hatchways, as near to the centre line as practicable.

O.3 General provisions

O.3.1 Where wire ropes are fitted, turnbuckles are to be provided to ensure their tautness.

O.3.2 Where necessary for the normal operation of the ship, steel wire ropes may be accepted in lieu of guard rails.

O.3.3 Where necessary for the normal operation of the ship, chains fitted between two fixed stanchions are acceptable in lieu of guard rails.

O.3.4 Where stanchions are fitted, every third stanchion is to be supported by a bracket or stay.

O.3.5 Removable or hinged stanchions are to be capable of being locked in upright position.

O.3.6 A means of passage over obstructions such as pipes or other fittings of a permanent nature is to be provided.

O.3.7 Generally, the width of the gangway or deck-level walkway should not exceed 1.5 m.

P Smaller Openings and Hatches

P.1 Miscellaneous openings in freeboard and superstructure decks

P.1.1 Manholes and flush scuttles in position 1 or 2 or within superstructures other than enclosed superstructures are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

(ICLL Annex I, II, 18(1))

P.1.2 Openings in freeboard decks other than hatchways, machinery space openings, manholes and flush scuttles are to be protected by an enclosed superstructure, or by a deckhouse or companionway of equivalent strength and weathertightness. Similarly, any such openings in an exposed superstructure deck, in the top of a deckhouse on the freeboard deck which gives access to a space below the freeboard deck or a space within an enclosed superstructure are to be protected by an efficient deckhouse or companionway. Doorways in such companionways or deckhouses that lead or give access to stairways leading below are to be fitted with doors in accordance with R.1. Alternatively, if stairways within a deckhouse are enclosed within properly constructed companionways fitted with doors complying with R.1, the external door need not be weathertight.

(ICLL Annex I, II, 18(2))

P.1.3 Openings in the top of a deckhouse on a raised quarterdeck or superstructure of less than standard height, having a height equal to or greater than the standard quarterdeck height, are to be provided with an acceptable means of closing but need not be protected by an efficient deckhouse or companionway as defined in the regulation, provided that the height of the deckhouse is at least the standard height of a superstructure. Openings in the top of the deckhouse on a deckhouse of less than a standard superstructure height may be treated in a similar manner.

(ICLL Annex I, II, 18(3))

P.1.4 In position 1 the height above the deck of sill to the doorways in companionways is to be at least 600 mm. In position 2 it is to be at least 380 mm.

(ICLL Annex I, II, 18(4))

P.1.5 Where access is provided from the deck above as an alternative to access from the freeboard deck in accordance with **ICLL**, regulation 3(10)(b), the height of sills into a bridge or poop is to be 380 mm. The same is to apply to deckhouses on the freeboard deck.

(ICLL Annex I, II, 18(5))

P.1.6 Where access is not provided from above, the height of the sills to doorways in deckhouses on the freeboard deck is to be 600 mm.

(ICLL Annex I, II, 18(6))

P.1.7 Where the closing appliances of access openings in superstructures and deckhouses are not in accordance with R.1, interior deck openings are to be considered exposed (i.e. situated in the open deck).

(ICLL Annex I, II, 18(7))

P.1.8 Access hatchways are to have a clear width of at least $600 \cdot 600$ mm.

P.1.9 Weathertight small hatches in Load Line Position 1 and 2 according to **ICLL** are to be generally equivalent to the international standard ISO 5778.

P.1.10 For special requirements for strength and securing of small hatches on the exposed fore deck, see O.2.

P.1.11 According to the IACS Unified Interpretation SC 247 the following applies to securing devices of emergency escape hatches:

- Securing devices are to be of a type which can be opened from both sides.
- The maximum force needed to open the hatch cover should not exceed 150 N.
- The use of a spring equalizing, counterbalance or other suitable device on the ring side to reduce the force needed for opening is acceptable.

P.2 Strength and securing of small hatches on the exposed fore deck

P.2.1 General

P.2.1.1 The strength of, and securing devices for, small hatches fitted on the exposed fore deck over the forward 0.25 **L** are to comply with the following requirements.

(IACS UR S26.1.1)

P.2.1.2 Small hatches in this context are hatches designed for access to spaces below the deck and are capable to be closed weathertight or watertight, as applicable. Their opening is normally 2.5 square meters or less.

(IACS UR S26.1.2)

P.2.1.3 For securing devices of emergency escape hatches see O.1.8. Additionally the hatches are to be fitted with central locking devices according to O.2.4.1 (method C). Regulations O.2.5.3 and O.2.6 need not be complied with.

(IACS UR S26.1.3 and 1.4)

P.2.2 Application

For ships on the exposed deck over the forward 0.25 **L**, applicable to all types of sea going ships

- that are contracted for construction on or after 1st January 2004 and
- where the height of the exposed deck in way of the hatch is less than 0.1 **L** or 22 m above the summer load waterline, whichever is the lesser

(IACS UR S26.2.1 and 2.2)

Note

For ships contracted for construction prior to 1st July 2007 refer to IACS UR S26, para. 3.

P.2.3 Strength

P.2.3.1 For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with Table 21.7 and Fig. 21.3.

Table 21.7 Scantlings for small steel hatch covers on the fore deck

Nominal size [mm x mm]	Cover plate thickness [mm]	Primary stiffeners	Secondary stiffeners
		Flatbar [mm x mm]; number	
630 × 630	8	—	—
630 × 830	8	100 × 8; 1	—
830 × 630	8	100 × 8; 1	—
830 × 830	8	100 × 10; 1	—
1030 × 1030	8	120 × 12; 1	80 × 8; 2
1330 × 1330	8	150 × 12; 2	100 × 10; 2
For ships with $\mathbf{L} < 80$ m the cover scantlings may be reduced by the factor: $0.11 \cdot \sqrt{\mathbf{L}} \geq 0.75$			

Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in O.2.5.1, see Fig. 21.3. Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener, see Fig. 21.4.

(IACS UR S26.4.1)

P.2.3.2 The upper edge of the hatchway coamings is to be suitably reinforced by a horizontal section, normally not more than 170 mm to 190 mm from the upper edge of the coamings.

(IACS UR S26.4.2)

P.2.3.3 For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement is to be specially considered.

(IACS UR S26.4.3)

P.2.3.4 For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

(IACS UR S26.4.4)

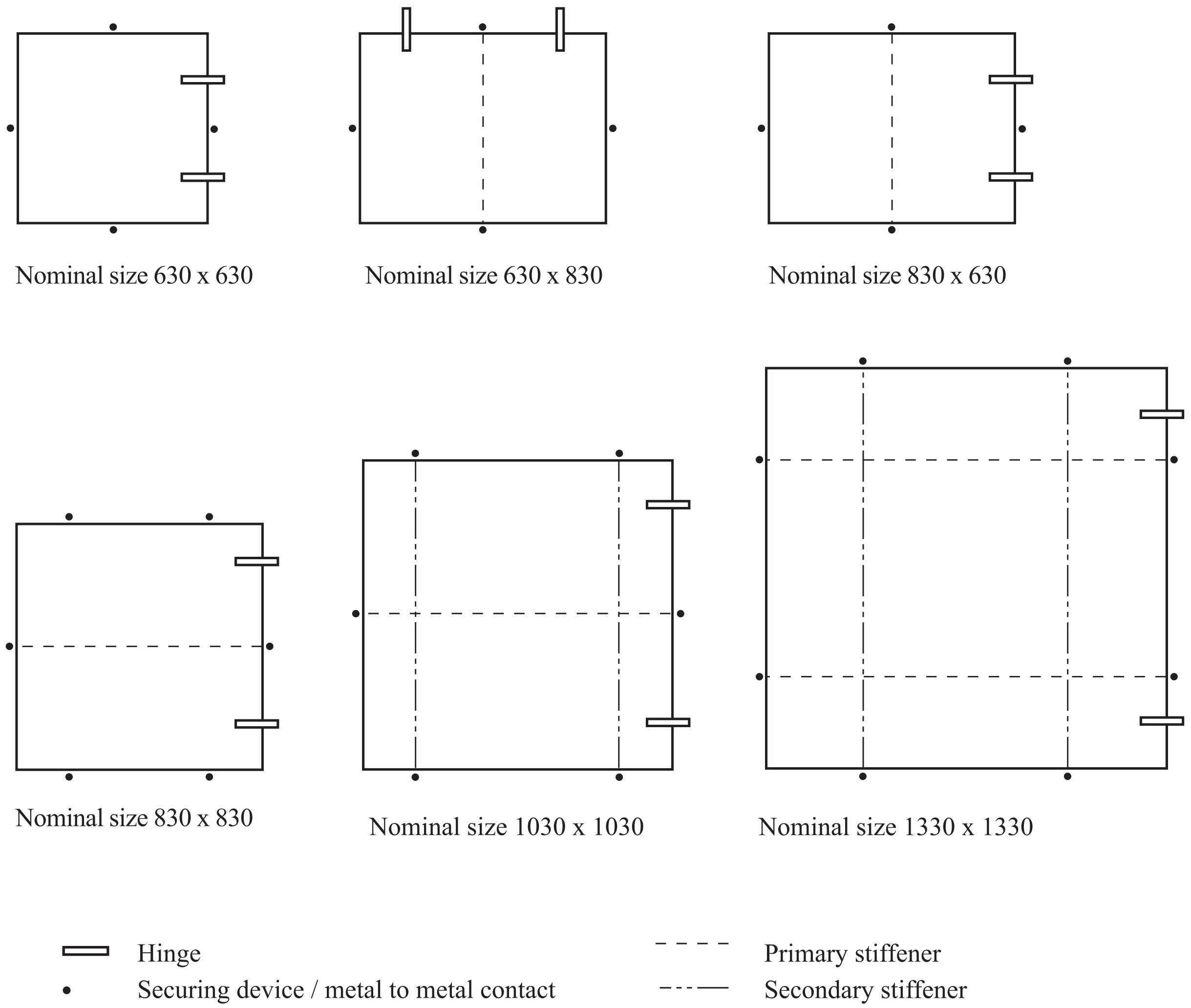


Fig. 21.3 Arrangement of stiffeners

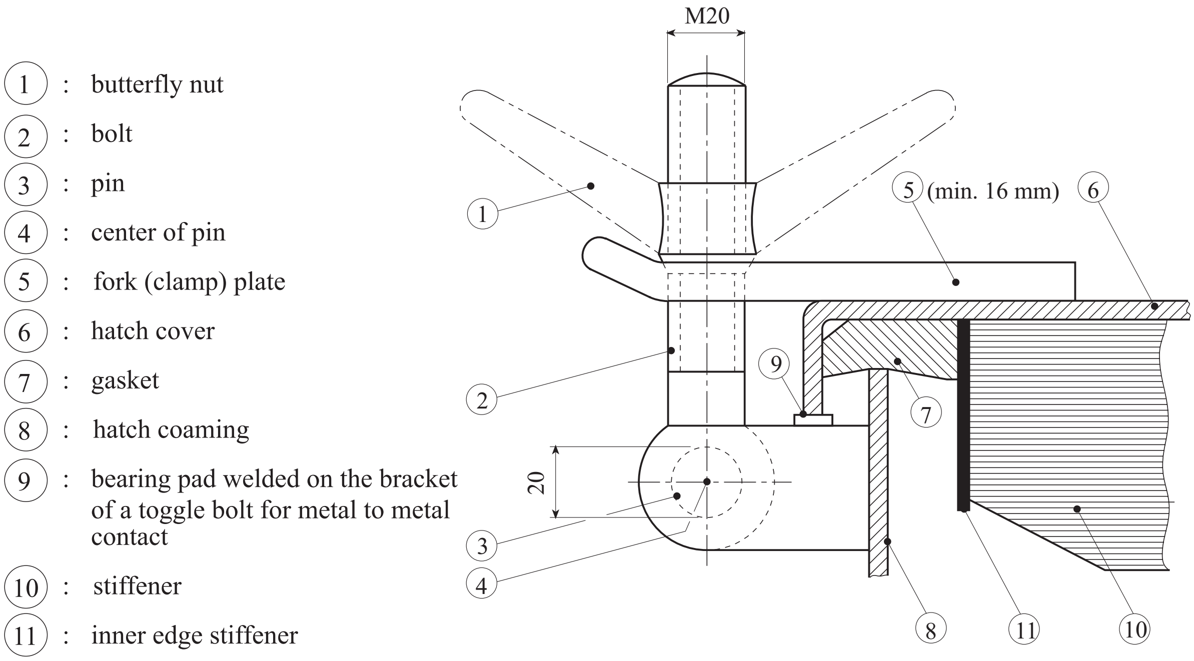


Fig. 21.4 Example of a primary securing method

P.2.4 Primary securing devices

P.2.4.1 Small hatches located on exposed fore deck subject to the application according to O.2.2 are to be fitted with primary securing devices such that their hatch covers can be secured in place and weathertight by means of a mechanism employing any one of the following methods:

- method A: butterfly nuts tightening onto forks (clamps)
- method B: quick acting cleats
- method C: central locking device

(IACS UR S26.5.1)

P.2.4.2 Dogs (twist tightening handles) with wedges are not acceptable.

(IACS UR S26.5.2)

P.2.5 Requirements for primary securing

P.2.5.1 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 Fig. 21.3 and of sufficient capacity to withstand the bearing force.

(IACS UR S26.6.1)

P.2.5.2 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.

(IACS UR S26.6.2)

P.2.5.3 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 Fig. 21.4.

(IACS UR S26.6.3)

P.2.5.4 For small hatch covers located on the exposed deck forward of the foremost 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.

(IACS UR S26.6.4)

P.2.5.5 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.

(IACS UR S26.6.5)

P.2.6 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.

Fall arresters against accidental closing are to be provided.

(IACS UR S26.7)

Q Engine and Boiler Room Hatchways

Q.1 Deck openings

Q.1.1 The openings above engine rooms and boiler rooms should not be larger than necessary. In way of these rooms sufficient transverse strength is to be ensured.

Q.1.2 Engine and boiler room openings are to be well rounded at their corners, and if required, to be provided with strengthenings, unless proper distribution of the longitudinal stresses is ensured by the side walls of superstructures or deckhouses. See also Section 7, B.3.

Q.2 Engine and boiler room casings

Q.2.1 Engine and boiler room openings on weather decks and inside open superstructures are to be protected by casings of sufficient height.

Q.2.2 The height of casings on the weather deck of ships with full scantling draught is to be not less than 1.8 m where $\mathbf{L}$ does not exceed 75 m, and not less than 2.3 m where $\mathbf{L}$ is 125 m or more. Intermediate values are to be determined by interpolation.

Q.2.3 The scantlings of stiffeners, plating and covering of exposed casings are to comply with the requirements for superstructure end bulkheads and for deckhouses according to Section 16, E.

Q.2.4 Inside open superstructures the casings are to be stiffened and plated according to Section 16, E, as for an aft end bulkhead.

Q.2.5 The height of casings on superstructure decks is to be at least 760 mm. The thickness of their plating may be 0.5 mm less than derived from P.2.3, and the stiffeners are to have the same web thickness like the plating and a depth of web of 75 mm, being spaced at 750 mm.

Q.2.6 The plate thickness of engine and boiler room casings below the freeboard deck or inside closed superstructures is to be 5 mm, and 6.5 mm in cargo holds; stiffeners are to have at least 75 mm web depth, and the same thickness as the plating, when being spaced at 750 mm.

Q.2.7 The coaming plates are to be extended to the lower edge of the deck beams.

Q.3 Doors in engine and boiler room casings

Q.3.1 The doors in casings on exposed decks and within open superstructures are to be of steel, well stiffened and hinged, and capable of being closed from both sides and secured weathertight by toggles and rubber sealings.

Note

*For ships with reduced freeboard (B-minus) or tanker freeboard (A), Regulation 26 (1) of **ICLL** is to be observed.*

Q.3.2 The doors are to be at least of the same strength as the casing walls in which they are fitted.

Q.3.3 The height of the doorway sills is to be 600 mm above decks in position 1 and 380 mm above decks in position 2.

R Doors

R.1 All access openings in end bulkheads of closed superstructures are to be fitted with weather tight doors permanently attached to the bulkhead, having the same strength as the bulkhead. The doors are to be so arranged that they can be operated from both sides of the bulkhead. The coaming heights of the access opening above the deck are to be determined according to **ICLL**.

Weathertight doors in Load Line Position 1 and 2 according to **ICLL** are to be generally equivalent to the international standard ISO 6042.

R.2 Any opening in a superstructure deck or in a deckhouse deck directly above the freeboard deck (deckhouse surrounding companionways), is to be protected by efficient weather tight closures.

R.3 Unless otherwise permitted by the Administration, doors are to open outwards to provide additional security against the impact of the sea.

R.4 Except as otherwise provided in these regulations, the height of the sills of access openings in bulkheads at ends of enclosed superstructures is to be at least 380 mm above the deck.

R.5 Portable sills are to be avoided. However, in order to facilitate the loading/unloading of heavy spare parts or similar, portable sills may be fitted on the following conditions:

- they are to be installed before the ship leaves port; and
- they are to be gasketed and fastened by closely spaced through bolts.

S Machinery Space Openings

S.1 Machinery space openings in position 1 or 2 are to be properly framed and efficiently enclosed by steel casings of ample strength, and where the casings are not protected by other structures their strength is to be specially considered. Access openings in such casings are to be fitted with doors complying with the requirements of Q.1, the sills of which are to be at least 600 mm above the deck if in position 1, and at least 380 mm above the deck if in position 2. Other openings in such casings are to be fitted with equivalent covers, permanently attached in their proper position.

(ICLL Annex I, II, 17(1))

S.2 Coamings of any fiddley, funnel or machinery space ventilator in an exposed position on the freeboard deck or superstructure deck are to be as high above the deck as is reasonable and practicable. In general, ventilators necessary to continuously supply the machinery space are to have coamings of sufficient height to comply with R.1, without having to fit weathertight closing appliances. Ventilators necessary to continuously supply the emergency generator room if this is considered buoyant in the stability calculation or protecting openings leading below, are to have coamings of sufficient height to comply with R.1, without having to fit weathertight closing appliances.

(ICLL Annex I, II, 17(3))

S.3 Where due to the ship size and arrangement this is not practicable, lesser heights for machinery space or emergency generator room ventilator coamings, fitted with weathertight closing appliances in accordance with G.3, may be permitted by the Administration in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of air to these spaces.

(ICLL Annex I, II, 17(4))

S.4 Fiddley openings are to be fitted with strong covers of steel or other equivalent material permanently attached in their proper position and capable of being secured weathertight.

(ICLL Annex I, II, 17(5))

Section 22 Structural Fire Protection

A General

A.1 Application, submission of plans

A.1.1 The requirements of this Section apply to ships for unrestricted service. Ships intended for restricted service or ships not subject to **SOLAS** may diverge from the requirements provided that an adequate level of safety is ensured [1].

A.1.2 The terms used in this Section correspond to the definitions as per Chapter II–2, Regulation 3 of **SOLAS 74**.

A.1.3 The term "Approved" relates to a material or construction, for which GL has issued an Approval Certificate. A type approval can be issued on the basis of a successful standard fire test, which has been carried out by a neutral and recognized fire testing institute.

A.1.4 The fire safety design and arrangements may differ from the prescriptive regulations of this Section, provided that the design and arrangements meet the fire safety objectives and functional requirements of Chapter II-2 of **SOLAS 74** [2]. Compliance of the alternative design and arrangements with the relevant requirements needs to be demonstrated by an engineering analysis and approved by the responsible flag state administration.

A.1.5 The following drawings and documents are to be submitted for review.

- Escape way plan
- Fire division plan
- Insulation plan
- Joiner plan
- Ventilation and Air condition scheme
- Deck covering plan
- Door plan
- Window plan
- Fire control plan (for information only)
- Report on alternative design and arrangements if applicable
- List of approved materials and equipment
- General Arrangement (for information only)

1 Reference is made to the "No. 99 Recommendation for the Safety of Cargo Vessels of less than Convention Size (IACS Rec. 2007)" or equivalent.

2 Reference is made to the "Guidelines on Alternative Design and Arrangements for Fire Safety" adopted by IMO by MSC/ Circ.1002

Additional drawings for passenger ships

- Escape way plan incl. escape way calculation
- Evacuation analysis (only Ro-Ro passenger ships)
- Fire load calculation
- Report on the safe return to port capabilities if applicable

A.1.6 Type "A", "B" and "C" class partitions, fire dampers, duct penetrations as well as the insulation materials, linings, ceilings, surface materials and not readily ignitable deck coverings shall be of approved type.

A.1.7 For regulations on fire alarm systems and on fire extinguishing arrangements, see the GL Rules for Machinery Installations (I-1-2), Section 12.

A.1.8 IACS Unified Requirements and Interpretations (UR, UI) have to be observed and shall be complied with. Reference is made to the IACS Blue Books.

B Passenger Ships carrying more than 36 Passengers

B.1 Materials

B.1.1 The hull, decks, structural bulkheads, superstructures and deckhouses are to be of steel or other equivalent material (Aluminium alloy suitably insulated).

B.1.2 Components made from aluminium alloys require special treatment, with regard to the mechanical properties of the material in case of temperature increase. In principle, the following is to be observed:

B.1.2.1 The insulation of "A" or "B" class divisions shall be such that the temperature of the structural core does not rise more than 200 °C above the ambient temperature at any time during the applicable fire exposure to the standard fire test.

B.1.2.2 Special attention shall be given to the insulation of aluminium alloy components of columns, stanchions and other structural members required to support lifeboat and liferaft stowage, launching and embarkation areas, and "A" and "B" class divisions to ensure:

that for such members supporting lifeboat and liferaft areas and "A" class divisions, the temperature rise limitation specified in B.1.2.1 shall apply at the end of one hour; and

that for such members required to support "B" class divisions, the temperature rise limitation specified in B.1.2.1 shall apply at the end of half an hour.

B.1.2.3 Crowns and casings of machinery spaces of category A shall be of steel construction and be insulated as required by Table 22.1 as appropriate. Openings therein, if any, shall be suitably arranged and protected to prevent the spread of fire.

B.2 Main vertical zones and horizontal zones

B.2.1 The hull, superstructure and deckhouses are to be subdivided into main vertical zones the average length and width of which on any deck is generally not to exceed 40 m.

Subdivision is to be effected by "A-60" class divisions. Steps and recesses shall be kept to a minimum. Where a category 4.3 [5], 4.3 [9] or 4.3 [10] space is on one side of the division or where fuel oil tanks are on both sides of the division the standard may be reduced to "A-0".

As far as practicable, the bulkheads forming the boundaries of the main vertical zones above the bulkhead deck shall be in line with watertight subdivision bulkheads situated immediately below the bulkhead deck.

The length and width of main vertical zones may be extended to a maximum of 48 m in order to bring the ends of main vertical zones to coincide with subdivision watertight bulkheads or in order to accommodate a large public space extending for the whole length of the main vertical zone provided that the total area of the main vertical zone is not greater than 1 600 m^2 on any deck. The length or width of a main vertical zone is the maximum distance between the furthermost points of the bulkheads bounding it.

The divisions are to be extended from deck to deck and to the shell or other boundaries. At the edges insulating bridges are to be provided where required.

B.2.2 On ships designed for special purposes (automobile or railroad car ferries), where the provision of main vertical zone bulkheads would defeat the purpose for which the ship is intended, equivalent means for controlling and limiting a fire are to be provided and specifically approved. Service spaces and ship stores shall not be located on ro-ro decks unless protected in accordance with the applicable regulations.

B.3 Bulkheads within main vertical zones

B.3.1 All bulkheads which are not required to be "A" class divisions shall be at least "B" class or "C" class divisions as prescribed in Table 22.1. All such divisions may be faced with combustible materials.

B.3.2 All bulkheads required to be "B" class division shall extend from deck to deck and to the shell or other boundaries unless the continuous "B" class ceilings or linings fitted on both sides of the bulkheads are at least of the same fire resistance as the bulkhead, in which case the bulkheads may terminate at the continuous ceiling or lining.

B.4 Fire integrity of bulkheads and decks

B.4.1 In addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned elsewhere in this Part, the minimum fire integrity of all bulkheads and decks shall be as prescribed in Table 22.1 to 22.2.

B.4.2 The following requirements shall govern application of the tables.

Table 22.1 shall apply to bulkheads and walls not bounding either main vertical zones or horizontal zones.

Table 22.2 shall apply to decks not forming steps in main vertical zones nor bounding horizontal zones.

B.4.3 For the purpose of determining the appropriate fire integrity standards to be applied to boundaries between adjacent spaces, such spaces are classified according to their fire risk as shown in the following categories 1 to 14. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of this regulation, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space that have less than 30 % communicating openings to that space are to be considered separate spaces. The fire integrity of the boundary bulkheads of such smaller rooms shall be as prescribed in Tables 22.1 and 22.2. The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row number in the tables.

Table 22.1 Bulkheads not bounding either main vertical zones or horizontal zones

Spaces		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
Control stations	[1]	B–0 [1]	A–0	A–0	A–0	A–0	A–60	A–60	A–60	A–0	A–0	A–60	A–60	A–60	A–60
Stairways	[2]		A–0 [1]	A–0	A–0	A–0	A–0	A–15	A–15	A–0 [3]	A–0	A–15	A–30	A–15	A–30
Corridors	[3]			B–15	A–60	A–0	B–15	B–15	B–15	B–15	A–0	A–15	A–30	A–0	A–30

Evacuation stations and external escape routes	[4]					A–0	A–60 [2,4]	A–60 [2,4]	A–60 [2,4]	A–0 [4]	A–0	A–60 [2]	A–60 [2]	A–60 [2]	A–60 [2]
Open deck spaces	[5]					–	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0
Accommodation spaces of minor fire risk	[6]						B–0	B–0	B–0	C	A–0	A–0	A–30	A–0	A–30
Accommodation spaces of moderate fire risk	[7]							B–0	B–0	C	A–0	A–15	A–60	A–15	A–60
Accommodation spaces of greater fire risk	[8]								B–0	C	A–0	A–30	A–60	A–15	A–60
Sanitary and similar spaces	[9]									C	A–0	A–0	A–0	A–0	A–0
Tanks, voids and auxiliary machinery spaces having little or no fire risk	[10]										A–0 [1]	A–0	A–0	A–0	A–0
Auxiliary machinery spaces, cargo spaces, cargo and other oil tanks and other similar spaces of moderate fire risk	[11]											A–0 [1]	A–0	A–0	A–15
Machinery spaces and main galleys	[12]												A–0 [1]	A–0	A–60
Store-rooms, workshops, pantries, etc.	[13]													A–0 [1]	A–0
other spaces in which flammable liquids are stowed	[14]														A–30

Notes to be applied to Table 22.1 to 22.2, as appropriate.

1 Where adjacent spaces are in the same numerical category and superscript 1 appears, a bulkhead or deck between such spaces need not be fitted. For example, in category [12] a bulkhead need not be required between a galley and its annexed pantries provided the pantry bulkhead and decks maintain the integrity of the galley boundaries. A bulkhead is, however, required between a galley and a machinery space even though both spaces are in category [12].

2 The ship's side, to the waterline in the lightest seagoing condition, superstructure and deckhouse sides situated below and adjacent to the liferafts and evacuation slides may be reduced to "A-30".

3 Where public toilets are installed completely within the stairway enclosure, the public toilet bulkhead within the stairway enclosure can be of "B" class integrity.

4 Where spaces of category [6], [7], [8] and [9] are located completely within the outer perimeter of the muster station, the bulkheads of these spaces are allowed to be of "B-0" class integrity. Control positions for audio, video and light installations may be considered as part of the muster station.

Table 22.2 Decks not forming steps in main vertical zones nor bounding zones

Spaces above / Spaces below		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
Control stations	[1]	A–30	A–30	A–15	A–0	A–0	A–0	A–15	A–30	A–0	A–0	A–0	A–60	A–0	A–60
Stairways	[2]	A–0	A–0	–	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–30	A–0	A–30
Corridors	[3]	A–15	A–0	A–0 [1]	A–60	A–0	A–0	A–15	A–15	A–0	A–0	A–0	A–30	A–0	A–30
Evacuation stations and external escape routes	[4]	A–0	A–0	A–0	A–0	–	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0
Open deck spaces	[5]	A–0	A–0	A–0	A–0	–	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0
Accommodation spaces of minor fire risk	[6]	A–60	A–15	A–0	A–60	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0
Accommodation spaces of moderate fire risk	[7]	A–60	A–15	A–15	A–60	A–0	A–0	A–15	A–15	A–0	A–0	A–0	A–0	A–0	A–0
Accommodation spaces of greater fire risk	[8]	A–60	A–15	A–15	A–60	A–0	A–15	A–15	A–30	A–0	A–0	A–0	A–0	A–0	A–0
Sanitary and similar spaces	[9]	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0
Tanks, voids and auxiliary machinery spaces having little or no fire risk	[10]	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0	A–0 [1]	A–0	A–0	A–0	A–0
Auxiliary machinery spaces, cargo spaces, cargo and other oil tanks and other similar spaces of moderate fire risk	[11]	A–60	A–60	A–60	A–60	A–0	A–0	A–15	A–30	A–0	A–0	A–0 [1]	A–0	A–0	A–30
Machinery spaces and main galleys	[12]	A–60	A–60	A–60	A–60	A–0	A–60	A–60	A–60	A–0	A–0	A–30	A–30 [1]	A–0	A–60
Store-rooms, workshops, pantries, etc.	[13]	A–60	A–30	A–15	A–60	A–0	A–15	A–30	A–30	A–0	A–0	A–0	A–0	A–0	A–0
Other spaces in which flammable liquids are stowed	[14]	A–60	A–60	A–60	A–60	A–0	A–30	A–60	A–60	A–0	A–0	A–0	A–0	A–0	A–0

See Notes under Table 22.1.

[1] : **Control stations**

Spaces containing emergency sources of power and lighting. Wheelhouse and chartroom. Spaces containing the ship's radio equipment. Fire control stations. Control room for propulsion machinery when located outside the propulsion machinery space. Spaces containing centralized fire alarm equipment. Spaces containing centralized emergency public address system stations and equipment.

[2] : **Stairways**

Interior stairways, lifts, totally enclosed emergency escape trunks and escalators (other than those wholly contained within the machinery spaces) for passengers and crew and enclosures thereto.

In this connection, a stairway which is enclosed at only one level shall be regarded as part of the space from which it is not separated by a fire door.

[3] : **Corridors**

Passenger and crew corridors and lobbies.

[4] : **Evacuation stations and external escape routes**

Survival craft stowage area.

Open deck spaces and enclosed promenades forming lifeboat and liferaft embarkation and lowering stations.

Assembly stations, internal and external.

External stairs and open decks used for escape routes.

The ship's side to the waterline in the lightest seagoing condition, superstructure and deckhouse sides situated below and adjacent to the liferafts and evacuation slide's embarkation areas.

[5] : **Open deck spaces**

Open deck spaces and enclosed promenades clear of lifeboat and liferaft embarkation and lowering stations. To be considered in this category, enclosed promenades shall have no significant fire risk, meaning that furnishings shall be restricted to deck furniture. In addition, such spaces shall be naturally ventilated by permanent openings. Air spaces (the space outside superstructures and deckhouses).

[6] : **Accommodation spaces of minor fire risk**

Cabins containing furniture and furnishings of restricted fire risk. Offices and dispensaries containing furniture and furnishings of restricted fire risk. Public spaces containing furniture and furnishings of restricted fire risk and having a deck area of less than $50\ m^2$.

[7] : **Accommodation spaces of moderate fire risk**

Spaces as in category 6 above but containing furniture and furnishings of other than restricted fire risk. Public spaces containing furniture and furnishings of restricted fire risk and having a deck area of $50\ m^2$ or more. Isolated lockers and small store-rooms in accommodation spaces having areas less than $4\ m^2$ (in which flammable liquids are not stowed). Sale shops. Motion picture projection and film stowage rooms. Diet kitchens (containing no open flame). Cleaning gear lockers (in which flammable liquids are not stowed). Laboratories (in which flammable liquids are not stowed). Pharmacies. Small drying rooms (having a deck area of $4\ m^2$ or less). Specie rooms, operating rooms, electrical distribution boards (see B.4.3.2 and B.4.3.3).

[8] : **Accommodation spaces of greater fire risk**

Public spaces containing furniture and furnishings of other than restricted fire risk and having a deck area of $50\ m^2$ or more. Barber shops and beauty parlours. Saunas.

[9] : **Sanitary and similar spaces**

Communal sanitary facilities, showers, baths, water closets, etc. Small laundry rooms. Indoor swimming pool area. Isolated pantries containing no cooking appliances in accommodation spaces.

Private sanitary facilities shall be considered a portion of the space in which they are located.

[10] : **Tanks, voids and auxiliary machinery spaces having little or no fire risk**

Water tanks forming part of the ship's structure. Voids and cofferdams. Auxiliary machinery spaces which do not contain machinery having a pressure lubrication system and where storage of combustibles is prohibited, such as:

Ventilation and air-conditioning rooms; windlass room; steering gear room; stabilizer equipment room; electrical propulsion motor room; rooms containing section switchboards and purely electrical equipment other than oil-filled electrical transformers (above 10 kVA); shaft alleys and pipe tunnels; spaces for pumps and refrigeration machinery (not handling or using flammable liquids).

Closed trunks serving the spaces listed above. Other closed trunks such as pipe and cable trunks.

[11] : **Auxiliary machinery spaces, cargo spaces, cargo and other oil tanks and other similar spaces of moderate fire risk**

Cargo oil tanks. Cargo holds, trunkways and hatchways. Refrigerated chambers. Oil fuel tanks (where installed in a separate space with no machinery). Shaft alleys and pipe tunnels allowing storage of combustibles. Auxiliary machinery spaces as in category [10] which contain machinery having a pressure lubrication system or where storage of combustibles is permitted. Oil fuel filling stations. Spaces containing oil-filled electrical transformers (above 10 kVA). Spaces containing turbine and reciprocating steam engine driven auxiliary generators and small internal combustion engines of power output up to 110 kW driving generators, sprinkler, drencher or fire pumps, bilge pumps, etc. Closed trunks serving the spaces listed above.

[12] : **Machinery spaces and main galleys**

Main propulsion machinery rooms (other than electric propulsion motor rooms) and boiler rooms. Auxiliary machinery spaces other than those in categories [10] and [11] which contain internal combustion machinery or other oil-burning, heating or pumping units. Main galleys and annexes. Trunks and casings to the spaces listed above.

[13] : **Store-rooms, workshops, pantries, etc.**

Main pantries not annexed to galleys. Main laundry. Large drying rooms (having a deck area of more than 4 m^2). Miscellaneous stores. Mail and baggage rooms. Garbage rooms. Workshops (not part of machinery spaces, galleys, etc.), lockers and store-rooms having areas greater than 4 m^2, other than those spaces which have provisions for the storage of flammable liquids.

[14] : **Other spaces in which flammable liquids are stowed**

Lamp rooms. Paint rooms. Store-rooms containing flammable liquids (including dyes, medicines, etc.). Laboratories (in which flammable liquids are stowed).

B.4.3.1 In respect of category [5] spaces Germanischer Lloyd shall determine whether the insulation values in Table 22.1 shall apply to ends of deckhouses and superstructures, and whether the insulation values in Table 22.2 shall apply to weather decks. In no case shall the requirements of category [5] of Table 22.1 or 22.2 necessitate enclosure of spaces which in the opinion of Germanischer Lloyd need not be enclosed.

B.4.3.2 Electrical distribution boards may be located behind panels/linings within accommodation spaces including stairway enclosures, without the need to categorize the space, provided no provision for storage is made.

B.4.3.3 If distribution boards are located in an identifiable space having a deck area of less than 4 m^2, this space shall be categorized in [7].

B.4.4 Continuous "B" class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing wholly or in part, to the required insulation and integrity of a division.

B.4.5 At intersections and terminal points of the required fire insulation constructions due regard is to be paid to the effect of thermal bridges. In order to avoid this, the insulation of a deck or bulkhead shall be carried past the intersection or terminal point for a distance of at least 450 mm.

B.4.6 Protection of atriums

B.4.6.1 Atriums shall be within enclosures formed of "A" class divisions having a fire rating determined in accordance with Table 22.2, as applicable.

B.4.6.2 Decks separating spaces within atriums shall have a fire rating determined in accordance with Table 22.2, as applicable.

B.5 Protection of stairways and lifts in accommodation and service spaces

B.5.1 All stairways in accommodation and service spaces are to be of steel frame or other approved equivalent construction; they are to be arranged within enclosures formed by "A" class division, with effective means of closure for all openings.

The following exceptions are admissible:

B.5.1.1 A stairway connecting only two decks need not be enclosed, provided that the integrity of the pierced deck is maintained by suitable bulkheads or doors at one of the two decks. When a stairway is closed at one 'tween deck space, the stairway enclosure shall be protected in accordance with the tables for decks.

B.5.1.2 Stairways fitted within a closed public space need not be enclosed.

B.5.2 Stairway enclosures are to be directly accessible from the corridors and of sufficient area to prevent congestion, having in mind the number of persons likely to use them in an emergency. Within the perimeter of such stairway enclosures, only public toilets, lockers of non-combustible material providing storage for safety equipment and open information counters are permitted. Only corridors, public toilets, special category spaces, other escape stairways required by B.12.3.3 and external areas are permitted to have direct access to these stairway enclosures. Public spaces may also have direct access to stairways enclosures except for the backstage of a theatre.

Small corridors or lobbies used to separate an enclosed stairway from galleys or main laundries may have direct access to the stairway provided they have a minimum deck area of $4.5\ m^2$, a width of no less than 900 mm and contain a fire hose station.

B.5.3 Lift trunks shall be so fitted as to prevent the passage of smoke and flame from one 'tween deck to another and shall be provided with means of closing so as to permit the control of draught and smoke.

B.6 Openings in "A" class divisions

B.6.1 Where "A" class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements shall be made to ensure that the fire resistance is not impaired, subject to the provisions of B.6.7.

B.6.2 All openings in the divisions are to be provided with permanently attached means of closing which shall be at least as effective for resisting fire as the divisions This does not apply for hatches between cargo, special category, store and baggage spaces and between such spaces and the weather decks.

B.6.3 The construction of all doors and door frames in "A" class divisions, with the means of securing them when closed, shall provide resistance to fire as well as to the passage of smoke and flame equivalent to that of the bulkheads in which the doors are situated [3]. Such doors and door frames shall be approved by GL and constructed of steel or other equivalent material. Doors approved without the sill

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[3] Reference is made to the Fire Test Procedure Code, Annex 1, Part 3, adopted by IMO by Resolution MSC.61(67). On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

being part of the frame, which are installed on or after 1 July 2010, shall be installed such that the gap under the door does not exceed 12 mm. A non-combustible sill shall be installed under the door such that floor coverings do not extend beneath the closed door.

B.6.4 Watertight doors need not be insulated.

B.6.5 It shall be possible for each door to be opened and closed from each side of the bulkhead by one person only.

B.6.6 Fire doors in main vertical zone bulkheads, galley boundaries and stairway enclosures other than power-operated watertight doors and those which are normally locked, shall satisfy the following requirements:

B.6.6.1 The doors shall be self-closing and be capable of closing against an angle of inclination of up to $3.5\,°$ opposing closure.

B.6.6.2 The approximate time of closure for hinged fire doors shall be no more than 40 s and no less than 10 s from the beginning of their movement with the ship in upright position. The approximate uniform rate of closure for sliding fire doors shall be of no more than 0.2 m/s and no less than 0.1 m/s with the ship in the upright position.

B.6.6.3 The doors, except those for emergency escape trunks shall be capable of remote release from the continuously manned central control station, either simultaneously or in groups and shall be capable of release also individually from a position at both sides of the door. Release switches shall have an on-off function to prevent automatic resetting of the system.

B.6.6.4 Hold-back hooks not subject to central control station release are prohibited.

B.6.6.5 A door closed remotely from the central control station shall be capable of being re-opened at both sides of the door by local control. After such local opening, the door shall automatically close again (see also the GL Rules for Electrical Installations (I-1-3), Section 9).

B.6.6.6 Indication shall be provided at the fire door indicator panel in the continuously manned central control station whether each of the remote-released doors are closed.

B.6.6.7 The release mechanism shall be so designed that the door will automatically close in the event of disruption of the control system or main source of electric power.

B.6.6.8 Local power accumulators for power-operated doors shall be provided in the immediate vicinity of the doors to enable the doors to be operated after disruption of the control system or main source of electric power at least ten times (fully opened and closed) using the local controls (see also the GL Rules for Machinery Installations (I-1-2), Section 14).

B.6.6.9 Disruption of the control system or main source of electric power at one door shall not impair the safe functioning of the other doors.

B.6.6.10 Remote-released sliding or power-operated doors shall be equipped with an alarm that sounds for at least 5 s but no more than 10 s after the door is released from the central control station and before the door begins to move and continue sounding until the door is completely closed.

B.6.6.11 A door designed to re-open upon contacting an object in its path shall re-open not more than 1 m from the point of contact.

B.6.6.12 Double-leaf doors equipped with a latch necessary to their fire integrity shall have a latch that is automatically activated by the operation of the doors when released by the control system.

B.6.6.13 Doors giving direct access to special category spaces which are power-operated and automatically closed need not be equipped with the alarms and remote-release mechanisms required in B.6.6.3 and B.6.6.10.

B.6.6.14 The components of the local control system shall be accessible for maintenance and adjusting.

B.6.6.15 Power-operated doors shall be provided with a control system of an approved type which shall be able to operate in case of fire [3]. This system shall satisfy the following requirements:

B.6.6.15.1 the control system shall be able to operate the door at the temperature of at least 200 °C for at least 60 min, served by the power supply.

B.6.6.15.2 the power supply for all other doors not subject to fire shall nor be impaired; and

B.6.6.15.3 at temperatures exceeding 200 °C the control system shall be automatically isolated from the power supply and shall be capable of keeping the door closed up to at least 945 °C.

B.6.7 The requirements for "A" class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and sidescuttles, provided that there is no requirement for such boundaries to have "A" class integrity in B.8.3. The requirements for "A" class integrity of the outer boundaries of the ship shall not apply to exterior doors, except for those in superstructures and deckhouses facing life-saving appliances, embarkation and external muster station areas, external stairs and open decks used for escape routes. Stairway enclosure doors need not meet this requirement.

B.6.8 Except for watertight, weathertight doors (semi-watertight doors), doors leading to the open deck and doors which need to be reasonably gastight, all "A" class doors located in stairways, public spaces and main vertical zone bulkheads in escape routes shall be equipped with a self-closing hose port of material, construction and fire resistance which is equivalent to the door into which it is fitted, and shall be a 150 mm square clear opening with the door closed and shall be inset into the lower edge of the door, opposite the door hinges, or in the case of sliding doors, nearest the opening.

B.7 Openings in "B" class divisions

B.7.1 Where "B" class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements shall be made to ensure that the fire resistance is not impaired. Pipes other than steel or copper that penetrate "B" class divisions shall be protected by either:

- a fire tested penetration device, suitable for the fire resistance of the division pierced and the type of pipe used; or
- a steel sleeve, having a thickness of not less than 1.8 mm and a length of not less than 900 mm for pipe diameters of 150 mm or more and not less than 600 mm for pipe diameters of less than 150 mm, preferably equally divided to each side of the division. The pipe shall be connected to the ends of the sleeve by flanges or couplings; or the clearance between the sleeve and the pipe shall not exceed 2.5 mm; or any clearance between pipe and sleeve shall be made tight by means of non-combustible or other suitable material.

B.7.2 Doors and door frames in "B" class divisions and means of securing them shall provide a method of closure which shall have resistance to fire equivalent to that of the divisions [3] except that ventilation openings may be permitted in the lower portion of such doors. Where such opening is in or under a door the total net area of any such opening or openings shall not exceed 0.05 m^2. Alternatively, a non-combustible air balance duct routed between the cabin and the corridor, and located below the sanitary unit is permitted where the cross-sectional area of the duct does not exceed 0.05 m^2. All ventilation openings shall be fitted with a grill made of non-combustible material. Doors shall be non-combustible and approved by GL. Doors approved without the sill being part of the frame, which are installed on or after 1 July 2010, shall be installed such that the gap under the door does not exceed 25 mm.

B.7.3 Cabin doors in "B" class divisions shall be of a self-closing type. Hold-backs are not permitted.

B.7.4 The requirements for "B" class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and sidescuttles. Similarly, the requirements for "B" class integrity shall not apply to exterior doors in superstructures and deckhouses.

B.8 Windows and sidescuttles

B.8.1 All windows and sidescuttles in bulkheads within accommodation and service spaces and control stations other than those to which the provisions of B.6.6 and of B.7.4 apply, shall be so constructed as to preserve the integrity requirements of the type of bulkheads in which they are fitted.

B.8.2 Notwithstanding the requirements of the Tables 22.1 to 22.2 all windows and sidescuttles in bulkheads separating accommodation and service spaces and control stations from weather shall be constructed with frames of steel or other suitable material. The glass shall be retained by a metal glazing bead or angle.

B.8.3 Windows facing life-saving appliances, embarkation and muster areas, external stairs and open decks used for escape routes, and windows situated below liferaft and escape slide embarkation areas shall have the fire integrity as required in the Tables 22.1 to 22.2. Where automatic dedicated sprinkler heads are provided for windows (see also the GL Rules for Machinery Installations (I-1-2), Section 12), "A-0" windows may be accepted as equivalent. Windows located in the ship's side below the lifeboat embarkation areas shall have the fire integrity at least equal to "A-0" class.

B.9 Ventilation systems

B.9.1 In general, the ventilation fans shall be so disposed that the ducts reaching the various spaces remain within the main vertical zone.

B.9.2 Where ventilation systems penetrate decks, precautions shall be taken, in addition to those relating to the fire integrity of the deck required by B.6. to reduce the likelihood of smoke and hot gases passing from one between deck space to another through the system. In addition to insulation requirements contained in B.9. vertical ducts shall, if necessary, be insulated as required by the appropriate tables in B.4

B.9.3 The main inlets and outlets of all ventilation systems shall be capable of being closed from outside the respective spaces in the event of a fire.

B.9.4 Except in cargo spaces, ventilation ducts shall be constructed of the following materials:

B.9.4.1 Ducts not less than $0.075\ m^2$ in sectional area and all vertical ducts serving more than a single 'tween deck space shall be constructed of steel or other equivalent material.

B.9.4.2 Ducts less than $0.075\ m^2$ in sectional area other than vertical ducts referred to in B.9.4.1 shall be constructed of steel or equivalent. Where such ducts penetrate "A" or "B" Class divisions due regard shall be given to ensuring the fire integrity of the division.

B.9.4.3 Short lengths of duct, not in general exceeding $0.02\ m^2$ in sectional area nor $2\ m$ in length, need not be steel or equivalent provided that all of the following conditions are met:

B.9.4.3.1 Subject to B.9.4.3.2 the duct is constructed of any material having low flame spread characteristics [4] which is type approved.

B.9.4.3.2 on ships constructed on or after 1 July 2010, the ducts shall be made of heat resisting non-combustible material, which may be faced internally and externally with membranes having low flame-spread characteristics and, in each case, a calorific value [5] not exceeding $45\ MJ / m^2$ of their surface area for the thickness used;

B.9.4.3.3 the duct is used only at the terminal end of the ventilation system; and

B.9.4.3.4 the duct is not located closer than $0.6\ m$ measured along its length to a penetration of an "A" or "B" class division, including continuous "B" class ceilings.

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4 Reference is made to the Fire Test Procedure Code, Annex 1, Part 5, adopted by IMO by Resolution MSC.61(67). On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

5 Refer to the recommendations published by the International Organization for Standardization, in particular publication ISO 1716 : 2002, *Determination of calorific potential*.

B.9.5 Stairway enclosures shall be ventilated by an independent fan and duct system which shall not serve any other spaces in the ventilation system.

B.9.6 All power ventilation, except machinery and cargo spaces ventilation and any alternative system which may be required under B.9.9, shall be fitted with controls so grouped that all fans may be stopped from either of two positions which shall be situated as far apart as practicable. Controls provided for the power ventilation serving machinery spaces shall also be grouped so as to be operable from two positions, one of which shall be outside such spaces. Fans serving power ventilation systems to cargo spaces shall be capable of being stopped from a safe position outside such spaces.

B.9.7 Where a thin plated duct with a free cross-sectional area equal to or less than $0.02\ \mathrm{m}^2$ passes through "A" class bulkheads or decks, the opening shall be lined with a steel sheet sleeve having a thickness of at least $3\ \mathrm{mm}$ and a length of at least $200\ \mathrm{mm}$, divided preferably into $100\ \mathrm{mm}$ on each side of the bulkhead or, in the case of the deck, wholly laid on the lower side of the decks pierced.

Where ventilation ducts with a free cross-sectional area exceeding $0.02\ \mathrm{m}^2$ pass through "A" class bulkheads or decks, the opening shall be lined with a steel sheet sleeve. However, where such ducts are of steel construction and pass through a deck or bulkhead, the ducts and sleeves shall comply with the following:

B.9.7.1 The sleeves shall have a thickness of at least $3\ \mathrm{mm}$ and a length of at least $900\ \mathrm{mm}$. When passing through bulkheads, this length shall be divided preferably into $450\ \mathrm{mm}$ on each side of the bulkhead. These ducts, or sleeves lining such ducts, shall be provided with fire insulation. The insulation shall have at least the same fire integrity as the bulkhead or deck through which the duct passes.

B.9.7.2 Ducts with a free cross-sectional area exceeding $0.075\ \mathrm{m}^2$ shall be fitted with fire dampers in addition to the requirements of B.9.7.1. The fire damper shall operate automatically but shall also be capable of being closed manually from both sides of the bulkhead or deck. The damper shall be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where ducts pass through spaces surrounded by "A" class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they pierce. The fire dampers should be easily accessible. Where they are placed behind ceilings and linings, these latter should be provided with an inspection door on which a plate reporting the identification number of the fire damper. Such plate and identification number should be placed also on any remote control required.

B.9.7.3 The following arrangement shall be of an approved type [3].

B.9.7.3.1 Fire dampers, including relevant means of operation.

B.9.7.3.2 Duct penetrations through "A" class divisions. Where steel sleeves are directly joined to ventilation ducts by means of riveted or screwed flanges or by welding, the test is not required.

B.9.8 Exhaust ducts from galley ranges in which grease or fat is likely to accumulate shall meet the requirements as mentioned in B.9.11.2 and shall be fitted with:

B.9.8.1 a grease trap readily removable for cleaning unless an alternative approved grease removal system is fitted;

B.9.8.2 a fire damper located in the lower end of the duct which is automatically and remotely operated, and in addition a remotely operated fire damper located in the upper end of the duct;

B.9.8.3 a fixed means for extinguishing a fire within the duct (see also the GL Rules for Machinery Installations (I-1-2), Section 12);

B.9.8.4 remote control arrangements for shutting off the exhaust fans and supply fans, for operating the fire dampers mentioned in B.9.8.2 and for operating the fire-extinguishing system, which shall be placed in a position close to the entrance to the galley. Where a multi-branch system is installed, means shall be provided to close all branches exhausting through the same main duct before an extinguishing medium is released into the system; and

B.9.8.5 suitably located hatches for inspection and cleaning.

B.9.8.6 Exhaust ducts from ranges for cooking equipment installed on open decks shall conform to paragraph B.9.8 to B.9.8.5, as applicable, when passing through accommodation spaces or spaces containing combustible materials.

B.9.9 Such measures as are practicable shall be taken in respect of control stations outside machinery spaces in order to ensure that ventilation, visibility and freedom from smoke are maintained, so that in the event of fire the machinery and equipment contained therein may be supervised and continue to function effectively. Alternative and separate means of air supply shall be provided; air inlets of the two sources of supply shall be so disposed that the risk of both inlets drawing in smoke simultaneously is minimized. Such requirements need not apply to control stations situated on, and opening on to, an open deck.

The ventilation system serving safety centres may be derived from the ventilation system serving the navigation bridge, unless located in an adjacent main vertical zone.

B.9.10 The ventilation systems for machinery spaces of category A, vehicle spaces, ro-ro spaces, galleys, special category spaces and cargo spaces shall, in general, be separated from each other and from the ventilation system serving other spaces.

B.9.11 Ducts provided for the ventilation of machinery spaces of category A, galleys, vehicle spaces, ro-ro cargo spaces or special category spaces shall not pass through accommodation spaces, service spaces or control stations unless the ducts are either complying with B.9.11.1 or B.9.11.2.

B.9.11.1 constructed of steel having a thickness of at least 3 mm and 5 mm for ducts the widths or diameters of which are up to and including 300 mm and 760 mm and over respectively and, in the case of such ducts, the widths or diameters of which are between 300 mm and 760 mm having a thickness to be obtained by interpolation;

suitably supported and stiffened;

fitted with automatic fire dampers close to the boundaries penetrated; and

insulated to "A-60" standard from the machinery spaces, galleys, vehicle spaces, ro-ro cargo spaces or special category spaces to a point at least 5 m beyond each fire damper; or

B.9.11.2 constructed of steel suitable supported and stiffened in accordance with B.9.11.1 and

insulated to "A-60" standard throughout the accommodation spaces, service spaces or control stations;

B.9.11.3 except that penetrations of main zone divisions shall also comply with the requirements of B.9.14.

B.9.12 Ducts provided for the ventilation to accommodation spaces, service spaces or control stations shall not pass through machinery spaces of category A, galleys, vehicle spaces, ro-ro cargo spaces or special category spaces unless either complying with B.9.12.1 or B.9.12.2.

B.9.12.1 the ducts where they pass through a machinery space of category A, galley, vehicle space, ro-ro cargo space or special category space are constructed of steel, suitable supported and stiffened in accordance with B.9.11.1 and

automatic fire dampers are fitted close to the boundaries penetrated; and

integrity of the machinery space, galley, vehicle space, ro-ro cargo space or special category space boundaries is maintained at the penetrations; or

B.9.12.2 the ducts where they pass through a machinery space of category A, galley, vehicle space, ro-ro cargo space or special category space are constructed of steel, suitable supported and stiffened in accordance with B.9.11.1

are insulated to "A-60" standard within the machinery space galley, vehicle space, ro-ro cargo space or special category space;

B.9.12.3 except that penetrations of main zone division shall also comply with the requirements in B.9.14.

B.9.13 Ventilation ducts with a free cross-sectional area exceeding $0.02\ m^2$ passing through "B" class bulkheads shall be lined with steel sheet sleeves of 900 mm in length divided preferably into 450 mm on each side of the bulkheads unless the duct is of steel for this length.

B.9.14 Where in a passenger ship it is necessary that a ventilation duct passes through a main vertical zone division, a fail-safe automatic closing fire damper shall be fitted adjacent to the division. The damper shall also be capable of being manually closed from each side of the division. The operating position shall be readily accessible and be marked in red light-reflecting colour. The duct between the division and the damper shall be of steel or other equivalent material and, if necessary, insulated to comply with the requirements of B.6.1. The damper shall be fitted on at least one side of the division with a visible indicator showing whether the damper is in the open position.

B.9.15 Power ventilation of accommodation spaces service spaces, cargo spaces, control stations and machinery spaces shall be capable of being stopped from an easily accessible position outside the space being served. This position should not be readily cut off in the event of a fire in the spaces served. The means provided for stopping the power ventilation of the machinery spaces shall be entirely separate from the means provided for stopping ventilation of other spaces.

B.9.16 Controls for shutting down the ventilation fans shall be centralized in a continuously manned central control station. The ventilation fans shall be capable of reactivation by the crew at this location, whereby the control panels shall be capable of indicating closed or off status of fans.

B.9.17 Exhaust ducts shall be provided with suitably located hatches for inspection and cleaning. The hatches shall be located near the fire damper.

B.9.18 Where public spaces span three or more open decks and contain combustibles such as furniture and enclosed spaces such as shops, offices and restaurants, the space shall be equipped with a smoke extraction system (see also the GL Rules for Machinery Installations (I-1-2), Section 12).

B.9.19 Exhaust ducts from main laundries shall be fitted with:

B.9.19.1 filters readily removable for cleaning purposes;

B.9.19.2 a fire damper located in the lower end of the duct which is automatically and remotely operated;

B.9.19.3 remote-control arrangements for shutting off the exhaust fans and supply fans from within the space and for operating the fire damper mentioned in B.9.19.2; and

B.9.19.4 suitably located hatches for inspection and cleaning.

B.10 Restriction of combustible materials

B.10.1 Except in cargo spaces, mail rooms, baggage rooms, saunas [6] or refrigerated compartments of service spaces, all linings, grounds, draught stops, ceilings and insulation's shall be of non-combustible materials. Partial bulkheads or decks used to subdivide a space for utility or artistic treatment shall also be of non-combustible material.

Linings, ceilings and partial bulkheads or decks used to screen or to separate adjacent cabin balconies shall be of non-combustible material.

B.10.2 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings, for cold service systems need not be non-combustible but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame spread characteristics.

B.10.3 The following surfaces shall have low flame-spread characteristics [4]:

B.10.3.1 exposed surfaces in corridors and stairway enclosures, and of bulkheads, wall and ceiling linings in accommodation and service spaces (except saunas) and control stations;

B.10.3.2 concealed or inaccessible spaces in accommodation, service spaces and control stations,

6 Insulation materials used in saunas shall be of non-combustible material.

B.10.3.3 exposed surfaces of cabin balconies, except for natural hard wood decking systems.

B.10.4 The total volume of combustible facings, mouldings, decorations and veneers in any accommodation and service space shall not exceed a volume equivalent to 2.5 mm veneer on the combined area of the walls and ceilings. Furniture fixed to linings, bulkheads or decks need not be included in the calculation of the total volume of combustible materials. This applies also to traditional wooden benches and wooden linings on bulkheads and ceilings in saunas. In the case of ships fitted with an automatic sprinkler system, the above volume may include some combustible material used for erection of "C" class divisions.

B.10.5 Combustible materials used on surfaces and linings covered by the requirements of B.10.3 shall have a calorific value [7] not exceeding $45 \text{ MJ} / \text{m}^2$ of the area for the thickness used. This does not apply to surfaces of furniture fixed to linings or bulkheads as well as to traditional wooden benches and wooden linings on bulkheads and ceilings in saunas.

B.10.6 Furniture in stairway enclosures shall be limited to seating. It shall be fixed, limited to six seats on each deck in each stairway enclosure, be of restricted fire risk, and shall not restrict the passenger escape route.

Furniture shall not be permitted in passenger and crew corridors forming escape routes in cabin areas. Lockers of non-combustible material, providing storage for safety equipment, may be permitted within these areas.

Drinking water dispensers and ice cube machines may be permitted in corridors provided they are fixed and do not restrict the width of the escape route. This applies as well to decorative flower arrangements, statues or other objects d'art such as paintings and tapestries in corridors and stairways.

B.10.7 Furniture and furnishings on cabin balconies shall comply with the following, unless such balconies are protected by a fixed pressure water-spraying and fixed fire detection and fire alarm systems

B.10.7.1 case furniture shall be constructed entirely of approved non-combustible materials, except that a combustible veneer not exceeding 2 mm may be used on the working surface;

B.10.7.2 free-standing furniture shall be constructed with frames of non-combustible materials;

B.10.7.3 draperies and other suspended textile materials shall have qualities of resistance to the propagation of flame not inferior to those of wool having a mass of $0.8 \text{ kg} / \text{m}^2$ [8];

B.10.7.4 upholstered furniture shall have qualities of resistance to the ignition and propagation of flame [9] and

B.10.7.5 bedding components shall have qualities of resistance to the ignition and propagation of flame [10].

B.10.8 Paints, varnishes and other finishes used on exposed interior surfaces, including cabin balconies with the exclusion of natural hard wood decking systems, shall not be capable of producing excessive quantities of smoke and toxic products [11].

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7 The gross calorific value measured in accordance with ISO standard 1716 - "Building Materials - Determination of Calorific Potential", should be quoted. On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

8 Reference is made to the Fire Test Procedure Code, Annex 1, Part 7, adopted by IMO by Resolution MSC.61(67). On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

9 Reference is made to the Fire Test Procedure Code, Annex 1, Part 8, adopted by IMO by Resolution MSC.61(67). On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

10 Reference is made to the Fire Test Procedure Code, Annex 1, Part 9, adopted by IMO by Resolution MSC.61(67). On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

11 Reference is made to the Fire Test Procedure Code, Annex 1, Part 2, adopted by IMO by Resolution MSC.61(67). On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

B.10.9 Primary deck coverings, if applied within accommodation and service spaces and control stations or if applied on cabin balconies, shall be of approved material which will not readily ignite, or give rise to smoke or toxic or explosive hazards at elevated temperatures [12].

B.10.10 Waste receptacles shall be constructed of non-combustible materials with no openings in the sides or bottom. Containers in galleys, pantries, bars, garbage handling or storage spaces and incinerator rooms which are intended purely for the carriage of wet waste, glass bottles and metal cans may be constructed of combustible materials.

B.11 Details of construction

B.11.1 In accommodation and service spaces, control stations, corridors and stairways, air spaces enclosed behind ceilings, panelling or linings shall be suitably divided by close-fitting draught stops not more than 14 m apart. In the vertical direction, such enclosed air spaces, including those behind linings of stairways, trunks, etc. shall be closed at each deck.

B.11.2 The construction of ceilings and bulkheads shall be such that it will be possible, without impairing the efficiency of the fire protection, for the fire patrols to detect any smoke originating in concealed and inaccessible spaces.

B.11.3 Non-load bearing partial bulkheads separating adjacent cabin balconies shall be capable of being opened by the crew from each side for the purpose of fighting fires.

B.11.4 The cargo holds and machinery spaces shall be capable of being effectively sealed such as to prevent the inlet of air.

Doors leading to machinery spaces of category A are to be provided with self-closing devices and 2 securing devices. All other machinery spaces, which are protected by gas fire extinguishing system, are to be equipped with self-closing doors.

B.11.5 Construction and arrangement of saunas

B.11.5.1 The perimeter of the sauna shall be of "A" class boundaries and may include changing rooms, showers and toilets. The sauna shall be insulated to "A–60" standard against other spaces except those inside the perimeter and spaces of category [5], [9] and [10].

B.11.5.2 Bathrooms with direct access to saunas may be considered as part of them. In such cases, the door between sauna and the bathroom need not comply with fire safety requirements.

B.11.5.3 The traditional wooden lining on the bulkheads and on the ceiling are permitted in the sauna. The ceiling above the oven shall be lined with a non-combustible plate with an air-gap of at least 30 mm. The distance from the hot surfaces to combustible materials shall be at least 500 mm or the combustible materials shall be suitably protected.

B.11.5.4 The traditional wooden benches are permitted to be used in the sauna.

B.11.5.5 The sauna door shall open outwards by pushing.

B.11.5.6 Electrically heated ovens shall be provided with a timer.

B.12 Means of escape

B.12.1 Unless expressly provided otherwise in this regulation, at least two widely separated and ready means of escape shall be provided from all spaces or group of spaces. Lifts shall not be considered as forming one of the required means of escape.

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[12] Reference is made to the Fire Test Procedure Code, Annex 1, Part 6, adopted by IMO by Resolution MSC.61(67). On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

B.12.2 Doors in escape routes shall, in general, open in way of the direction of escape, except that:

- individual cabin doors may open into the cabins in order to avoid injury to persons in the corridor when the door is opened
- doors in vertical emergency escape trunks may open out of the trunk in order to permit the trunk to be used both for escape and access

B.12.3 Stairways and ladders shall be arranged to provide ready means of escape to the lifeboat and liferaft embarkation deck from all passenger and crew spaces and from spaces in which the crew is normally employed, other than machinery spaces. In particular, the following provisions shall be complied with:

B.12.3.1 Below the bulkhead deck two means of escape, at least one of which shall be independent of watertight doors, shall be provided from each watertight compartment or similarly restricted space or group of spaces. Due regard being paid to the nature and location of spaces and to the number of persons who normally might be employed there, exceptions are possible, however, stairways shall not be less than 800 mm in clear width with handrails on both sides.

B.12.3.2 Above the bulkhead deck, there shall be at least two means of escape from each main vertical zone or similarly restricted space or group of spaces at least one of which shall give access to a stairway forming a vertical escape.

B.12.3.3 At least one of the means of escape required by paragraphs B.12.3.1 and B.12.3.2 shall consist of a readily accessible enclosed stairway, which shall provide continuous fire shelter from the level of its origin to the appropriate lifeboat and liferaft embarkation decks, or to the uppermost weather deck if the embarkation deck does not extend to the main vertical zone being considered. In the latter case, direct access to the embarkation deck by way of external open stairways and passageways shall be provided and shall have emergency lighting (see also the GL Rules for Electrical Installations (I-1-3), Section 3 and 11) and slip-free surfaces under foot. Boundaries facing external open stairways and passageways forming part of an escape route and boundaries in such a position that their failure during a fire would impede escape to the embarkation deck shall have fire integrity, including insulation values, in accordance with the Tables 22.1 and 22.2. The widths, number and continuity of escapes shall be as follows:

B.12.3.3.1 Stairways shall not be less than 900 mm in clear width. Stairways shall be fitted with handrails on each side. The minimum clear width of stairways shall be increased by 10 mm for every one person provided for in excess of 90 persons. The maximum clear width between handrails where stairways are wider than 900 mm shall be 1 800 mm. The total number of persons to be evacuated by such stairways shall be assumed to be two thirds of the crew and the total number of passengers in the areas served by such stairways [13].

B.12.3.3.2 All stairways sized for more than 90 persons shall be aligned fore and aft.

B.12.3.3.3 Doorways and corridors and intermediate landings included in means of escape shall be sized in the same manner as stairways. The aggregate width of stairway exit doors to the assembly station shall not be less than the aggregate width of stairways serving this deck.

B.12.3.3.4 Stairways shall not exceed 3.5 m in vertical rise without the provision of a landing and shall not have an angle of inclination greater than 45 °.

B.12.3.3.5 Landings at each deck level shall be not less than 2 m^2 in area and shall increase by 1 m^2 for every 10 persons provided for in excess of 20 persons but need not exceed 16 m^2, except for those landings servicing public spaces having direct access onto the stairway enclosure.

B.12.3.4 Stairways serving only a space and a balcony in that space shall not be considered as forming one of the means of escape.

B.12.3.5 A corridor, lobby, or part of a corridor from which there is only one route of escape shall not be permitted. Dead-end corridors used in service areas which are necessary for the practical utility of the ship, such as fuel oil stations and athwartship supply corridors shall be permitted provided such dead-end corridors are separated from crew accommodation areas and are inaccessible from passenger accom-

[13] Reference is made to the Fire Safety Systems Code, adopted by IMO by Resolution MSC.98(73). On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

modation areas. Also, a part of the corridor that has a depth not exceeding its width is considered a recess or local extension and is permitted.

B.12.3.6 In addition to the emergency lighting (see also the GL Rules for Electrical Installations (I-1-3), Section 14), the means of escape including stairways and exits, shall be marked by lighting or photoluminescent strip indicators placed not more than 0.3 m above the deck at all points of the escape route including angles and intersections. The marking shall enable passengers to identify all the routes of escape and readily identify the escape exits. If electric illumination is used, it shall be supplied by the emergency source of power and it shall be so arranged that the failure of any single light or cut in a lighting strip, will not result in the marking being ineffective. Additionally, all escape route signs and fire equipment location markings shall be of photoluminescent material or marked by lighting. Such lighting or photoluminescent equipment shall be of an approved type [13].

B.12.3.6.1 In lieu of the escape route lighting system required by paragraph B.12.3.6, alternative evacuation guidance systems may be accepted if they are of approved type (see also the GL Rules for Electrical Installations (I-1-3), Section 14) [14].

B.12.3.7 The requirement of B.12.3.6 shall also apply to the crew accommodation areas.

B.12.3.8 Public Spaces spanning three or more decks and contain combustibles such as furniture and enclosed spaces such as shops, offices and restaurants shall have at each level within the space two means of escape, one of which shall have direct access to an enclosed vertical means of escape as mentioned under B.12.3.3.

B.12.4 If a radiotelegraph station has no direct access to the open deck, two means of escape from or access to such station shall be provided, one of which may be a porthole or window of sufficient size or another means.

B.12.5 In special category spaces the number and disposition of the means of escape both below and above the bulkhead deck shall be satisfactory as mentioned under B.12.3.1, .2 and .3.

B.12.6 Two means of escape shall be provided from each machinery space. In particular, the following provisions shall be complied with:

B.12.6.1 Where the space is below the bulkhead deck the two means of escape shall consist of either:

B.12.6.1.1 two sets of steel ladders as widely separated as possible, leading to doors in the upper part of the space similarly separated and from which access is provided to the appropriate lifeboat and liferaft embarkation decks. One of these ladders shall be located within a protected enclosure having fire integrity, including insulation values, in accordance with the Tables 22.1 and 22.2 for a category [2] space, from the lower part of the space to a safe position outside the space. Self-closing doors of the same fire integrity standards shall be fitted in the enclosure. The ladder shall be fixed in such a way that heat is not transferred into the enclosure through non-insulated fixing points. The protected enclosure shall have minimum internal dimensions of at least 800 mm x 800 mm, and shall have emergency lighting provisions.

B.12.6.1.2 or one steel ladder leading to a door in the upper part of the space from which access is provided to the embarkation deck and additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the embarkation deck.

B.12.6.2 Where the space is above the bulkhead deck, two means of escape shall be as widely separated as possible and the doors leading from such means of escape shall be in a position from which access is provided to the appropriate lifeboat and liferaft embarkation decks. Where such escapes require the use of ladders these shall be of steel.

B.12.6.3 A ship of a gross tonnage less than 1 000 may be dispensed with one of the means of escape, due regard being paid to the width and disposition of the upper part of the space; and a ship of a gross tonnage of 1 000 and above, may be dispensed with one means of escape from any such space so long

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14 Refer to the Functional requirements and performance standards for the assessment of evacuation guidance systems (MSC/ Circ. 1167) and the Interim guidelines for the testing, approval and maintenance of evacuation guidance systems used as an alternative to low-location lighting systems (MSC/Circ. 1168).

as either a door or a steel ladder provides a safe escape route to the embarkation deck, due regard being paid to the nature and location of the space and whether persons are normally employed in that space.

B.12.6.4 In the steering gear room, a second means of escape shall be provided when the emergency steering position is located in that space unless there is direct access to the open deck.

B.12.6.5 One of the escape routes from the machinery spaces where the crew is normally employed shall avoid direct access to any special category space.

B.12.6.6 Two means of escape shall be provided from a machinery control room within a machinery space, at least one of which shall provide continuous fire shelter to a safe position outside the machinery space.

B.12.7 Additional requirements for ro-ro passenger ships

B.12.7.1 Handrails or other handholds shall be provided in all corridors along the entire escape route, so that a firm handhold is available every step of the way, where possible, to the assembly stations and embarkation stations. Such handrails shall be provided on both sides of longitudinal corridors more than $1.8\ \mathrm{m}$ in width and transverse corridors more than $1\ \mathrm{m}$ in width. Particular attention shall be paid to the need to be able to cross lobbies, atriums and other large open spaces along escape routes. Handrails and other handholds shall be of such strength as to withstand a distributed horizontal load of $750\ \mathrm{N/m}$ applied in the direction of the centre of the corridor or space, and a distributed vertical load of $750\ \mathrm{N/m}$ applied in the downward direction. The two loads need not be applied simultaneously.

B.12.7.2 Escape routes shall be provided from every normally occupied space on the ship to an assembly station. These escape routes shall be arranged so as to provide the most direct route possible to the assembly station and shall be marked with relevant symbols.

B.12.7.3 Where enclosed spaces adjoin an open deck, openings from the enclosed space to the open deck shall, where practicable, be capable of being used as an emergency exit.

B.12.7.4 Decks shall be sequentially numbered, starting with "1" at the tank top or lowest deck. These numbers shall be prominently displayed at stair landings and lift lobbies. Decks may also be named, but the deck number shall always be displayed with the name.

B.12.7.5 Simple "mimic" plans showing the "you are here" position and escape routes marked by arrows, shall be prominently displayed on the inside of each cabin door and in public spaces. The plan shall show the directions of escape, and shall be properly oriented in relation to its position on the ship.

B.12.7.6 Cabin and stateroom doors shall not require keys to unlock them from inside the room. Neither shall there be any doors along any designed escape route which require keys to unlock them when moving in the direction of escape.

B.12.7.7 The lowest $0.5\ \mathrm{m}$ of bulkheads and other partitions forming vertical divisions along escape routes shall be able to sustain a load of $750\ \mathrm{N/m}$ to allow them to be used as walking surfaces from the side of the escape route with the ship at large angles of heel.

B.12.7.8 The escape route from cabins to stairway enclosures shall be as direct as possible, with a minimum number of changes in direction. It shall not be necessary to cross from one side of the ship to the other to reach an escape route. It shall not be necessary to climb more than two decks up or down in order to reach an assembly station or open deck from any passenger space.

B.12.7.9 External routes shall be provided from open decks, referred to in B.12.7.8, to the survival craft embarkation stations.

B.12.7.10 Escape routes are to be evaluated by an evacuation analysis early in the design process [15].

The analysis shall be used to identify and eliminate, as far as practicable, congestion which may develop during an abandonment, due to normal movement of passengers and crew along escape routes, including the possibility that crew may need to move along these routes in a direction opposite the movement of

[15] Reference is made to the Interim Guidelines for evacuation analyses for new and existing passenger ships adopted by IMO by MSC/Circ. 1238.

passengers. In addition, the analysis shall be used to demonstrate the escape arrangements are sufficiently flexible to provide for the possibility that certain escape routes, assembly stations, embarkation stations or survival craft may not be available as a result of a casualty.

B.12.7.11 Designated walkways to the means of escape with a breadth of at least 600 mm shall be provided in special category and open ro-ro spaces to which any passengers carried have access.

B.12.7.12 At least two means of escape shall be provided in ro-ro spaces where the crew are normally employed. The escape routes shall provide safe escape to the lifeboat and liferaft embarkation decks and shall be located at the fore and aft ends of the space.

B.13 Fixed fire detection and fire alarm systems and automatic sprinkler, fire detection and fire alarm systems.

B.13.1 Any ship shall be equipped with:

- an automatic sprinkler, fire detection and fire alarm system in all service spaces, control stations and accommodation spaces, including corridors and stairways (see also the GL Rules for Machinery Installations (I-1-2), Section 12)
- a fixed fire detection and alarm system so installed and arranged as to provide smoke detection in service spaces, control stations and accommodation spaces, including corridors and stairways (see also the GL Rules for Machinery Installations (I-1-2), Section 12)

B.13.2 Control stations where water may cause damage to essential equipment may be fitted with a fixed fire-extinguishing system of another type (see also the GL Rules for Machinery Installations (I-1-2), Section 12).

B.13.3 Cabin balconies shall be equipped with a fixed fire detection and fire alarm system and a fixed pressure water-spraying system (see also the GL Rules for Machinery Installations (I-1-2), Section 12), when furniture and furnishings on such balconies are not complying with B.10.7.

B.13.4 Smoke detectors need not be fitted in private bathrooms and galleys. Spaces having little or no fire risk such as voids, public toilets and similar spaces need not be fitted with an automatic sprinkler, or fixed fire detection and alarm system.

B.14 Protection of vehicle, special category and ro-ro spaces

B.14.1 The subdivision of such spaces in main vertical zones would defeat their intended purpose. Therefore equivalent protection shall be obtained in such spaces on the basis of a horizontal zone concept. A horizontal zone may include special category and ro-ro spaces on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m, whereas the total overall clear height is the sum of distances between deck and web frames of the decks forming the horizontal zone.

B.14.2 Structural Protection

The boundary bulkheads and decks of special category spaces and ro-ro spaces shall be insulated to "A-60" class standard. However, where a category 4.3 [5], 4.3 [9] or 4.3 [10] space is on one side of the division the standard may be reduced to "A-0".

Where fuel oil tanks are below a special category space, the integrity of the deck between such spaces may be reduced to "A-0" standard.

Indicators shall be provided on the navigating bridge which shall indicate when any fire door leading to or from the special category space is closed.

B.14.3 Fixed fire-extinguishing system

B.14.3.1 Vehicle spaces and ro-ro spaces which are not special category spaces and are capable of being sealed from a location outside of the cargo spaces shall be fitted with a fixed gas fire-extinguishing system of an approved type (see also the GL Rules for Machinery Installations (I-1-2), Section 12).

B.14.3.2 Ro-ro and vehicle spaces not capable of being sealed and special category spaces shall be fitted with a fixed pressure water spraying system for manual operation of an approved type (see also the GL Rules for Machinery Installations (I-1-2), Section 12).

B.14.4 Ventilation system

There shall be provided an effective power ventilation system for special category spaces and closed ro-ro and vehicle spaces sufficient to give at least 10 air changes per hour. Beyond this, a higher air exchange rate is required during the period of loading and unloading. The system for such spaces shall be entirely separated from other ventilation systems and shall be operating at all times when vehicles are in such spaces.

Ventilation ducts serving such spaces capable of being effectively sealed shall be separated for each such space. The system shall be capable of being controlled from a position outside such spaces.

The ventilation shall be such as to prevent air stratification and the formation of air pockets.

Means shall be provided to indicate on the navigating bridge any loss or reduction of the required ventilating capacity.

Arrangements shall be provided to permit a rapid shut-down and effective closure of the ventilation system in case of fire, taking into account the weather and sea conditions.

Ventilation ducts, including dampers, within a common horizontal zone shall be made of steel.

Ducts passing through other horizontal zones or machinery spaces shall be "A-60" class steel ducts complying with B.9.11.1 and B.9.11.2.

Permanent openings in the side plating, the ends or deckhead of the space shall be so situated that a fire in the cargo space does not endanger stowage areas and embarkation stations for survival craft and accommodation spaces, service spaces and control stations in superstructures and deckhouses above the cargo spaces.

B.14.5 Fire detection

There shall be provided a fixed fire detection and fire alarm system of an approved type (see also the GL Rules for Machinery Installations (I-1-2), Section 12).

A sample extraction smoke detection system of an approved type (see also the GL Rules for Machinery Installations (I-1-2), Section 12) may be accepted as equivalent, except for open ro-ro spaces, open vehicle spaces and special category spaces.

An efficient fire patrol system shall be maintained in special category spaces. In case of a continuous fire watch at all times during the voyage, a fixed fire detection and alarm system is not required therein.

B.15 Special arrangements in machinery spaces of category A

B.15.1 The number of skylights, doors, ventilators, openings in funnels to permit exhaust ventilation and other openings to machinery spaces shall be reduced to a minimum consistent with the needs of ventilation and the proper and safe working of the ship.

B.15.2 Skylights shall be of steel and shall not contain glass panels. Suitable arrangements shall be made to permit the release of smoke in the event of fire, from the space to be protected. The normal ventilation systems may be acceptable for this purpose.

B.15.3 Means of control shall be provided for permitting the release of smoke and such controls shall be located outside the space concerned so that, in the event of fire, they will not be cut off from the space they serve. The controls shall be situated at one control position or grouped in as few positions as possible. Such positions shall have safe access from the open deck.

B.15.4 Such doors other than power-operated watertight doors shall be arranged so that positive closure is assured in case of fire in the space, by power-operated closing arrangements or by the provision of self-closing doors capable of closing against an inclination of 3.5 ° opposing closure and having a fail-safe hook-back facility, provided with a remotely operated release device. Doors for emergency escape trunks need not be fitted with a fail-safe hold-back facility and a remotely operated release device.

B.15.5 Means of control shall be provided for closing power-operated doors or actuating release mechanism on doors other than power-operated watertight doors. The control shall be located outside the space concerned, where they will not be cut off in the event of fire in the space it serves. The means of control shall be situated at one control position or grouped in as few positions as possible having direct access and safe access from the open deck.

B.15.6 Windows shall not be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

B.15.7 The floor plating of normal passageways shall be made of steel.

B.16 Special requirements for ships carrying dangerous goods

B.16.1 Ventilation

Adequate power ventilation shall be provided in enclosed cargo spaces. The arrangement shall be such as to provide for at least six air changes per hour in the cargo space based on an empty cargo space and for removal of vapours from the upper or lower parts of the cargo space, as appropriate.

The fans shall be such as to avoid the possibility of ignition of flammable gas air mixtures. Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings.

B.16.2 Insulation of machinery space boundaries

Bulkheads forming boundaries between cargo spaces and machinery spaces of category A shall be insulated to "A-60" standard, unless the dangerous goods are stowed at least 3 m horizontally away from such bulkheads. Other boundaries between such spaces shall be insulated to "A-60" standard.

B.16.3 Miscellaneous items

The kind and extent of the fire extinguishing equipment are defined in the GL Rules for Machinery Installations (I-1-2), Section 12.

Electrical apparatus and cablings are to meet the requirements of the GL Rules for Electrical Installations (I-1-3), Section 16.

B.17 Safety centre on passenger ships

B.17.1 Application

Passenger ships constructed on or after 1 July 2010 shall have on board a safety centre complying with the requirements of this regulation.

B.17.2 Location and arrangement

The safety centre shall either be a part of the navigation bridge or be located in a separate space adjacent to and having direct access to the navigation bridge, so that the management of emergencies can be performed without distracting watch officers from their navigational duties.

B.17.3 Layout and ergonomic design

The layout and ergonomic design of the safety centre shall take into account the IMO guidelines [16] (communication and control and monitoring of safety systems see also the GL Rules for Electrical Installations (I-1-3), Section 14).

16 Refer to guidelines according to MSC.1/Circ. 1368

C Passenger Ships carrying not more than 36 Passengers

C.1 Materials

C.1.1 The hull, decks, structural bulkheads, superstructures and deckhouses are to be of steel or other equivalent materials (aluminium alloy suitably insulated).

C.1.2 Components made from aluminium alloys require special treatment, with regard to the mechanical properties of the material in case of temperature increase. In principle, the following is to be observed:

C.1.2.1 The insulation of "A" or "B" class divisions shall be such that the temperature of the structural core does not rise more than 200 °C above the ambient temperature at any time during the applicable fire exposure to the standard fire test.

C.1.2.2 Special attention shall be given to the insulation of aluminium alloy components of columns, stanchions and other structural members required to support lifeboat and liferaft stowage, launching and embarkation areas, and "A" and "B" class divisions to ensure:

that for such members supporting lifeboat and liferaft areas and "A" class divisions, the temperature rise limitation specified in C.1.2.1 shall apply at the end of one hour; and

that for such members required to support "B" class divisions, the temperature rise limitation specified in C.1.2.1 shall apply at the end of half an hour.

C.1.2.3 Crowns and casings of machinery spaces of category A shall be of steel construction and be insulated as required by Table 22.3 as appropriate. Openings therein, if any, shall be suitably arranged and protected to prevent the spread of fire.

C.2 Main vertical zones and horizontal zones

C.2.1 The hull, superstructure and deckhouses in way of accommodation and service spaces are to be subdivided into main vertical zones the average length and width of which on any deck is generally not to exceed 40 m.

Subdivision is to be effected by "A" class divisions.

As far as practicable, the bulkheads forming the boundaries of the main vertical zones above the bulkhead deck shall be in line with watertight subdivision bulkheads situated immediately below the bulkhead deck. The length and width of main vertical zones may be extended to a maximum of 48 m in order to bring the ends of main vertical zones to coincide with subdivision watertight bulkheads or in order to accommodate a large public space extending for the whole length of the main vertical zone provided that the total area of the main vertical zone is not greater than 1 600 m^2 on any deck. The length or width of a main vertical zone is the maximum distance between the furthermost points of the bulkheads bounding it.

The divisions are to extend from deck to deck and to the shell or other boundaries and shall have insulation values in accordance with Table 22.3. At the edges insulating bridges are to be provided where required.

C.2.2 Where a main vertical zone is subdivided by horizontal "A" class divisions into horizontal zones for the purpose of providing an appropriate barrier between sprinklered and non-sprinklered zones of the ship the divisions shall extend between adjacent main vertical zone bulkheads and to the shell or exterior boundaries of the ship and shall be insulated in accordance with the fire insulation and integrity values given in Table 22.4.

C.2.3 On ships designed for special purposes (automobile or railroad car ferries), where the provision of main vertical zone bulkheads would defeat the purpose for which the ships is intended, equivalent means for controlling and limiting a fire are to be provided and specifically approved. Service spaces and ship stores shall not be located on ro-ro decks unless protected in accordance with the applicable regulations.

C.3 Bulkheads within main vertical zones

C.3.1 All bulkheads within accommodation and service spaces which are not required to be "A" class divisions shall be at least "B" class or "C" class divisions as prescribed in Table 22.3. All such divisions may be faced with combustible materials.

C.3.2 All corridor bulkheads where not required to be "A" class shall be "B" class divisions which shall extend from deck to deck.

Exceptions may be permitted when continuous "B" class ceilings are fitted on both sides of the bulkhead or when the accommodations are protected by an automatic sprinkler system.

C.3.3 All bulkheads required to be "B" class division, except corridor bulkheads prescribed in C.3.2, shall extend from deck to deck and to the shell or other boundaries unless the continuous "B" class ceilings or linings fitted on both sides of the bulkheads are at least of the same fire resistance as the bulkhead, in which case the bulkhead may terminate at the continuous ceiling or lining.

C.4 Fire integrity of bulkheads and decks

C.4.1 In addition to complying with the specific provisions for fire integrity of bulkheads and deck mentioned elsewhere in this Section, the minimum fire integrity of all bulkheads and decks shall be as prescribed in Tables 22.3 to 22.4.

C.4.2 The following requirements shall govern application of the tables:

Table 22.3 shall apply to bulkheads, separating adjacent spaces.

Table 22.4 shall apply to deck, separating adjacent spaces.

C.4.3 For the purpose of determining the appropriate fire integrity standards to be applied to boundaries between adjacent spaces, such spaces are classified according to their fire risk as shown in the following Categories 1 to 11. Where the contents and use of a space are such that there is a doubt as to its classifica-tion for the purpose of this regulation, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space that have less than 30 % communicating openings to that space are to be considered separate spaces. The fire integrity of the boundary bulkheads of such smaller rooms shall be as prescribed in Tables 22.3 and 22.4. The title of each category is intended to be typical rather than restrictive.

The number in parentheses preceding each category refers to the applicable column or row number in the tables.

Table 22.3 Fire integrity of bulkheads separating adjacent spaces

Spaces		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
Control stations	[1]	A–0 [3]	A–0	A–60	A–0	A–15	A–60	A–15	A–60	A–60	[7]	A–60
Corridors	[2]		C [5]	B–0 [5]	A–0 [1] B–0 [5]	B–0 [5]	A–60	A–0	A–0	A–15 A–0 [4]	[7]	A–15
Accommodation spaces	[3]			C [5]	A–0 [1] B–0 [5]	B–0 [5]	A–60	A–0	A–0	A–15 A–0 [4]	[7]	A–30 A–0 [4]
Stairways	[4]				A–0 [1] B–0 [5]	A–0 [1] B–0 [5]	A–60	A–0	A–0	A–15 A–0 [4]	[7] [7]	A–15
Service spaces (low risk)	[5]					C [5]	A–60	A–0	A–0	A–0	[7]	A–0

Machinery spaces of category A	[6]						7	A–0	A–0	A–60	7	A–60
Other machinery spaces	[7]							A–0 [2]	A–0	A–0	7	A–0
Cargo spaces	[8]								7	A–0	7	A–0
Service spaces (high risk)	[9]									A–0	7	A–30
Open decks	[10]										–	A–0
Special category spaces and ro-ro cargo spaces	[11]											A–0

Notes to be applied to Tables 22.3 and 22.4, as appropriate

1 For clarification as to which applies see C.3. and C.5.

2 Where spaces are of the same numerical category and superscript 2 appears, a bulkhead or deck of the ratings shown in the tables in only required when the adjacent spaces are for a different purpose, e.g. in category 9. A galley next to a galley does not require a bulkhead but a galley next to a paint room requires an "A–0" bulkhead.

3 Bulkheads separating the wheelhouse and chartroom from each other may be "B–0" rating. No fire rating is required for those partitions separating the navigation bridge and the safety centre when the latter is within the navigation bridge.

4 In determining the applicable fire integrity standard of a boundary between two spaces which are protected by an automatic sprinkler system, the lesser of the two values given in the tables shall apply.

5 For the application of C.2.1, "B–0" and "C", where appearing in Table 22.3, shall be read as "A–0".

6 Fire insulation need not be fitted if the machinery space of category 7, in the opinion of the Administration, has little or no fire risk.

7 Where a 7 appears in the tables, the division is required to be of steel or other equivalent material but is not required to be of "A" class standard.

For the application of C.2.1 a 7. where appearing in Table 22.4, except for categories 8 and 10, shall be read as "A–0".

Table 22.4 Fire integrity of decks separating adjacent spaces

Space above / Space below		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
Control stations	[1]	A–0	A–0	A–0	A–0	A–0	A–60	A–0	A–0	A–0	7	A–30
Corridors	[2]	A–0	7	7	A–0	7	A–60	A–0	A–0	A–0	7	A–0
Accommodation spaces	[3]	A–60	A–0	7	A–0	7	A–60	A–0	A–0	A–0	7	A–30 A–0 [4]
Stairways	[4]	A–0	A–0	A–0	7	A–0	A–60	A–0	A–0	A–0	7	A–0
Service spaces (low risk)	[5]	A–15	A–0	A–0	A–0	7	A–60	A–0	A–0	A–0	7	A–0
machinery spaces of category A	[6]	A–60	A–60	A–60	A–60	A–60	7	A–60 [6]	A–30	A–60	7	A–60
Other machinery spaces	[7]	A–15	A–0	A–0	A–0	A–0	A–0	7	A–0	A–0	7	A–0
Cargo spaces	[8]	A–60	A–0	A–0	A–0	A–0	A–0	A–0	7	A–0	7	A–0
Service spaces (high risk)	[9]	A–60	A–30 A–0 [4]	A–30 A–0 [4]	A–30 A–0 [4]	A–0	A–60	A–0	A–0	A–0	7	A–30

Open decks	[10]	7	7	7	7	7	7	7	7	7	–	A–0
Special category spaces and ro-ro cargo spaces	[11]	A–60	A–15	A–30 A–0 4	A–15	A–0	A–30	A–0	A–0	A–30	A–0	A–0
See notes under Table 22.3.												

[1] : **Control stations**

Spaces containing emergency sources of power and lighting. Wheelhouse and chartroom. Spaces containing the ship's radio equipment. Fire control stations. Control room for propulsion machinery when located outside the propulsion machinery space. Spaces containing centralized fire alarm equipment.

[2] : **Corridors**

Passenger and crew corridors and lobbies.

[3] : **Accommodation spaces**

Spaces used for public spaces, lavatories, cabins, offices, hospitals, cinemas, games and hobby rooms, barber shops, pantries containing no cooking appliances and similar spaces.

[4] : **Stairways**

Interior stairways, lifts, totally enclosed emergency escape trunks and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto.

In this connection, a stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door.

[5] : **Service spaces (low risk)**

Lockers and store-rooms not having provisions for the storage of flammable liquids and having areas less than $4\ m^2$ and drying rooms and laundries.

[6] : **Machinery spaces of category A**

Spaces and trunks to such spaces which contain:

internal combustion machinery used for main propulsion; or

internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or

any oil-fired boiler or oil fuel unit.

[7] : **Other machinery spaces**

Spaces, other than machinery spaces of category A, containing propulsion machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces. Electrical equipment rooms (auto-telephone exchange, air-conditioning duct spaces)

[8] : **Cargo spaces**

All spaces used for cargo (including cargo oil tanks) and trunkways and hatchways to such spaces, other than special category spaces.

[9] : **Service spaces (high risk)**

Galleys, pantries containing cooking appliances, paint and lamp rooms, lockers and store-rooms having areas of $4\ m^2$ or more, spaces for the storage of flammable liquids, saunas and workshops other than those forming part of the machinery spaces.

[10] : **Open decks**

Open deck spaces and enclosed promenades having little or no fire risk. Enclosed promenades shall have no significant fire risk, meaning that furnishing should be restricted to deck furniture. In addition, such spaces shall be naturally ventilated by permanent openings. Air spaces (the space outside superstructure and deckhouses).

[11] : **Special category spaces and ro-ro cargo spaces**

C.4.4 Continuous "B" class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing wholly or in part, to the required insulation and integrity of a division.

C.4.5 See B.4.5.

C.4.6 Protection of atriums

C.4.6.1 Atriums shall be within enclosures formed of "A" class divisions having a fire rating determined in accordance with Table 22.4, as applicable.

C.4.6.2 Decks separating spaces within atriums shall have a fire rating determined in accordance with Table 22.4, as applicable.

C.5 Protection of stairways and lifts in accommodation and service spaces

C.5.1 All stairways in accommodation and service spaces are to be of steel frame or other approved equivalent construction; they are to be arranged within enclosures formed by "A" Class divisions, with effective means of closure for all openings.

The following exceptions are admissible:

C.5.1.1 A stairway connecting only two decks need not be enclosed, provided that the integrity of the pierced deck is maintained by suitable bulkheads or doors at one of the two decks. When a stairway is closed at one 'tween deck space, the stairway enclosed shall be protected in accordance with the tables for decks.

C.5.1.2 Stairways fitted within a closed public space need not be enclosed.

C.5.2 Stairway enclosures are to be directly accessible from the corridors and of sufficient area to prevent congestion, having in mind the number of persons likely to use them in an emergency. Within the perimeter of such stairway enclosures, only public spaces, lockers of non-combustible material providing storage for safety equipment and open information counters are permitted. Only corridors, public toilets, special category spaces, other escape stairways required by C.12.3.3 and external areas are permitted to have direct access to these stairway enclosures. Public spaces may also have direct access to stairways enclosures except for the backstage of a theatre. Small corridors or lobbies used to separate an enclosed stairway from galleys or main laundries may have direct access to the stairway provided they have a minimum deck area of $4.5\ m^2$, a width of no less than 900 mm and contain a fire hose station.

C.5.3 Lift trunks shall be so fitted as to prevent the passage of smoke and flame from one 'tween deck to another and shall be provided with means of closing so as to permit the control of draught and smoke.

C.6 Openings in "A" class divisions

C.6.1 Where "A" class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements shall be made to ensure that the fire resistance is not impaired, subject to the provisions of C.6.7.

C.6.2 All openings in the divisions are to be provided with permanently attached means of closing which shall be at least as effective for resisting fire as the divisions [3]. This does not apply for hatches between cargo, special category, store and baggage spaces and between such spaces and the weather decks.

C.6.3 The construction of all doors and door frames in "A" class divisions, with the means of securing them when closed, shall provide resistance to fire as well as to the passage of smoke and flame, equivalent to that of the bulkheads in which the doors are situated [3]. Such doors and door frames shall be approved by GL and constructed of steel or other equivalent material. Doors approved without the sill being part of the frame, which are installed on or after 1 July 2010, shall be installed such that the gap under the door does not exceed $12\ \mathrm{mm}$. A non-combustible sill shall be installed under the door such that floor coverings do not extend beneath the closed door.

C.6.4 Watertight doors need not be insulated.

C.6.5 It shall be possible for each door to be opened and closed from each side of the bulkhead by one person only.

C.6.6 Fire doors in main vertical zone bulkheads, galley boundaries and stairway enclosures other than power-operated watertight doors and those which are normally locked, shall satisfy the following requirements:

C.6.6.1 The doors shall be self-closing and be capable of closing against an angle of inclination of up to $3.5\ °$ opposing closure.

C.6.6.2 The approximate time of closure for hinged fire doors shall be no more than $40\ \mathrm{s}$ and no less than $10\ \mathrm{s}$ from the beginning of their movement with the ship in upright position. The approximate uniform rate of closure for sliding fire doors shall be of no more than $0.2\ \mathrm{m/s}$ and no less than $0.1\ \mathrm{m/s}$ with the ship in the upright position.

C.6.6.3 The doors, except those for emergency escape trunks shall be capable of remote release from the continuously manned central control station, either simultaneously or in groups and shall be capable of release also individually from a position at both sides of the door. Release switches shall have an on-off function to prevent automatic resetting of the system.

C.6.6.4 Hold-back hooks not subject to central control station release are prohibited.

C.6.6.5 A door closed remotely from the central control station shall be capable of being re-opened at both sides of the door by local control. After such local opening, the door shall automatically close again (see also the GL Rules for Electrical Installations (I-1-3), Section 9).

C.6.6.6 Indication shall be provided at the fire door indicator panel in the continuously manned central control station whether each of the remote-released doors are closed.

C.6.6.7 The release mechanism shall be so designed that the door will automatically close in the event of disruption of the control system or main source of electric power.

C.6.6.8 Local power accumulators for power-operated doors shall be provided in the immediate vicinity of the doors to enable the doors to be operated after disruption of the control system or main source of electric power at least ten times (fully opened and closed) using the local controls (see also the GL Rules for Machinery Installations (I-1-2), Section 14).

C.6.6.9 Disruption of the control system or main source of electric power at one door shall not impair the safe functioning of the other doors.

C.6.6.10 Remote-released sliding or power-operated doors shall be equipped with an alarm that sounds for at least $5\ \mathrm{s}$ but no more than $10\ \mathrm{s}$ after the door is released from the central control station and before the door begins to move and continue sounding until the door is completely closed.

C.6.6.11 A door designed to re-open upon contacting an object in its path shall re-open not more than 1 m from the point of contact.

C.6.6.12 Double-leaf doors equipped with a latch necessary to their fire integrity shall have a latch that is automatically activated by the operation of the doors when released by the control system.

C.6.6.13 Doors giving direct access to special category spaces which are power-operated and automatically closed need not be equipped with the alarms and remote-release mechanisms required in C.6.6.3 and C.6.6.10.

C.6.6.14 The components of the local control system shall be accessible for maintenance and adjusting.

C.6.6.15 Power-operated doors shall be provided with a control system of an approved type which shall be able to operate in case of fire [3]. This system shall satisfy the following requirements:

C.6.6.15.1 the control system shall be able to operate the door at the temperature of at least 200 °C for at least 60 min, served by the power supply;

C.6.6.15.2 the power supply for all other doors not subject to fire shall nor be impaired; and

C.6.6.15.3 at temperatures exceeding 200 °C the control system shall be automatically isolated from the power supply and shall be capable of keeping the door closed up to at least 945 °C.

C.6.7 Where a space is protected by an automatic sprinkler system or fitted with a continuous "B" class ceiling, openings in decks not forming steps in main vertical zones nor bounding horizontal zones shall be closed reasonably tight and such decks shall meet the "A" class integrity requirements in so far as is reasonable and practicable.

C.6.8 The requirements for "A" class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and sidescuttles, provided that there is no requirement for such boundaries to have "A" class integrity in C.8.3. The requirements for "A" class integrity of the outer boundaries of the ship shall not apply to exterior doors, except for those in superstructures and deckhouses facing life-saving appliances, embarkation and external muster station areas, external stairs and open decks used for escape routes. Stairway enclosure doors need not meet this requirement.

C.6.9 Except for watertight, weathertight doors (semi-watertight doors), doors leading to the open deck and doors which need reasonably gastight, all "A" class doors located in stairways, public spaces and main vertical zone bulkheads in escape routes shall be equipped with a self-closing hose port of material, construction and fire resistance which is equivalent to the door into which it is fitted, and shall be a 150 mm square clear opening with the door closed and shall be inset into the lower edge of the door, opposite the door hinges, or in the case of sliding doors, nearest the opening.

C.7 Openings in "B" class divisions

C.7.1 Where "B" class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements shall be made to ensure that the fire resistance is not impaired. See also B.7.1.

C.7.2 Doors and door frames in "B" class divisions and means of securing them shall provide a method of closure which shall have resistance to fire equivalent to that of the divisions [3] except that ventilation openings may be permitted in the lower portion of such doors. Doors approved as "A" class without the sill being part of the frame, which are installed on or after 1 July 2010, shall be installed such that the gap under the door does not exceed 12 mm and a non-combustible sill shall be installed under the door such that floor coverings do not extend beneath the closed door. Doors approved as "B" class without the sill being part of the frame, which are installed on or after 1 July 2010, shall be installed such that the gap under the door does not exceed 25 mm. Where such opening is in or under a door the total net area of any such opening or openings shall not exceed $0.05\ m^2$. Alternatively, a non-combustible air balance duct between the cabin and the corridor, and located below the sanitary unit is permitted where the cross-sectional area of the duct does not exceed $0.05\ m^2$. All ventilation openings shall be fitted with a grill made of non-combustible material. Doors shall be non-combustible and approved by GL.

C.7.3 Cabin doors in "B" class division shall be of a self closing type. Hold-backs are not permitted.

C.7.4 The requirements for "B" class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and sidescuttles. Similarly, the requirements for "B" class integrity shall not apply to exterior doors in superstructures and deckhouses.

C.7.5 Where an automatic sprinkler system is fitted:

C.7.5.1 openings in decks not forming steps in main vertical zones nor bounding horizontal zones shall be closed reasonably tight and such decks shall meet the "B" class integrity requirements in so far as is reasonable and practicable and

C.7.5.2 openings in corridor bulkheads of "B" class materials shall be protected in accordance with the provisions of C.3.2.

C.8 Windows and sidescuttles

C.8.1 All windows and sidescuttles in bulkheads within accommodation and service spaces and control stations other than those to which the provisions of C.6.8 and of C.7.4 apply, shall be so constructed as to preserve the integrity requirements of the type of bulkheads in which they are fitted.

C.8.2 Notwithstanding the requirements of the Tables 22.3 and 22.4 all windows and sidescuttles in bulkheads separating accommodation and service spaces and control stations from weather shall be constructed with frames of steel or other suitable material. The glass shall be retained by a metal glazing bead or angle.

C.8.3 Windows facing life-saving appliances, embarkation and muster areas, external stairs and open decks used for escape routes, and windows situated below liferaft and escape slide embarkation areas shall have the fire integrity as required in the Tables 22.1 and 22.2. Where automatic dedicated sprinkler heads are provided for windows (see also the GL Rules for Machinery Installations (I-1-2), Section 12), A-0 windows may be accepted as equivalent. Windows located in the ship's side below the lifeboat embarkation areas shall have the fire integrity at least equal to "A-0" class.

C.9 Ventilation systems

C.9.1 Ventilation ducts shall be of steel or equivalent material. Short ducts, however, not generally exceeding 2 m in length and with a cross-section not exceeding $0.02\ m^2$ need not be steel or equivalent, subject to the following conditions:

C.9.1.1 subject to C.9.1.2 these ducts shall be of any material having low flame spread characteristics[4] which is type approved;

C.9.1.2 on ships constructed on or after 1 July 2010, the ducts shall be made of heat resisting non-combustible material, which may be faced internally and externally with membranes having low flame-spread characteristics and, in each case, a calorific value [5] not exceeding $45\ MJ / m^2$ of their surface area for the thickness used;

C.9.1.3 they may only be used at the end of the ventilation device;

C.9.1.4 they shall not be situated less than 600 mm, measured along the duct, from an opening in an "A" or "B" class division including continuous "B" class ceilings.

C.9.2 Where a thin plated duct with a free cross-sectional area equal to or less than $0.02\ m^2$ pass through "A" class bulkheads or decks, the opening shall be lined with a steel sheet sleeve having a thickness of at least 3 mm and a length of at least 200 mm, divided preferably into 100 mm on each side of the bulkhead or, in the case of the deck, wholly laid on the lower side of the decks pierced.

Where ventilation ducts with a free cross-sectional area exceeding $0.02\ m^2$ pass through "A" class bulkheads or decks, the opening shall be lined with a steel sheet sleeve. However, where such ducts are of steel construction and pass through a deck or bulkhead, the ducts and sleeves shall comply with the following:

C.9.2.1 The sleeves shall have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length shall be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, shall be provided with fire insulation. The insulation shall have at least the same fire integrity as the bulkhead or deck through which the duct passes.

C.9.2.2 Ducts with a free cross-sectional area exceeding $0.075\ m^2$ shall be fitted with fire dampers in addition to the requirements of C.9.2.1. The fire damper shall operate automatically but shall also be capable of being closed manually from both sides of the bulkhead or deck. The damper shall be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where ducts pass through spaces surrounded by "A" class division, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they pierce. The fire dampers should be easily accessible. Where they are placed behind ceilings and linings, these latter should be provided with an inspection door on which a plate reporting the identification number of the fire damper. Such plate and identification number should be placed also on any remote control required.

C.9.2.3 The following arrangement shall be of an approved type [3]:

- fire dampers, including relevant means of operation
- duct penetrations through "A" class divisions. Where steel sleeves are directly joined to ventilation ducts by means of riveted or screwed flanges or by welding, the test is not required.

C.9.3 The main inlets and outlets of all ventilation systems shall be capable of being closed from outside the respective spaces in the event of a fire.

C.9.4 Where they pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges shall be constructed of insulated "A" class divisions. Each exhaust duct shall be fitted with:

- a grease trap readily removable for cleaning;
- a fire damper located in the lower end of the duct and in addition, a fire damper in the upper end of the duct;
- arrangements, operable from within the galley, for shutting off the exhaust fan; and
- fixed means for extinguishing a fire within the duct (see the GL Rules for Machinery Installations (I-1-2), Section 12).

C.9.5 Such measures as are practicable shall be taken in respect of control stations outside machinery spaces in order to ensure that ventilation, visibility and freedom from smoke are maintained, so that in the event of fire the machinery and equipment contained therein may be supervised and continue to function effectively. Alternative and separate means of air supply shall be provided; air inlets of the two sources of supply shall be so disposed that the risk of both inlets drawing in smoke simultaneously is minimized. Such requirements need not apply to control stations situated on, and opening on to, an open deck.

The ventilation system serving safety centres may be derived from the ventilation system serving the navigation bridge, unless located in an adjacent main vertical zone.

C.9.6 The ventilation systems for machinery spaces of category A, vehicle spaces, ro-ro spaces, galleys, special category spaces and cargo spaces shall, in general, be separated from each other and from the ventilation system serving other spaces. Except, that the galley ventilation systems need not be completely separated, but may be served by separate ducts from a ventilation unit serving other spaces. In any case, an automatic fire damper shall be fitted in the galley ventilation duct near the ventilation unit.

C.9.7 Ducts provided for the ventilation of machinery spaces of category A, galleys, vehicle spaces, ro-ro cargo spaces or special category spaces shall not pass through accommodation spaces, service spaces or control stations unless the ducts are either complying with C.9.7.1 or C.9.7.2:

C.9.7.1 constructed of steel having a thickness of at least 3 mm and 5 mm for ducts the widths or diameters of which are up to and including 300 mm and 760 mm and over respectively and, in the case of such ducts, the widths or diameters of which are between 300 mm and 760 mm having a thickness to be obtained by interpolation;

suitably supported and stiffened;

fitted with automatic fire dampers close to the boundaries penetrated; and

insulated to "A-60" standard from the machinery spaces, galleys, vehicle spaces, ro-ro cargo spaces or special category spaces to a point at least 5 m beyond each fire damper; or

C.9.7.2 constructed of steel suitable supported and stiffened in accordance with C.9.7.1 and

insulated to "A-60" standard throughout the accommodation spaces, service spaces or control stations;

except that penetrations of main zone divisions shall also comply with the requirements of C.9.11.

C.9.8 Ducts provided for the ventilation to accommodation spaces, service spaces or control stations shall not pass through machinery spaces of category A, galleys, vehicle spaces, ro-ro cargo spaces or special category spaces unless either complying with C.9.8.1 or C.9.8.2.

C.9.8.1 the ducts where they pass through a machinery space of category A, galley, vehicle space, ro-ro cargo space or special category space are constructed of steel, suitable supported and stiffened in accordance with C.9.7.1 and

automatic fire dampers are fitted close to the boundaries penetrated; and

integrity of the machinery space, galley, vehicle space, ro-ro cargo space or special category space boundaries is maintained at the penetrations; or

C.9.8.2 the ducts where they pass through a machinery space of category A, galley, vehicle space, ro-ro cargo space or special category space are constructed of steel, suitable supported and stiffened in accordance with C.9.7.1 and

are insulated to "A-60" standard within the machinery space, galley, vehicle space, ro-ro cargo space or special category space;

except that penetrations of main zone division shall also comply with the requirements of C.9.11.

C.9.9 Ventilation ducts with a free cross-sectional area exceeding $0.02\ m^2$ passing through "B" class bulkheads shall be lined with steel sheet sleeves of 900 mm in length divided preferably into 450 mm on each side of the bulkheads unless the duct is of steel for this length.

C.9.10 Power ventilation of accommodation spaces, service spaces, cargo spaces, control stations and machinery spaces shall be capable of being stopped from an easily accessible position outside the space being served. This position should not be readily cut off in the event of a fire in the spaces served. The means provided for stopping the power ventilation of the machinery spaces shall be entirely separate from the means provided for stopping ventilation of other spaces.

C.9.11 Where in a passenger ship it is necessary that a ventilation duct passes through a main vertical zone division, a fail-safe automatic closing fire damper shall be fitted adjacent to the division. The damper shall also be capable of being manually closed from each side of the division. The operating position shall be readily accessible and be marked in red light-reflecting colour. The duct between the division and the damper shall be of steel or other equivalent material and, if necessary, insulated to comply with the requirements of C.6.1. The damper shall be fitted on at least one side of the division with a visible indicator showing whether the damper is in the open position.

C.10 Restriction of combustible materials

C.10.1 Except in cargo spaces, mail rooms, baggage rooms, saunas [6] or refrigerated compartments of service spaces, all linings, grounds, draughts stops, ceilings and insulation's shall be of non-combustible materials [3]. Partial bulkheads or decks used to subdivide a space for utility or artistic treatment shall also be of non-combustible material.

Linings, ceilings and partial bulkheads or decks used to screen or to separate adjacent cabin balconies shall be of non-combustible material.

C.10.2 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings, for cold service systems need not be non-combustible but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame spread characteristics.

C.10.3 The following surfaces shall have low flame-spread characteristics [4]:

C.10.3.1 exposed surfaces in corridors and stairway enclosures, and of bulkheads, wall and ceiling linings in all accommodation and service spaces (except saunas) and control stations;

C.10.3.2 concealed or inaccessible spaces in accommodation, service spaces and control stations,

C.10.3.3 exposed surfaces of cabin balconies, except for natural hard wood decking systems.

C.10.4 The total volume of combustible facings, mouldings, decorations and veneers in any accommodation and service space shall not exceed a volume equivalent to 2.5 mm veneer on the combined area of the walls and ceilings. Furniture fixed to linings, bulkheads or decks need not be included in the calculation of the total volume of combustible materials. This applies also to traditional wooden benches and wooden linings on bulkheads and ceilings in saunas. In the case of ships fitted with an automatic sprinkler system, the above volume may include some combustible material used for erection of "C" class divisions.

C.10.5 Combustible materials used on surfaces and linings covered by the requirements of C.10.3 shall have a calorific value [17] not exceeding $45\ MJ / m^2$ of the area for the thickness used. This does not apply to surfaces of furniture fixed to linings or bulkheads as well as to traditional wooden benches and wooden linings on bulkheads and ceilings in saunas.

C.10.6 Furniture in stairway enclosures shall be limited to seating. It shall be fixed, limited to six seats on each deck in each stairway enclosure, be of restricted fire risk, and shall not restrict the passenger escape route.

Furniture shall not be permitted in passenger and crew corridors forming escape routes in cabin areas. Lockers of non-combustible material, providing storage for safety equipment, may be permitted within these areas.

Drinking water dispensers and ice cube machines may be permitted in corridors provided they are fixed and do not restrict the width of the escape route. This applies as well to decorative flower arrangements, statues or other objects d'art such as paintings and tapestries in corridors and stairways.

C.10.7 Furniture and furnishings on cabin balconies shall comply with the following, unless such balconies are protected by a fixed pressure water-spraying and fixed fire detection and fire alarm systems (see B.10.7).

C.10.8 Paints, varnishes and other finishes used on exposed interior surfaces, including cabin balconies with the exclusion of natural hard wood decking systems, shall not be capable of producing excessive quantities of smoke and toxic products [11].

C.10.9 Primary deck coverings, if applied within accommodation and service spaces and control stations, or if applied on cabin balconies, shall be of approved material which will not readily ignite, or give rise to smoke or toxic or explosive hazards at elevated temperatures [12].

C.10.10 Waste receptacles (see B.10.10).

C.11 Details of construction

C.11.1 In accommodation and service spaces, control stations, corridors and stairways:

air spaces enclosed behind ceilings, panelling or linings shall be suitably divided by close-fitting draught stops not more than 14 m apart;

in the vertical direction, such enclosed air spaces, including those behind linings of stairways, trunks, etc. shall be closed at each deck.

C.11.2 The construction of ceilings and bulkheads shall be such that it will be possible, without impairing the efficiency of the fire protection, for the fire patrols to detect any smoke originating in concealed and inaccessible spaces.

C.11.3 Non-load bearing partial bulkheads separating adjacent cabin balconies shall be capable of being opened by the crew from each side for the purpose of fighting fires.

C.11.4 The cargo holds and machinery spaces shall be capable of being effectively sealed such as to prevent the inlet of air.

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17 The gross calorific value measured in accordance with ISO standard 1716 - "Building materials - Determination of Calorific Potential", should be quoted.

Doors leading to machinery spaces of group A are to be provided with self-closing devices and 2 securing devices. All other machinery spaces, which are protected by a gas fire extinguishing system, are to be equipped with self-closing doors.

C.11.5 Construction and arrangement of saunas (see B.11.5).

C.12 Means of escape

C.12.1 Unless expressly provided otherwise in this regulation, at least two widely separated and ready means of escape shall be provided from all spaces or group of spaces. Lifts shall not be considered as forming one of the required means of escape.

C.12.2 Doors in escape routes shall, in general, open in-way of the direction of escape, except that

C.12.2.1 individual cabin doors may open into the cabins in order to avoid injury to persons in the corridor when the door is opened, and

C.12.2.2 doors in vertical emergency escape trunks may open out of the trunk in order to permit the trunk to be used both for escape and access.

C.12.3 Stairways and ladders shall be arranged to provide ready means of escape to the lifeboat and liferaft embarkation deck from all passenger and crew spaces and from spaces in which the crew is normally employed, other than machinery spaces. In particular, the following provisions shall be complied with:

C.12.3.1 Below the bulkhead deck, two means of escape, at least one of which shall be independent of watertight doors, shall be provided from each watertight compartment or similarly restricted space or group of spaces. Due regard being paid to the nature and location of spaces and to the number of persons who normally might be employed there, exceptions are possible, however, stairways shall not be less than 800 mm in clear width with handrails on both sides.

C.12.3.2 Above the bulkhead deck, there shall be at least two means of escape from each main vertical zone or similarly restricted space or group of spaces at least one of which shall give access to a stairway forming a vertical escape.

C.12.3.3 At least one of the means of escape required by paragraphs C.12.3.1 and C.12.3.2 shall consist of a readily accessible enclosed stairway, which shall provide continuous fire shelter from the level of its origin to the appropriate lifeboat and liferaft embarkation decks, or to the uppermost weather deck if the embarkation deck does not extend to the main vertical zone being considered. In the latter case, direct access to the embarkation deck by way of external open stairways and passageways shall be provided and shall have emergency lighting (see also the GL Rules for Electrical Installations (I-1-3), Section 3 and 11) and slip-free surfaces under foot. Boundaries facing external open stairways and passageways forming part of an escape route and boundaries in such a position that their failure during a fire would impede escape to the embarkation deck shall have fire integrity, including insulation values, in accordance with the Tables 22.3 and 22.4. The widths, number and continuity of escapes shall be as follows:

C.12.3.3.1 Stairways shall not be less than 900 mm in clear width. Stairways shall be fitted with handrails on each side. The minimum clear width of stairways shall be increased by 10 mm for every one person provided for in excess of 90 persons. The maximum clear width between handrails where stairways are wider than 900 mm shall be 1 800 mm. The total number of persons to be evacuated by such stairways shall be assumed to be two thirds of the crew and the total number of passengers in the areas served by such stairways [13].

C.12.3.3.2 All stairways sized for more than 90 persons shall be aligned fore and aft.

C.12.3.3.3 Doorways and corridors and intermediate landings included in means of escape shall be sized in the same manner as stairways.

C.12.3.3.4 Stairways shall not exceed 3.5 m in vertical rise without the provision of a landing and shall not have an angle of inclination greater than 45 °.

C.12.3.3.5 Landings at each deck level shall be not less than $2 \mathrm{m}^2$ in area and shall increase by $1 \mathrm{m}^2$ for every 10 persons provided for in excess of 20 persons but need not exceed $16 \mathrm{m}^2$, except for those landings servicing public spaces having direct access onto the stairway enclosure.

C.12.3.4 Stairways serving only a space and a balcony in that space shall not be considered as forming one of the means of escape.

C.12.3.5 A corridor, lobby, or part of a corridor from which there is only one route of escape shall be prohibited. Dead-end corridors used in service areas which are necessary for the practical utility of the ship, such as fuel oil stations and athwartship supply corridors shall be permitted provided such dead-end corridors are separated from crew accommodation areas and are inaccessible from passenger accommodation areas. Also, a part of the corridor that has a depth not exceeding its width is considered a recess or local extension and is permitted.

C.12.3.6 In addition to the emergency lighting (see also the GL Rules for Electrical Installations (I-1-3), Section 14) the means of escape including stairways and exits, shall be marked by lighting or photoluminescent strip indicators placed not more than $0.3 \mathrm{m}$ above the deck at all points of the escape route including angles and intersections. The marking shall enable passengers to identify all the routes of escape and readily identify the escape exits. If electric illumination is used, it shall be supplied by the emergency source of power and it shall be so arranged that the failure of any single light or cut in a lighting strip, will not result in the marking being ineffective. Additionally, all escape route signs and fire equipment location markings shall be of photoluminescent material or marked by lighting. Such lighting or photoluminescent equipment shall be of an approved type [13].

C.12.3.6.1 In lieu of the escape route lighting system required by paragraph C.12.3.6, alternative evacuation guidance systems may be accepted if they are of approved type (see also the GL Rules for Electrical Installations (I-1-3), Section 14) [14].

C.12.3.7 Public Spaces spanning three or more decks and contain combustibles such as furniture and enclosed spaces such as ships, offices and restaurants shall have at each level within the space two means of escape, one of which shall have direct access to an enclosed vertical means of escape as mentioned under C.12.3.3.

C.12.4 If a radiotelegraph station has no direct access to the open deck, two means of escape from or access to such station shall be provided, one of which may be a porthole or window of sufficient size or another means.

C.12.5 In special category spaces the number and disposition of the means of escape both below and above the bulkhead deck shall be satisfactory as mentioned under C.12.3.1, .2 and .3.

C.12.6 Two means of escape shall be provided from each machinery space. In particular, the following provisions shall be complied with:

C.12.6.1 Where the space is below the bulkhead deck the two means of escape shall consist of either:

C.12.6.1.1 two sets of steel ladders as widely separated as possible, leading to doors in the upper part of the space similarly separated and from which access is provided to the appropriate lifeboat and liferaft embarkation decks. One of these ladders shall be located within a protected enclosure having fire integrity, including insulation values, in accordance with the Tables 22.3 and 22.4 for a category (4) space, from the lower part of the space to a safe position outside the space. Self-closing doors of the same fire integrity standards shall be fitted in the enclosure. The ladder shall be fixed in such a way that heat is not transferred into the enclosure through non-insulated fixing points. The protected enclosure shall have minimum internal dimensions of at least $800 \mathrm{mm} \times 800 \mathrm{mm}$, and shall have emergency lighting provisions.

C.12.6.1.2 or one steel ladder leading to a door in the upper part of the space from which access is provided to the embarkation deck an additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the embarkation deck.

C.12.6.2 Where the space is above the bulkhead deck, two means of escape shall be as widely separated as possible and the doors leading from such means of escape shall be in a position from which access is provided to the appropriate lifeboat and liferaft embarkation decks. Where such escapes require the use of ladders these shall be of steel.

C.12.6.3 A ship of a gross tonnage less than 1 000 may be dispensed with one of the means of escape, due regard being paid to the width and disposition of the upper part of the space; and a ship of a gross tonnage of 1 000 and above, may be dispensed with one means of escape from any such space so long as either a door or a steel ladder provides a safe escape route to the embarkation deck, due regard being paid to the nature and location of the space and whether persons are normally employed in that space.

C.12.6.4 In the steering gear room, a second means of escape shall be provided when the emergency steering position is located in that space unless there is direct access to the open deck.

C.12.6.5 One of the escape routes from the machinery spaces where the crew is normally employed shall avoid direct access to any special category space.

C.12.6.6 Two means of escape shall be provided from a machinery control room within a machinery space, at least one of which shall provide continuous fire shelter to a safe position outside the machinery space.

C.12.7 Additional requirements for ro-ro passenger ships

See B.12.7.

C.13 Fixed fire detection and fire alarm systems and automatic sprinkler, fire detection and fire alarm systems

In any ship there shall be installed throughout each separate zone, whether vertical or horizontal, in all accommodation and service spaces and, where it is considered necessary, in control stations, except spaces which afford no substantial fire risk (such as void spaces, sanitary spaces, etc.) either:

C.13.1 a fixed fire detection and fire alarm system (see also the GL Rules for Machinery Installations (I-1-2), Section 12); or

C.13.2 an automatic sprinkler, fire detection and fire alarm system and in addition a fixed fire detection and fire alarm system so installed and arranged as to provide smoke detection in corridors, stairways and escape routes within accommodation spaces.

C.13.3 Cabin balconies (see B.13.3).

C.14 Protection of vehicle, special category and ro-ro spaces

C.14.1 The subdivision of such spaces in main vertical zones would defeat their intended purpose. Therefore equivalent protection shall be obtained in such spaces on the basis of a horizontal zone concept. A horizontal zone may include special category and ro-ro spaces on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m, whereas the total overall clear height is the sum of distances between deck and web frames of the decks forming the horizontal zone.

C.14.2 Structural Protection

The boundary bulkheads and decks of special category spaces shall be insulated as required for category (11) spaces in Tables 22.3 and 22.4, whereas the boundary bulkheads and decks of closed and open ro-ro spaces shall have fire integrity as required for category (8) spaces in Tables 22.3 and 22.4.

Indicators shall be provided on the navigating bridge which shall indicate when any fire door leading to or from the special category space is closed.

C.14.3 Fixed fire-extinguishing system

C.14.3.1 Vehicle spaces and ro-ro spaces which are not special category spaces and are capable of being sealed from a location outside of the cargo spaces shall be fitted with a fixed gas fire-extinguishing system of an approved type (see also the GL Rules for Machinery Installations (I-1-2), Section 12).

C.14.3.2 Ro-ro and vehicle spaces not capable of being sealed and special category spaces shall be fitted with a fixed pressure water spraying system for manual operation of an approved type (see also the GL Rules for Machinery Installations (I-1-2), Section 12).

C.14.4 Ventilation system

There shall be provided an effective power ventilation system for special category spaces sufficient to give at least 10 air changes per hour and for closed ro-ro and vehicle spaces sufficient to give at least 6 air changes per hour. Beyond this, a higher air exchange rate is required during the period of loading and unloading. The system for such spaces shall be entirely separated from other ventilation systems and shall be operating at all times when vehicles are in such spaces.

Ventilation ducts serving such spaces capable of being effectively sealed shall be separated for each such space. The system shall be capable of being controlled from a position outside such spaces.

The ventilation shall be such as to prevent air stratification and the formation of air pockets.

Means shall be provided to indicate on the navigating bridge any loss or reduction of the required ventilating capacity.

Arrangements shall be provided to permit a rapid shut-down and effective closure of the ventilation system in case of fire, taking into account the weather and sea conditions.

Ventilation ducts, including dampers, within a common horizontal zone shall be made of steel.

Ducts passing through other horizontal zones or machinery spaces shall be "A-60" class steel ducts complying with C.9.11.

Permanent openings in the side plating, the ends or deckhead of the spaces shall be so situated that a fire in the cargo space does not endanger stowage areas and embarkation stations for survival craft and accommodation spaces, service spaces and control stations in superstructures and deckhouses above the cargo spaces.

C.14.5 Fire detection

There shall be provided a fixed fire detection and fire alarm system of an approved type (see also the GL Rules for Machinery Installations (I-1-2), Section 12).

A sample extraction smoke detection system of an approved type (see also the GL Rules for Machinery Installations (I-1-2), Section 12) may be accepted as equivalent, except for open ro-ro spaces, open vehicle spaces and special category spaces.

An efficient fire patrol system shall be maintained in special category spaces. In case of a continuous fire watch at all times during the voyage, a fixed fire detection and alarm system is not required therein.

C.15 Special arrangements in machinery spaces of category A

C.15.1 The number of skylights, doors, ventilators, openings in funnels to permit exhaust ventilation and other openings to machinery spaces shall be reduced to a minimum consistent with the needs of ventilation and the proper and safe working of the ship.

C.15.2 Skylights shall be of steel and shall not contain glass panels. Suitable arrangements shall be made to permit the release of smoke in the event of fire, from the space to be protected. The normal ventilation systems may be acceptable for this purpose.

C.15.3 Means of control shall be provided for permitting the release of smoke and such controls shall be located outside the space concerned so that, in the event of fire, they will not be cut off from the space they serve. The controls shall be situated at one control position or grouped in as few positions as possible. Such positions shall have safe access from the open deck.

C.15.4 Such doors other than power-operated watertight doors shall be arranged so that positive closure is assured in case of fire in the space, by power-operated closing arrangements or by the provision of self-closing doors capable of closing against an inclination of 3.5 ° opposing closure and having a fail-safe hook-back facility, provided with a remotely operated release device. Doors for emergency escape trunks need not be fitted with a fail-safe hold-back facility and a remotely operated release device.

C.15.5 Means of control shall be provided for closing power-operated doors or actuating release mechanism on doors other than power-operated watertight doors. The control shall be located outside the space concerned, where they will not be cut off in the event of fire in the space it serves. The means of control shall be situated at one control position or grouped in as few positions as possible having direct access and safe access from the open deck.

C.15.6 Windows shall not be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

C.15.7 The floor plating of normal passageways shall be made of steel.

C.16 Special requirements for ships carrying dangerous goods

C.16.1 Ventilation

Adequate power ventilation shall be provided in enclosed cargo spaces. The arrangement shall be such as to provide for at least six air changes per hour in the cargo space based on an empty cargo space and for removal of vapours from the upper or lower parts of the cargo space, as appropriate.

The fans shall be such as to avoid the possibility of ignition of flammable gas air mixtures. Suitable wire mesh guard shall be fitted over inlet and outlet ventilation openings.

C.16.2 Insulation of machinery space boundaries

Bulkheads forming boundaries between cargo spaces and machinery spaces of category A shall be insulated to "A-60" standard, unless the dangerous goods are stowed at least 3 m horizontally away from such bulkheads. Other boundaries between such spaces shall be insulated to "A-60" standard.

C.16.3 Miscellaneous items

The kind and extent of the fire extinguishing equipment are defined in the GL Rules for Machinery Installations (I-1-2), Section 12.

Electrical apparatus and cablings are to meet the requirements of the GL Rules for Electrical Installations (I-1-3), Section 14.

C.17 Safety centre on passenger ships

C.17.1 Application

Passenger ships constructed on or after 1 July 2010 shall have on board a safety centre complying with the requirements of this regulation.

C.17.2 Location and arrangement

The safety centre shall either be a part of the navigation bridge or be located in a separate space adjacent to and having direct access to the navigation bridge, so that the management of emergencies can be performed without distracting watch officers from their navigational duties.

C.17.3 Layout and ergonomic design

The layout and ergonomic design of the safety centre shall take into account the IMO guidelines[16] (communication and control and monitoring of safety systems see also the GL Rules for Electrical Installations (I-1-3), Section 14).

D Passenger Ships with 3 or more Main Vertical Zones or with a Load Line Length of 120 m and over

D.1 The requirements of this Sub-section are additional to those of B or C.

D.2 Ships constructed on or after 1 July 2010 having a load line length of 120 m and over or with three or more main vertical zones are required to meet design specifications in accordance with Chapter II-2 of **SOLAS 74** for

- a ship's safe return to port under its own propulsion after a fire or flooding casualty
- systems required to remain operational for supporting the orderly evacuation and abandonment of a ship when exceeding the casualty threshold and
- safe areas.

Any impacts thereof on issues addressed elsewhere in this Section are to be reported in an engineering analysis.

D.3 A safe area is any area which is not flooded or which is outside the main vertical zones in which a fire has occurred such that it can safely accommodate all persons on board to protect them from hazards to life or health. Safe areas shall provide all occupants with shelter from weather and access to life-saving appliances, taking into account that a main vertical zone may not be available for internal transit. They shall generally be internal spaces, unless particular circumstances allow for an external location, considering any restriction due to the area of operation and relevant expected environmental conditions.

E Cargo Ships of 500 GT and over

E.1 Materials

E.1.1 The hull, decks, structural bulkheads, superstructures and deckhouses are to be of steel except where in special cases the use of other suitable material may be approved, having in mind the risk of fire.

E.1.2 Components made from aluminium alloys require special treatment, with regard to the mechanical properties of the material in case of temperature increase. In principle, the following is to be observed:

E.1.2.1 The insulation of "A" or "B" class divisions shall be such that the temperature of the structural core does not rise more than 200 °C above the ambient temperature at any time during the applicable fire exposure to the standard fire test.

E.1.2.2 Special attention shall be given to the insulation of aluminium alloy components of columns, stanchions and other structural members required to support lifeboat and liferaft stowage, launching and embarkation areas, and "A" and "B" class divisions to ensure:

that for such members supporting lifeboat and liferaft areas and "A" class divisions, the temperature rise limitation specified in E.1.2.1 shall apply at the end of one hour; and

that for such members required to support "B" class divisions, the temperature rise limitation specified in E.1.2.1 shall apply at the end of half an hour.

E.1.2.3 Crowns and casings of machinery spaces of category A shall be of steel construction and be insulated as required by Table 22.5 as appropriate. Openings therein, if any, shall be suitably arranged and protected to prevent the spread of fire.

E.2 Accommodation and service spaces

E.2.1 One of the following methods of protection shall be adopted in accommodation and service areas:

E.2.1.1 **Method IC**: The construction of all internal divisional bulkheading of non-combustible "B" or "C" class divisions generally without the installation of an automatic sprinkler, fire detection and fire alarm system in the accommodation and service spaces, except as required by E.10.1; or

E.2.1.2 **Method IIC**: The fitting of an automatic sprinkler, fire detection and fire alarm system, as required by E.10.2 for the detection and extinction of fire in all spaces in which fire might be expected to originate, generally with no restriction on the type of internal divisional bulkheading; or

E.2.1.3 **Method IIIC**: The fitting of a fixed fire detection and fire alarm system, as required by E.10.3, in all spaces in which a fire might be expected to originate, generally with no restriction on the type of internal divisional bulkheading, except that in no case shall the area of any accommodation space or spaces bounded by an "A" or "B" class division exceed 50 m^2. Consideration may be given to increasing this area for public spaces.

E.2.2 The requirements for the use of non-combustible materials in construction and insulation of the boundary bulkheads of machinery spaces, control stations, service spaces, etc., and the protection of stairway enclosures and corridors will be common to all three methods.

E.3 Bulkheads within the accommodation and service spaces

E.3.1 All bulkheads required to be "B" class divisions shall extend from deck to deck and to the shell or other boundaries, unless continuous "B" class ceilings or linings are fitted on both sides of the bulkhead in which case the bulkhead may terminate at the continuous ceiling or lining.

E.3.2 Method IC

All bulkheads not required by this or other requirements of this Section to be "A" or "B" class divisions, shall be of at least "C" class construction.

E.3.3 Method IIC

There shall be no restriction on the construction of bulkheads not required by this or other requirements of this Section to be "A" or "B" class divisions except in individual cases where "C" class bulkheads are required in accordance with Table 22.5.

E.3.4 Method IIIC

There shall be no restriction on the construction of bulkheads not required by this Section to be "A" or "B" class divisions except that the area of any accommodation space or spaces bounded by a continuous "A" or "B" class division shall in no case exceed 50 m^2 except in individual cases where "C" class bulkheads are required in accordance with Table 22.5. Consideration may be given to increasing this area for public spaces.

E.4 Fire integrity of bulkheads and decks

E.4.1 In addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned elsewhere in this Section, the minimum fire integrity of bulkheads and decks shall be as prescribed in Tables 22.5 and 22.6.

E.4.2 On ships intended for the carriage of dangerous goods the bulkheads forming boundaries between cargo spaces and machinery spaces of category A shall be insulated to "A-60" standard, unless the dangerous goods are stowed at least 3 m horizontally away from such bulkheads. Other boundaries between such spaces shall be insulated to "A-60" standard.

E.4.3 Continuous "B" class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.

E.4.4 External boundaries which are required in E.1.1 to be of steel or other equivalent material may be pierced for the fitting of windows and sidescuttles provided that there is no requirement for such boundaries to have "A" class integrity elsewhere in these requirements. Similarly, in such boundaries which are not required to have "A" class integrity, doors may be of materials to meet the requirements of their application.

E.4.5 The following requirements shall govern application of the Tables:

Tables 22.5 and 22.6 shall apply respectively to the bulkheads and decks separating adjacent spaces.

E.4.6 For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified according to their fire risk as shown in the following categories 1 to 11. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of this regulation, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed room within a space that have less than 30 % communicating openings to that space are to be considered separate spaces. The fire integrity of the boundary bulkheads of such smaller rooms shall be as prescribed in Tables 22.5 and 22.6. The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row number in the tables.

Table 22.5 Fire integrity of bulkheads separating adjacent spaces

Spaces		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
Control stations	[1]	A–0 [5]	A–0	A–60	A–0	A–15	A–60	A–15	A–60	A–60	10	A–60
Corridors	[2]		C	B–0	B–0 A–0 [3]	B–0	A–60	A–0	A–0	A–0	10	A–30
Accommodation spaces	[3]			C [1,2]	B–0 A–0 [3]	B–0	A–60	A–0	A–0	A–0	10	A–30
Stairways	[4]				B–0 A–0 [3]	B–0 A–0 [3]	A–60	A–0	A–0	A–0	10 10	A–30
Service spaces (low risk))	[5]					C	A–60	A–0	A–0	A–0	10	A–0
Machinery spaces of category A	[6]						10	A–0	A–0 [7]	A–60	10	A–60 [6]
Other machinery spaces	[7]							A–0 [4]	A–0	A–0	10	A–0
Cargo spaces	[8]								10	A–0	10	A–0
Service spaces (high risk)	[9]									A–0 [4]	10	A–30
Open decks	[10]										–	A–0
Ro/ro cargo spaces	[11]											10, 8

Notes to be applied to Tables 22. 5 and 22.6, as appropriate

1 No special requirements are imposed upon bulkheads in methods IIC and IIIC fire protection.

2 In case of method IIC "B" class bulkheads of "B–0" rating shall be provided between spaces or groups of spaces of 50 m^2 and over in area.

3 For clarification as to which applies, see E.3. and E.5.

4 Where spaces are of the same numerical category and superscript 4 appears, a bulkhead or deck of the rating shown in the Tables in only required when the adjacent spaces are for a different purpose, e.g. in category 9. A galley next to a galley does not require a bulkhead but a galley next to a paint room requires an "A–0" bulkhead.

5 Bulkheads separating the wheelhouse, chartroom and radio room from each other may be "B–0" rating.

6 A–0 rating may be used if no dangerous goods are intended to be carried or if such goods are stowed not less than 3 m horizontally from such bulkhead.

7 For cargo spaces in which dangerous goods are intended to be carried, E.4.2 applies.

8 Bulkheads and deck separating ro/ro cargo spaces shall be capable of being closed reasonably gastight and such divisions shall have "A" class integrity in so far as is reasonable and practicable.

9 Fire insulation need not be fitted if the machinery space in category 7, has little or no fire risk.

10 Where a 10 appears in the Tables, the division is required to be of steel or other equivalent material but is not required to be of "A" class standard.

Table 22.6 Fire integrity of decks separating adjacent spaces

Space above / Space below		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
Control stations	[1]	A–0	A–0	A–0	A–0	A–0	A–60	A–0	A–0	A–0	10	A–60
Corridors	[2]	A–0	10	10	A–0	10	A–60	A–0	A–0	A–0	10	A–30
Accommodations spaces	[3]	A–60	A–0	10	A–0	10	A–60	A–0	A–0	A–0	10	A–30
Stairways	[4]	A–0	A–0	A–0	10	A–0	A–60	A–0	A–0	A–0	10	A–30
Service spaces (low risk)	[5]	A–15	A–0	A–0	A–0	10	A–60	A–0	A–0	A–0	10	A–0
Machinery spaces of category A	[6]	A–60	A–60	A–60	A–60	A–60	10	A–60 9	A–30	A–60	10	A–60
Other machinery spaces	[7]	A–15	A–0	A–0	A–0	A–0	A–0	10	A–0	A–0	10	A–0
Cargo spaces	[8]	A–60	A–0	A–0	A–0	A–0	A–0	A–0	10	A–0	10	A–0
Service spaces (high risk)	[9]	A–60	A–0	A–0	A–0	A–0	A–60	A–0	A–0	A–0 4	10	A–30
Open decks	[10]	10	10	10	10	10	10	10	10	10	–	10
Ro/ro cargo spaces	[11]	A–60	A–30	A–30	A–30	A–0	A–60	A–0	A–0	A–30	10	10, 8
See notes under Table 22.5.												

[1] : **Control stations**

Spaces containing emergency sources of power and lighting. Wheelhouse and chartroom. Spaces containing the ship's radio equipment. Fire control stations. Control room for propulsion machinery when located outside the machinery space. Spaces containing centralized fire alarm equipment.

[2] : **Corridors**

Corridors and lobbies.

[3] : **Accommodation spaces**

Spaces used for public spaces, lavatories, cabins, offices, hospitals, cinemas, games and hobby rooms, barber ships, pantries containing no cooking appliances and similar spaces.

[4] : **Stairways**

Interior stairways, lifts, totally enclosed emergency escape trunks and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto.

In this connection, a stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door.

[5] : **Service spaces (low risk)**

Lockers and store-rooms not having provisions for the storage of flammable liquids and having areas less than 4 m^2 and drying rooms and laundries.

[6] : **Machinery spaces of category A**

Spaces and trunks to such spaces which contain:

internal combustion machinery used for main propulsion; or

internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or

any oil-fired boiler or oil fuel unit.

[7] : **Other machinery spaces**

Spaces, other than machinery spaces of category A, containing propulsion machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces. Electrical equipment rooms (auto-telephone exchange, air-conditioning duct spaces)

[8] : **Cargo spaces**

All spaces used for cargo (including cargo oil tanks) and trunkways and hatchways to such spaces.

[9] : **Service spaces (high risk)**

Galleys, pantries containing cooking appliances, saunas, paint and lamp rooms, lockers and store-rooms having areas of 4 m^2 or more, spaces for the storage of flammable liquids, and workshops other than those forming part of the machinery spaces.

[10] : **Open decks**

Open deck spaces and enclosed promenades having no fire risk. Enclosed promenades shall have no significant fire risk, meaning that furnishing should be restricted to deck furniture. In addition, such spaces shall be naturally ventilated by permanent openings. Air spaces (the space outside superstructures and deckhouses).

[11] : **Ro-ro and vehicle spaces**

E.5 Protection of stairways and lift trunks in accommodation spaces, service spaces and control stations

E.5.1 Stairways which penetrate only a single deck shall be protected at least at one level by at least "B-0" class divisions and self-closing doors. Lifts which penetrate only a single deck shall be surrounded by "A-0" class divisions with steel doors at both levels. Stairways and lift trunks which penetrate more than a single deck shall be surrounded by at least "A-0" class divisions and be protected by self-closing doors at all levels.

E.5.2 On ships having accommodation for 12 persons or less, where stairways penetrate more than a single deck and where there are at least two escape routes direct to the open deck at every accommodation level, consideration may be given reducing the "A-0" requirements of E.5.1 to "B-0".

E.5.3 All stairways shall be of steel frame construction or of other equivalent material.

E.6 Openings in fire resisting divisions

E.6.1 Where "A" or "B" class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc. or for girders, beams or other structural members, arrangements shall be made to ensure that the fire resistance is not impaired.

E.6.2 Except for hatches between cargo, special category, store, and baggage spaces, and between such spaces and the weather decks, all openings shall be provided with permanently attached means of closing which shall be at least as effective for resisting fires as the divisions in which they are fitted [18].

E.6.3 The fire resistance of doors shall be equivalent to that of the division in which they are fitted. Doors approved as "A" class without the sill being part of the frame, which are installed on or after 1 July 2010, shall be installed such that the gap under the door does not exceed 12 mm and a non-combustible sill shall be installed under the door such that floor coverings do not extend beneath the closed door. Doors approved as "B" class without the sill being part of the frame, which are installed on or after 1 July 2010, shall be installed such that the gap under the door does not exceed 25 mm. Doors and door frames in "A" class divisions shall be constructed of steel. Doors in "B" class divisions shall be non-combustible.

18 Reference is made to the Fire Test Procedure Code, Annex 1, Part 3, adopted by IMO by Resolution MSC.61(67). On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

Doors fitted in boundary bulkheads of machinery spaces of category A shall be reasonably gastight and self-closing. In ships constructed according to method IC the use of combustible materials in doors separating cabins from individual interior sanitary accommodation such as showers may be permitted.

E.6.4 Doors required to be self-closing shall not be fitted with hold-back hooks. However, hold-back arrangements fitted with remote release devices of the fail-safe type may be utilized.

E.6.5 In corridor bulkheads ventilation openings may be permitted only in and under class B-doors of cabins and public spaces. Ventilation openings are also permitted in B-doors leading to lavatories, offices, pantries, lockers and store rooms. Except as permitted below, the openings shall be provided only in the lower half of a door. Where such opening is in or under a door the total net area of any such opening or openings shall not exceed $0.05\ m^2$. Alternatively, a non-combustible air balance duct routed between the cabin and the corridor, and located below the sanitary unit is permitted where the cross-sectional area of the duct does not exceed $0.05\ m^2$. Ventilation openings, except those under the door, shall be fitted with a grille made of non-combustible material.

E.6.6 Watertight doors need not be insulated.

E.7 Ventilation systems

E.7.1 Ventilation ducts shall be of steel or equivalent material. Short ducts, however, not generally exceeding 2 m in length and with a cross-section not exceeding $0.02\ m^2$ need not be steel or equivalent, subject to the following conditions:

E.7.1.1 subject to E.7.1.2 these ducts shall be of any material having low flame spread characteristics which is type approved [4].

E.7.1.2 on ships constructed on or after 1 July 2010, the ducts shall be made of heat resisting non-combustible material, which may be faced internally and externally with membranes having low flame-spread characteristics and, in each case, a calorific value [5] not exceeding $45\ MJ / m^2$ of their surface area for the thickness used;

E.7.1.3 they may only be used at the end of the ventilation device;

E.7.1.4 they shall not be situated less than 600 mm, measured along the duct, from an opening in an "A" or "B" class division including continuous "B" class ceilings.

E.7.2 Where a thin plated duct with a free cross-sectional area equal to, or less than, $0.02\ m^2$ passes through "A" class bulkheads or decks, the opening shall be lined with a steel sheet sleeve having a thickness of at least 3 mm and a length of at least 200 mm, divided preferably into 100 mm on each side of the bulkhead or, in the case of the deck, wholly laid on the lower side of the decks pierced.

Where ventilation ducts with a free cross-sectional area exceeding $0.02\ m^2$ pass through "A" class bulkheads or decks, the opening shall be lined with a steel sheet sleeve. However, where such ducts are of steel construction and pass through a deck or bulkhead, the ducts and sleeves shall comply with the following:

E.7.2.1 The sleeves shall have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length shall be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, shall be provided with fire insulation. The insulation shall have at least the same fire integrity as the bulkhead or deck through which the duct passes.

E.7.2.2 Ducts with a free cross-sectional area exceeding $0.075\ m^2$ shall be fitted with fire dampers in addition to the requirements of E.7.2.1. The fire damper shall also be capable of being closed manually from both sides of the bulkhead or deck. The damper shall be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where ducts pass through spaces surrounded by "A" class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they pierce.

E.7.2.3 The following arrangement shall be of an approved type [3].

E.7.2.3.1 fire dampers, including relevant means of operation

E.7.2.3.2 duct penetrations through "A" class divisions. Where steel sleeves are directly joined to ventilation ducts by means of riveted or screwed flanges or by welding, the test is not required.

E.7.3 The main inlets and outlets of all ventilation systems shall be capable of being closed from outside the respective spaces in the event of a fire.

E.7.4 Where they pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges shall be constructed of insulated "A" class divisions. Each exhaust duct shall be fitted with:

E.7.4.1 a grease trap readily removable for cleaning;

E.7.4.2 a fire damper located in the lower end of the duct and in addition, a fire damper in the upper end of the duct;

E.7.4.3 arrangements, operable from within the galley, for shutting off the exhaust fan; and

E.7.4.4 fixed means for extinguishing a fire within the duct (see the GL Rules for Machinery Installations (I-1-2), Section 12).

E.7.5 Such measures as are practicable shall be taken in respect of control stations outside machinery spaces in order to ensure that ventilation, visibility and freedom from smoke are maintained, so that in the event of fire the machinery and equipment contained therein may be supervised and continue to function effectively. Alternative and separate means of air supply shall be provided; air inlets of the two sources of supply shall be so disposed that the risk of both inlets drawing in smoke simultaneously is minimized. Such requirements need not apply to control stations situated on, and opening on to, an open deck.

E.7.6 The ventilation system for machinery spaces of category A, vehicle spaces, ro-ro spaces, galleys, special category spaces and cargo spaces shall, in general, be separated from each other and from the ventilation systems serving other spaces. Except that galley ventilation on cargo ships of less than 4 000 gross tonnage need not be completely separated, but may be served by separate ducts from a ventilation unit serving other spaces. In any case, an automatic fire damper shall be fitted in the galley ventilation ducts near the ventilation unit.

E.7.7 Ducts provided for the ventilation of machinery spaces of category A, galleys, vehicle spaces, ro-ro cargo spaces or special category spaces shall not pass through accommodation spaces, service spaces or control stations unless the ducts are either:

E.7.7.1 constructed of steel having a thickness of at least 3 mm and 5 mm for ducts the widths or diameters of which are up to and including 300 mm and 760 mm and over respectively and, in the case of such ducts, the widths or diameters of which are between 300 mm and 760 mm having a thickness to be obtained by interpolation;

suitably supported and stiffened;

fitted with automatic fire dampers close to the boundaries penetrated; and

insulated to "A-60" standard from the machinery spaces, galleys, vehicle spaces, ro-ro cargo spaces or special category spaces to a point at least 5 m beyond each fire damper;

or

E.7.7.2 constructed of steel suitable supported and stiffened and insulated to "A-60" standard throughout the accommodation spaces, service spaces or control stations.

E.7.8 Ducts provided for the ventilation to accommodation spaces, service spaces or control stations shall not pass through machinery spaces of category A, galleys, vehicle spaces, ro-ro cargo spaces or special category spaces unless either:

E.7.8.1 the ducts where they pass through a machinery space of category A, galley, vehicle space, ro-ro cargo space or special category space are constructed of steel, suitable supported and stiffened and

automatic fire dampers are fitted close to the boundaries penetrated; and the integrity of the machinery space, galley, vehicle space, ro-ro cargo space or special category space boundaries is maintained at the penetrations; or

E.7.8.2 the ducts where they pass through a machinery space of category A, galley, vehicle space, ro-ro cargo space or special category space are constructed of steel, suitable supported and stiffened, and

are insulated to "A-60" standard throughout the accommodation spaces, service spaces or control stations.

E.7.9 Ventilation ducts with a free cross-sectional area exceeding 0.02 m^2 passing through "B" class bulkheads shall be lined with steel sheet sleeves of 900 mm in length divided preferably into 450 mm on each side of the bulkheads unless the duct is of steel for this length.

E.7.10 Power ventilation of accommodation spaces, service spaces, cargo spaces, control stations and machinery spaces shall be capable of being stopped from an easily accessible position outside the space being served. This position should not be readily cut off in the event of a fire in the spaces served. The means provided for stopping the power ventilation of the machinery spaces shall be entirely separate from the means provided for stopping ventilation of other spaces.

E.8 Restricted use of combustible materials

E.8.1 All exposed surfaces in corridors and stairway enclosures and surfaces including grounds in concealed or inaccessible spaces in accommodation and service spaces and control stations shall have low flame-spread characteristics. Exposed surfaces of ceilings in accommodation and service spaces (except saunas) and control stations shall have low flame-spread characteristics [19].

E.8.2 Paints, varnishes and other finishes used on exposed interior surfaces shall not offer an undue fire hazard and shall not be capable of producing excessive quantities of smoke [20].

E.8.3 Primary deck coverings, if applied, in accommodation and service spaces and control stations shall be of an approved material which will not readily ignite, or give rise to toxic or explosive hazardous at elevated temperatures [21].

E.8.4 Waste receptacles (see B.10.10)

E.9 Details of construction

E.9.1 Method IC

In accommodation and service spaces and control stations all linings, draught stops, ceilings and their associated grounds shall be of non-combustible materials.

E.9.2 Methods IIC and IIIC

In corridors and stairway enclosures serving accommodation and service spaces and control stations, ceilings, linings, draught stops and their associated grounds shall be of non-combustible materials.

E.9.3 Methods IC, IIC and IIIC

E.9.3.1 Except in cargo spaces or refrigerated compartments of service spaces, insulating materials shall be non-combustible. Vapour barriers and adhesives used in conjunction with insulation, as well as the insulation of pipe fittings, for cold service systems, need not be of non-combustible materials, but they

19 Reference is made to the Fire Test Procedure Code, Annex 1, Part 5, adopted by IMO by Resolution MSC.61(67). On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

20 Reference is made to the Fire Test Procedure Code, Annex 1, Part 2, adopted by IMO by Resolution MSC.61(67). On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

21 Reference is made to the Fire Test Procedure Code, Annex 1, Part 6, adopted by IMO by Resolution MSC.61(67). On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame spread characteristics.

E.9.3.2 Where non-combustible bulkheads, linings and ceilings are fitted in accommodation and service spaces they may have a combustible veneer with a calorific value [22] not exceeding $45\ \mathrm{MJ/m^2}$ of the area for the thickness used.

E.9.3.3 The total volume of combustible facings, mouldings, decorations and veneers in any accommodation and service space bounded by non-combustible bulkheads, ceilings and linings shall not exceed a volume equivalent to a $2.5\ \mathrm{mm}$ veneer on the combined area of the walls and ceilings.

E.9.3.4 Air spaces enclosed behind ceilings, panellings, or linings, shall be divided by close-fitting draught stops spaced not more than $14\ \mathrm{m}$ apart. In the vertical direction, such air spaces, including those behind linings of stairways, trunks, etc., shall be closed at each deck.

E.10 Fixed fire detection and fire alarm systems, automatic sprinkler, fire detection and fire alarm system

E.10.1 In ships in which method IC is adopted, a smoke detection system shall be so installed and arranged as to protect all corridors, stairways and escape routes within accommodation spaces.

E.10.2 In ships in which method IIC is adopted, an automatic sprinkler, fire detection and fire alarm system shall be so installed and arranged as to protect accommodation spaces, galleys and other service spaces, except spaces which afford no substantial fire risk such as void spaces, sanitary spaces, etc. In addition, a fixed fire detection and fire alarm system shall be so arranged and installed as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces.

E.10.3 In ships in which method IIIC is adopted, a fixed fire detection and fire alarm system shall be so installed and arranged as to detect the presence of fire in all accommodation spaces and service spaces, except spaces which afford no substantial fire risk such as void spaces, sanitary spaces, etc. In addition, a fixed fire detection and fire alarm system shall be so arranged and installed as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces.

E.11 Means of escape

E.11.1 Unless expressly provided otherwise in this regulation, at least two widely separated and ready means of escape shall be provided from all spaces and group of spaces. Lifts shall not be considered as forming one of the required means of escape.

E.11.2 Doors in escape routes shall, in general, open in-way of the direction of escape, except that

E.11.2.1 individual cabin doors may open into the cabins in order to avoid injury to persons in the corridor when the door is opened, and

E.11.2.2 doors in vertical emergency escape trunks may open out of the trunk in order to permit the trunk to be used both for escape and access.

E.11.3 Stairways and ladders shall be so arranged as to provide, from all accommodation spaces and from spaces in which the crew is normally employed, other than machinery spaces, ready means of escape to the open deck and thence to the lifeboats and liferafts. In particular the following general provisions shall be complied with:

E.11.3.1 At all levels of accommodation there shall be provided at least two widely separated means of escape from each restricted space or group of spaces.

E.11.3.2 Below the lowest open deck the main means of escape shall be a stairway and the second escape may be a trunk or a stairway.

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22 The gross calorific value measured in accordance with ISO standard 1716 - "Building Materials - Determination of Calorific Potential", should be quoted. On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

E.11.3.3 Above the lowest open deck the means of escape shall be stairways or doors to an open deck or a combination thereof.

E.11.4 Stairways and corridors used as means of escape shall be not less than 700 mm in clear width and shall have a handrail on one side. Stairways and corridors with a clear width of 1 800 mm and above shall have handrails on both sides. The angle of inclination of stairways shall be, in general, 45 °, but not greater than 50 °, and in machinery spaces and small spaces not more than 60 °. Doorways which give access to a stairway shall be of the same size as the stairway [23].

E.11.5 Dispense may be given with one of the means of escape, due regard being paid to the nature and location of spaces and to the numbers of persons who normally might be quartered or employed there.

E.11.6 No dead-end corridors having a length of more than 7 m shall be accepted. A dead-end corridor is a corridor or part of a corridor from which there is only one escape route.

E.11.7 If a radiotelegraph station has no direct access to the open deck, two means of access to or egress from such station shall be provided, one of which may be a porthole or window of sufficient size or other means to provide an emergency escape.

E.11.8 At least two means shall be provided in ro-ro cargo spaces where the crew are normally employed. The escape routes shall provide safe escape to the lifeboat and liferaft embarkation decks and shall be located at the fore and aft ends of the space.

E.11.9 Two means of escape shall be provided from each machinery space of category A. In particular, one of the following provisions shall be complied with:

E.11.9.1 two sets of steel ladders as widely separated as possible leading to doors in the upper part of the space similarly separated and from which access is provided to the open deck. One of these ladders shall be located within a protected enclosure having fire integrity, including insulation values, in accordance with the Tables 22.5 and 22.6 for category (4) space from the lower part of the space to a safe position outside the space. Self-closing fire doors having the same fire integrity shall be fitted in the enclosure. The ladder shall be fixed in such a way that heat is not transferred into the enclosure through non-insulated fixing points. The enclosure shall have minimum internal dimensions of at least 800 mm x 800 mm, and shall have emergency lighting provisions;

or

E.11.9.2 one steel ladder leading to a door in the upper part of the space from which access is provided to the open deck and additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the open deck.

E.11.9.3 For a ship of a gross tonnage less than 1 000, dispense may be given with one of the means of escape due regard being paid to the dimension and disposition of the upper part of the space.

E.11.9.4 In the steering gear room, a second means of escape shall be provided when the emergency steering position is located in that space unless there is direct access to the open deck.

E.11.10 From machinery spaces other than those of category A; two escape routes shall be provided except that a single escape route may be accepted for spaces that are entered only occasionally, and for spaces where the maximum travel distance to the door is 5 m or less.

E.12 Miscellaneous items

E.12.1 The cargo holds and machinery spaces shall be capable of being effectively sealed such as to prevent the inlet of air. Doors fitted in boundary bulkheads of machinery spaces of category A shall be reasonably gastight and self-closing.

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[23] Reference is made to the Fire Safety Systems Code, adopted by IMO by Resolution MSC.98(73). On ships constructed on or after 1 July 2012, the new Fire Test Procedure Code, adopted by IMO by Resolution MSC.307(88), is applicable.

E.12.2 Construction and arrangement of saunas (see B.11.5).

E.13 Protection of cargo spaces

Fire-extinguishing arrangements in cargo spaces

Fire-extinguishing arrangements according to the GL Rules for Machinery Installations (I-1-2), Section 12 are to be provided for cargo spaces.

E.14 Protection of vehicle and ro-ro spaces

E.14.1 Fire detection

There shall be provided a fixed fire detection and fire alarm system of an approved type (see also the GL Rules for Machinery Installations (I-1-2), Section 12).

A sample extraction smoke detection system of an approved type (see also the GL Rules for Machinery Installations (I-1-2), Section 12) may be accepted as equivalent, except for open ro-ro and vehicle spaces.

E.14.2 Fire-extinguishing arrangements

E.14.2.1 Vehicle spaces and ro-ro spaces which are capable of being sealed from a location outside of the cargo spaces shall be fitted with a fixed gas fire-extinguishing system of an approved type (see also the GL Rules for Machinery Installations (I-1-2), Section 12).

E.14.2.2 Ro-ro and vehicle spaces not capable of being sealed shall be fitted with a fixed pressure water spraying system for manual operation of an approved type (see also the GL Rules for Machinery Installations (I-1-2), Section 12).

E.14.3 Ventilation system

Closed vehicle and ro-ro spaces shall be provided with an effective power ventilation system sufficient to give at least 6 air changes per hour. Beyond this, a higher air exchange rate may be required during the period of loading and unloading and/or depending on the electrical installation. The system for such cargo spaces shall be entirely separate from other ventilation systems and shall be operating at all times when vehicles are in such spaces.

Ventilation ducts serving such cargo spaces capable of being effectively sealed shall be separated for each such space. The system shall be capable of being controlled from a position outside such spaces.

The ventilation shall be such as to prevent air stratification and the formation of air pockets.

Means shall be provided to indicate on the navigating bridge any loss of the required ventilating capacity.

Arrangements shall be provided to permit a rapid shut-down and effective closure of the ventilation system in case of fire, taking into account the weather and sea conditions.

Ventilation ducts, including dampers, shall be made of steel.

Permanent openings in the side plating, the ends or deckhead of the space shall be so situated that a fire in the cargo space does not endanger stowage areas and embarkation stations for survival craft and accommodation spaces, service spaces and control stations in superstructures and deckhouses above the cargo spaces.

E.15 Special requirements for ships carrying dangerous goods

E.15.1 Ventilation

Adequate power ventilation shall be provided in enclosed cargo spaces. The arrangement shall be such as to provide for at least six air changes per hour in the cargo space based on an empty cargo space and for removal of vapours from the upper or lower parts of the cargo space, as appropriate.

The fans shall be such as to avoid the possibility of ignition of flammable gas air mixtures. Suitable wire mesh guard shall be fitted over inlet and outlet ventilation openings.

Natural ventilation shall be provided in enclosed cargo spaces intended for the carriage of solid dangerous goods in bulk, where there is no provision for mechanical ventilation.

E.15.2 Insulation of machinery space boundaries

Bulkheads forming boundaries between cargo spaces and machinery spaces of category A shall be insulated to "A-60" standard, unless the dangerous goods are stowed at least 3 m horizontally away from such bulkheads. Other boundaries between such spaces shall be insulated to "A-60" standard.

E.15.3 Separation of spaces

E.15.3.1 In ships having ro-ro spaces, a separation shall be provided between a closed ro-ro space and an adjacent open ro-ro space. The separation shall be such as to minimize the passage of dangerous vapours and liquids between such spaces. Alternatively, such separation need not be provided if the ro-ro space is considered to be a closed cargo space over its entire length and shall fully comply with the requirements of E.14.

E.15.3.2 In ships having ro-ro spaces, a separation shall be provided between a closed ro-ro space and the adjacent weather deck. The separation shall be such as to minimize the passage of dangerous vapours and liquids between such spaces. Alternatively, a separation need not be provided if the closed ro-ro spaces are in accordance with those required for the dangerous goods carried on the adjacent weather deck.

E.15.4 Miscellaneous items

The kind and extent of the fire extinguishing equipment are to meet the requirements of the GL Rules for Machinery Installations (I-1-2), Section 12.

Electrical apparatus and cablings are to meet the requirements of the GL Rules for Electrical Installations (I-1-3), Section 16.

F Oil Tankers of 500 GT and over

(These requirements are additional to those of E except as provided otherwise in F.3 and F.4.)

F.1 Application

F.1.1 Unless expressly provided otherwise, this Section shall apply to tankers carrying crude oil and petroleum products having a flashpoint not exceeding 60 °C (closed cup test), as determined by an approved flashpoint apparatus, and a Reid vapour pressure which is below atmospheric pressure and other liquid products having a similar fire hazard.

F.1.2 Where liquid cargoes other than those referred to in F.1.1 or liquefied gases which introduce additional fire hazards are intended to be carried the requirements for ships carrying liquefied gases in bulk, the GL Rules for Liquefied Gas Carriers (I-1-6) and the requirements for ships carrying dangerous chemicals in bulk, the GL Rules for Chemical Tankers (I-1-7) are to be taken into account.

F.1.3 Tankers carrying petroleum products having a flashpoint exceeding 60 °C (closed cup test) as determined by an approved flashpoint apparatus shall comply with the provisions of E.

F.1.4 Chemical tankers and gas carriers shall comply with the requirements of this Section, unless other and additional safety precautions according the requirements for ships carrying liquefied gases in bulk, the GL Rules for Liquefied Gas Carriers (I-1-6) and the requirements for ships carrying dangerous chemicals in bulk, the GL Rules for Chemical Tankers (I-1-7) apply.

F.2 Construction

F.2.1 Exterior boundaries of superstructures and deckhouses enclosing accommodation and including any overhanging decks which support such accommodation shall be constructed of steel and insulated to "A-60" standard for the whole of the portions which face the cargo area and on the outward sides for a distance of 3 m from the end boundary facing the cargo area. In the case of the sides of those superstructures and deckhouses, such insulation shall be carried up to the underside of the bridge deck.

F.2.2 Entrances, air inlets and openings to accommodation spaces, service spaces and control stations shall not face the cargo area. They shall be located on the end bulkhead not facing the cargo area and/or on the outboard side of the superstructure or deckhouse at a distance of at least 4 % of the length of the ship but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. This distance, however, need not exceed 5 m.

In this area doors to those spaces not having access to accommodation spaces, service spaces and control stations, such as cargo control stations, provision rooms, store-rooms and engine rooms may be permitted provided that the boundaries of the spaces are insulated to "A-60" standard.

Bolted plates for the removal of machinery may be fitted within the limits of such areas.

Navigating bridge doors and wheelhouse windows may be located within this area, so long as they are so designed that a rapid and efficient gas and vapour tightening of the navigating bridge can be ensured.

F.2.3 Windows and side scuttles facing the cargo area and on the sides of the superstructures and deckhouses within the limits specified in F.2.2 shall be of the fixed (non-opening) type [3].

Such windows and sidescuttles, except wheelhouse windows, shall be constructed to "A-60" class standard and shall be of an approved type, except the "A-0" class standard is acceptable for windows and side-scuttles outside the limits specified in F.2.1.

F.2.4 Skylights to cargo pump rooms shall be of steel, shall not contain any glass and shall be capable of being closed from outside the pump room.

F.2.5 Furthermore the requirements of Section 24, A.4. are to be observed.

F.3 Structure, bulkheads within accommodation and service spaces and details of construction

For the application of the requirements of E.2., E.3. and E.9. to tankers, only method IC as defined in E.2.1.1 shall be used.

F.4 Fire integrity of bulkheads and decks

F.4.1 In lieu of E.4. and in addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned elsewhere in this Section the minimum fire integrity of bulkheads and decks shall be as prescribed in Tables 22.7 and 22.8.

F.4.2 The following requirements shall govern application of the Tables:

Tables 22.7 and 22.8 shall apply respectively to the bulkhead and decks separating adjacent spaces.

F.4.3 For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified according to their fire risk as shown in categories 1 to 10 below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of this regulation, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space that have less than 30 % communicating openings to that space are considered separate spaces. The fire integrity of the boundary bulkheads of such smaller rooms shall be as prescribed in Tables 22.7 and 22.8. The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row in the Tables.

Table 22.7 Fire integrity of bulkheads separating adjacent spaces

Spaces		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Control stations	[1]	A–0 [3]	A–0	A–60	A–0	A–15	A–60	A–15	A–60	A–60	6
Corridors	[2]		C	B–0	B–0 A–0 [1]	B–0	A–60	A–0	A–60	A–0	6
Accommodation spaces	[3]			C	B–0 A–0 [1]	B–0	A–60	A–0	A–60	A–0	6
Stairways	[4]				B–0 A–0 [1]	B–0 A–0 [1]	A–60	A–0	A–60	A–0	6
Service spaces (low risk)	[5]					C	A–60	A–0	A–60	A–0	6
Machinery spaces of category A	[6]						6	A–0	A–0 [4]	A–60	6
Other machinery spaces	[7]							A–0 [2]	A–0	A–0	6
Cargo pump rooms	[8]								6	A–60	6
Service spaces (high risk)	[9]									A–0 [2]	6
Open decks	[10]										–

Notes to be applied to Tables 22.7 and 22.8, as appropriate

1 For clarification as to which applies, see D.3 and D.5

2 Where spaces are of the same numerical category and superscript 2 appears, a bulkhead or deck of the rating shown in the Tables in only required when the adjacent spaces are for a different purpose, e.g. in category 9. A galley next to a galley does not require a bulkhead but a galley next to a paint room requires an "A–0" bulkhead.

3 Bulkheads separating the wheelhouse, chartroom and radio room from each other may be"B-0" rating.

4 Bulkheads and decks between cargo pump rooms and machinery spaces of category. A may be penetrated by cargo pump shaft glands and similar glanded penetrations, provided that gastight seals with efficient lubrication or other means of ensuring the permanence of the gas seal are fitted in way of the bulkhead or deck.

5 Fire insulation need not be fitted if the machinery space in category 7 has little or no fire risk.

6 Where a 6 appears in the Tables, the division is required to be of steel or other equivalent material but is not required to be of "A" class standard.

Table 22.8 Fire integrity of decks separating adjacent spaces

Space above Space below		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Control stations	[1]	A–0	A–0	A–0	A–0	A–0	A–60	A–0	–	A–0	6
Corridors	[2]	A–0	6	6	A–0	6	A–60	A–0	–	A–0	6
Accommodation spaces	[3]	A–60	A–0	6	A–0	6	A–60	A–0	–	A–0	6
Stairways	[4]	A–0	A–0	A–0	6	A–0	A–60	A–0	–	A–0	6
Service space (low risk)	[5]	A–15	A–0	A–0	A–0	6	A–60	A–0	–	A–0	6
Machinery spaces of category A	[6]	A–60	A–60	A–60	A–60	A–60	6	A–60 [5]	A–0	A–60	6
Other machinery spaces	[7]	A–15	A–0	A–0	A–0	A–0	A–0	6	A–0	A–0	6

Cargo pump rooms	[8]	–	–	–	–	–	A–0 [4]	A–0	6	–	6
Service spaces (high risk)	[9]	A–60	A–0	A–0	A–0	A–0	A–60	A–0	–	A–0 [2]	6
Open decks	[10]	6	6	6	6	6	6	6	6	6	–
See notes under Table 22.7											

[1] : **Control stations**

Spaces containing emergency sources of power and lighting. Wheelhouse and chartroom. Spaces containing the ship's radio equipment. Fire control stations. Control room for propulsion machinery when located outside the machinery space. Spaces containing centralized fire alarm equipment.

[2] : **Corridors**

Corridors and lobbies.

[3] : **Accommodation spaces**

Spaces used for public spaces, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, barber shops, pantries containing no cooking appliances and similar spaces.

[4] : **Stairways**

Interior stairways, lifts, totally enclosed emergency escape trunks and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto.

In this connection, a stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door.

[5] : **Service spaces (low risk)**

Lockers and store-rooms not having provisions for the storage of flammable liquids and having areas less than $4\ m^2$ and drying rooms and laundries.

[6] : **Machinery spaces of category A**

Spaces and trunks to such spaces which contain:

internal combustion machinery used for main propulsion; or

internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or

any oil-fired boiler or oil fuel unit.

[7] : **Other machinery spaces**

Spaces, other than machinery spaces of category A, containing propulsion machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces. Electrical equipment rooms (auto-telephone exchange and air-conditioning duct spaces).

[8] : **Cargo pump rooms**

Spaces containing cargo pumps and entrances and trunks to such spaces.

[9] : **Service spaces (high risk)**

Galleys, pantries containing cooking appliances, saunas, paint and lamp rooms, lockers and store-rooms having areas of $4\ m^2$ or more,

spaces for the storage of flammable liquids, and workshops other than those forming part of the machinery spaces.

[10] : **Open decks**

Open deck spaces and enclosed promenades having little or no fire risk. Air spaces (the space outside superstructures and deckhouses).

F.4.4 Continuous "B" class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing wholly or in part, to the required insulation and integrity of a division.

F.4.5 External boundaries which are required in E.1. to be of steel or other equivalent material may be pierced for the fitting of windows and sidescuttles provided that there is not requirement for such boundaries to have "A" class integrity elsewhere in these requirements. Similarly, in such boundaries which are not required to have "A" class integrity, doors may be of materials to meet the requirements of their application.

F.4.6 Permanent approved gastight lighting enclosures for illuminating cargo pump rooms may be permitted in bulkheads and decks separating cargo pump rooms and other spaces provided they are of adequate strength and the integrity and gastightness of the bulkhead or deck is maintained.

F.4.7 Construction and arrangement of saunas

See B.11.5.

G Helicopter Decks

G.1 Helicopter decks shall be of a steel or steel equivalent fire-resistant construction. If the space below the helicopter deck forms the deckhead of a deckhouse or superstructure, it shall be insulated to "A-60" class standard. If an aluminium or other low melting metal construction will be allowed, the following provisions shall be satisfied:

G.1.1 If the platform is cantilevered over the side of the ship, after each fire on the ship or on the platform, the platform shall undergo a structural analysis to determine its suitability for further use.

G.1.2 If the platform is located above the ship's deckhouse or similar structure, the following conditions shall be satisfied:

G.1.2.1 the deckhouse top and bulkheads under the platform shall have no openings;

G.1.2.2 all windows under the platform shall be provided with steel shutters;

G.1.2.3 the required fire-fighting equipment shall be in accordance with the requirements of the GL Rules for Machinery Installations (I-1-2), Section 12.

G.1.2.4 after each fire on the platform or in close proximity, the platform shall undergo a structural analysis to determine its suitability for further use.

G.1.3 A helideck shall be provided with both a main and an emergency means of escape and access for fire fighting and rescue personnel. These shall be located as far as apart from each other as is practicable and preferably on opposite sides of the helideck.

Section 23 Bulk Carriers, Ore Carriers and Ships with Strengthenings for Bulk Cargo and Heavy Cargo

A General

A.1 Application

A.1.1 Ships intended to get the Notation **STRENGTHENED FOR HEAVY CARGO** are to be in compliance with B.

A.1.2 For ships, occasionally or regularly carrying heavy cargo, such as iron, ore, phosphate etc., and not intended to get the Notation **BULK CARRIER** or **ORE CARRIER**, strengthenings according to B are recommended.

In addition, these ships have to fulfil IMO Resolution MSC. 277(85) as defined in the GL Rules for Classification and Surveys (I-0), Section 2.

A.1.3 Ships intended to get the Notation **BULK CARRIER** are to be in compliance with C.

A.1.4 Ships intended to get the Notation **ORE CARRIER** are to be in compliance with C unless otherwise mentioned in D.

A.1.5 Ships intended to get the Notation **G** are to be in compliance with J.

A.1.6 Unless specially mentioned in this Section, the requirements of Sections 1 – 22 and 27 apply.

The stability requirements of Section 28 apply and in addition for ships engaged in the carriage of grain in bulk the Grain Code apply.

A.2 References

A.2.1 International convention(s) and / or code(s)

Paragraphs of this section are based on the following international convention(s) and / or code(s):

IACS UR S12 Rev.5
IACS UR S17 Rev.8
IACS UR S28 Rev.3

At the end of each relevant paragraph, the corresponding paragraphs of the international convention(s) and / or code(s) are given in brackets.

A.2.2 For bulk and ore carriers carrying also oil in bulk also Section 24, M applies.

A.2.3 For corrosion protection for cargo hold spaces see Section 35, G.

A.2.4 For dewatering requirements of forward spaces of bulk and ore carriers, see the GL Rules for Machinery Installations (I-1-2), Section 11, N.

A.2.5 For water ingress detection systems of bulk and ore carriers, see the GL Rules for Electrical Installations (I-1-3), Section 18.

A.3 Definitions

Single Side Skin Bulk Carrier

A bulk carrier is considered in this Section a "Single Side Skin Bulk Carrier" when one or more cargo holds are bound by the side shell only or by two watertight boundaries, one of which is the side shell, which are less than 1 000 mm apart. The distance between the watertight boundaries is to be measured perpendicular to the side shell.

Double Side Skin Bulk Carrier

A bulk carrier is considered in this Section a "Double Side Skin Bulk Carrier" when all cargo holds are bound by two watertight boundaries, one of which is the side shell, which are 1 000 mm or above apart. The distance between the watertight boundaries is to be measured perpendicular to the side shell.

Ore Carrier

Ore carriers are generally single-deck vessels with the machinery aft and two continuous longitudinal bulkheads with the ore cargo holds fitted between them, a double bottom throughout the cargo length area and intended primarily to carry ore cargoes in the centre holds only.

Symbols

a : length [m] of shorter side of plate field (distance of longitudinals)

a_y : transverse acceleration for the considered load case according to Section 4, E.1 As first approximation the following metacentric height $\overline{GM}$ and centre of gravity of the steel coil loading z can be used to determine a_y.

$$\overline{GM} = 0.24 \cdot \mathbf{B} \quad [m]$$

$$z = hdb + \left(1 + 0.866 \cdot \left(n_1 - 1\right)\right) \cdot d_c / 2 \quad [m]$$

$\overline{GM}$: metacentric height [m], defined as:

$$\overline{GM} = 0.24 \cdot \mathbf{B}$$

z : centre of gravity of the steel coil loading [m], defined as:

$$z = hdb + \left(1 + 0.866 \cdot \left(n_1 - 1\right)\right) \cdot d_c / 2$$

a_v : acceleration addition according to Section 4, A.3

b : length [m] oflonger side of plate field (distance transverses)

B_H : breadth [m] of cargo hold

c_d : coefficient for the distance of steel coils in ship's longitudinal direction, defined as:

$$c_d = \min\left(0.2; \frac{0.3}{\ell_c}\right)$$

d_c : diameter [m] of steel coils

g : gravitational acceleration [m / s²], defined as:

$$g = 9.81$$

h_{DB} : height [m] of double bottom

k : material factor according to Section 2, A.2

ℓ_c : length [m] of steel coils

$\mathbf{L}_{200}$: corresponds to the length of the ship as $\mathbf{L}$, but $\mathbf{L}_{200}$ is not to be taken greater than $200\ \text{m}$

p_L : bulk cargo pressure according to Section 4, C.1.4

p_I : load on inner bottom according to Section 4, C.2.1

t_K : corrosion addition according to Section 3, G

W : mass [kg] of one steel coil

φ : design roll angle [°], defined as:

$\varphi = 30$

μ : coefficient of friction, defined as:

$\mu = 0.3$ in general

ρ : sea water density $[t / m^3]$, defined as:

$\rho = 1.025$

σ_{LI} : maximum design hull girder bending stress in the inner bottom according to Section 5, D.2

σ_{LL} : maximum design hull girder bending stress in the longitudinal bulkhead according to Section 5, D.2

σ_{perm} : permissible design stress $[N / mm^2]$, as defined:

$$\sigma_{perm} = \left(0.8 + \frac{\mathbf{L}}{450}\right) \cdot \frac{230}{k} \quad \text{for } \mathbf{L} < 90\ \text{m}$$

$$\sigma_{perm} = \frac{230}{k} \quad \text{for } \mathbf{L} \geq 90\ \text{m}$$

τ_L : maximum design shear stress due to longitudinal hull girder bending according to Section 5, D.2

B Strengthenings for Bulk Cargo and Heavy Cargo

B.1 Double bottom

B.1.1 Where longitudinal framing is adopted for the double bottom, the spacing of plate floors is, in general, not to be greater than the height of the double bottom. The scantlings of the inner bottom longitudinals are to be determined for the load of the cargo according to Section 9, C.

For the longitudinal girder system, see Section 8, C.6.4.

B.1.2 Where transverse framing is adopted for the double bottom, plate floors according to Section 8, C.5. are to be fitted at every frame in way of the cargo holds.

B.1.3 In the drawings to be submitted, details are to be given regarding the loads resulting from the cargo, upon which the calculations are based.

B.2 Longitudinal strength

The longitudinal strength of the ship is to comply with the requirements of Section 5 irrespective of the ship's length.

C Bulk Carriers

C.1 General

Where reduced freeboards according to **ICLL** are to be assigned, the respective requirements of the **ICLL** are to be observed.

C.2 Longitudinal strength

C.2.1 General

C.2.1.1 The longitudinal strength of the ship is to comply with the requirements of Section 5 irrespective of the ship's length.

C.2.1.2 For alternate loading conditions Section 8, C.7 is to be observed.

C.2.2 Flooding

C.2.2.1 In addition to the requirements of Section 5, B, for all bulk carriers of 150 m in length and above and with the Notation **BC-A** or **BC-B** according to G.2.1 the longitudinal strength is to be checked to be adequate for specified flooded conditions , in each of the cargo and ballast conditions considered in the intact longitudinal strength calculations. The loading conditions "harbour", "docking, afloat", "loading and unloading transitory conditions" as well as "ballast water exchange" need not be considered.

The required moment of inertia according to Section 5, E.1.2.3 and the strength of local structural members are excluded from this proof.

(IACS UR S17.1)

C.2.2.2 Flooding criteria

To calculate the weight of ingressing water, the following assumptions are to be made:

- The permeability of empty cargo spaces and volume left in loaded cargo spaces above any cargo is to be taken as 0.95.
- Appropriate permeabilities and bulk densities are to be used for any cargo carried. For iron ore, a minimum permeability of 0.3 with a corresponding bulk density of 3.0 t/m^3 is to be used. For cement, a minimum permeability of 0.3 with a corresponding bulk density of 1.3 t/m^3 is to be used. In this respect, "permeability" for solid bulk cargo means the ratio of the floodable volume between the cargo parts 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. The permeability has to be harmonized case by case (pipes, flat steel, coils etc.) with GL.

(IACS UR S17.3)

C.2.2.3 Flooding conditions

Each cargo hold is to be considered individually flooded up to the equilibrium waterline. This does not apply for cargo holds of double hull construction where the double hull spacing exceeds $1\,000 \text{ mm}$, measured vertically to the shell at any location of the cargo hold length.

The wave induced vertical bending moments and shear forces in the flooded conditions are assumed to be equal to 80 % of the wave loads, as given in Section 5, D.1.3.1 and Section 5, D.1.3.2.

(IACS UR S17.2.1 and IACS UR S17.2.2)

C.3 Scantlings of bottom structure

C.3.1 General

The scantlings of the bottom structure are to be determined on the basis of direct calculations according to Section 8, C.7.

For ships according to C.2.2.1, E has to be observed in addition.

Note

Upon request, GL will carry out calculations for the bottom structure.

C.3.2 Floors under corrugated bulkheads

Plate floors are to be fitted under the face plate strips of corrugated bulkheads. A sufficient connection of the corrugated bulkhead elements to the double bottom structure is to be ensured. Under the inner bottom, scallops in the above mentioned plate floors are to be restricted to those required for crossing welds. The plate floors as well as the face plate strips are to be welded to the inner bottom according to the stresses to be transferred. In general, full or partial penetration welding is to be used, see also F.4.1.1.

C.3.3 Inner bottom and tank side slopes

C.3.3.1 The thickness of the inner bottom plating including the tank side slopes is to be determined according to Section 8, C.4.

When determining the load on inner bottom p_I, a cargo density of not less than $1\ t / m^2$ is to be used.

For determining scantlings of tank side slopes the load p_I is not to be taken less than the load which results from an angle of heel of $20\ °$.

C.3.3.2 Sufficient continuity of strength is to be provided for between the structure of the bottom wing tanks and the adjacent longitudinal structure.

C.4 Side structures

C.4.1 Side longitudinals, longitudinal stiffeners, main frames

The scantlings of side longitudinals are to be determined according to Section 9, C. The longitudinal stiffeners at the lower tank side slopes are to have the same section modulus as the side longitudinals. Their scantlings are also to be checked for the load according to C.3.3.1. For the longitudinal stiffeners of the topside tanks within the upper flange, Section 3, D.1 is to be observed.

(IACS UR S12.4)

C.4.2 Main frames and end connections

C.4.2.1 The section modulus of main frames of single side skin bulk carriers is to be increased by at least 20 % above the value required by Section 9, B.2.1.1.

C.4.2.2 The section modulus W of the frame and bracket or integral bracket, and associated shell plating, at the locations shown in Fig. 23.1, is not to be less than twice the section modulus W_F required for the frame midspan area.

The dimensions of the lower and upper brackets are not to be less than those shown in Fig. 23.2.

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 Fig. 23.3.

(IACS UR S12.4)

C.4.2.3 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 [mm], given by:

$$r = 0.4 \cdot \frac{b_f^2}{t_f}$$

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

In ships with $\mathbf{L} < 190\ m$, 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:

$$\frac{h_w}{t_w} = 60 \cdot \sqrt{k}$$ for symmetrically flanged frames

$$\frac{h_w}{t_w} = 50 \cdot \sqrt{k}$$ for asymmetrically flanged frames

The outstanding flange b_1 is not to exceed $10 \cdot \sqrt{k}$ times the flange thickness, see Fig. 23.1.

(IACS UR S12.5)

C.4.2.4 In way of the foremost hold, side frames of asymmetrical section are to be fitted with tripping brackets at every two frames according to Section 9, B.5.5.

(IACS UR S12.6)

C.4.2.5 Where proof of fatigue strength according to Section 20 is carried out for the main frames, this proof is to be based on the scantlings which do not include the 20 % increase in section modulus.

C.4.2.6 For bulk carrier ship configurations which incorporate hopper and topside tanks the minimum thickness of frame webs in cargo holds and ballast holds is not to be less than:

$$t_{w,min} = C \cdot \left(7.0 + 0.03 \cdot \mathbf{L}_{200}\right) \quad [\text{mm}]$$

C : coefficient, defined as:

$C = 1.15$ for the frame webs in way of the foremost hold

$C = 1.00$ for the frame webs in way of other holds

(IACS UR S12.3)

C.4.2.7 The thickness of the brackets at the lower frame ends is not to be less than the required web thickness t_w of the frames or $t_{w,min} + 2.0$ mm, whichever is the greater value.

The thickness of the frame upper bracket is not to be less than the greater of t_w and $t_{w,min}$.

(IACS UR S12.4)

C.4.3 Minimum thickness of side shell plating

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

$$t_{p,min} = \sqrt{\mathbf{L}} \quad [\text{mm}]$$

(IACS UR S12.8)

C.4.4 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 Fig. 23.1):

$0.44 \cdot t$ in zone "a"

$0.40 \cdot t$ in zone "b"

where t is the plate thickness of 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.

(IACS UR S12.7)

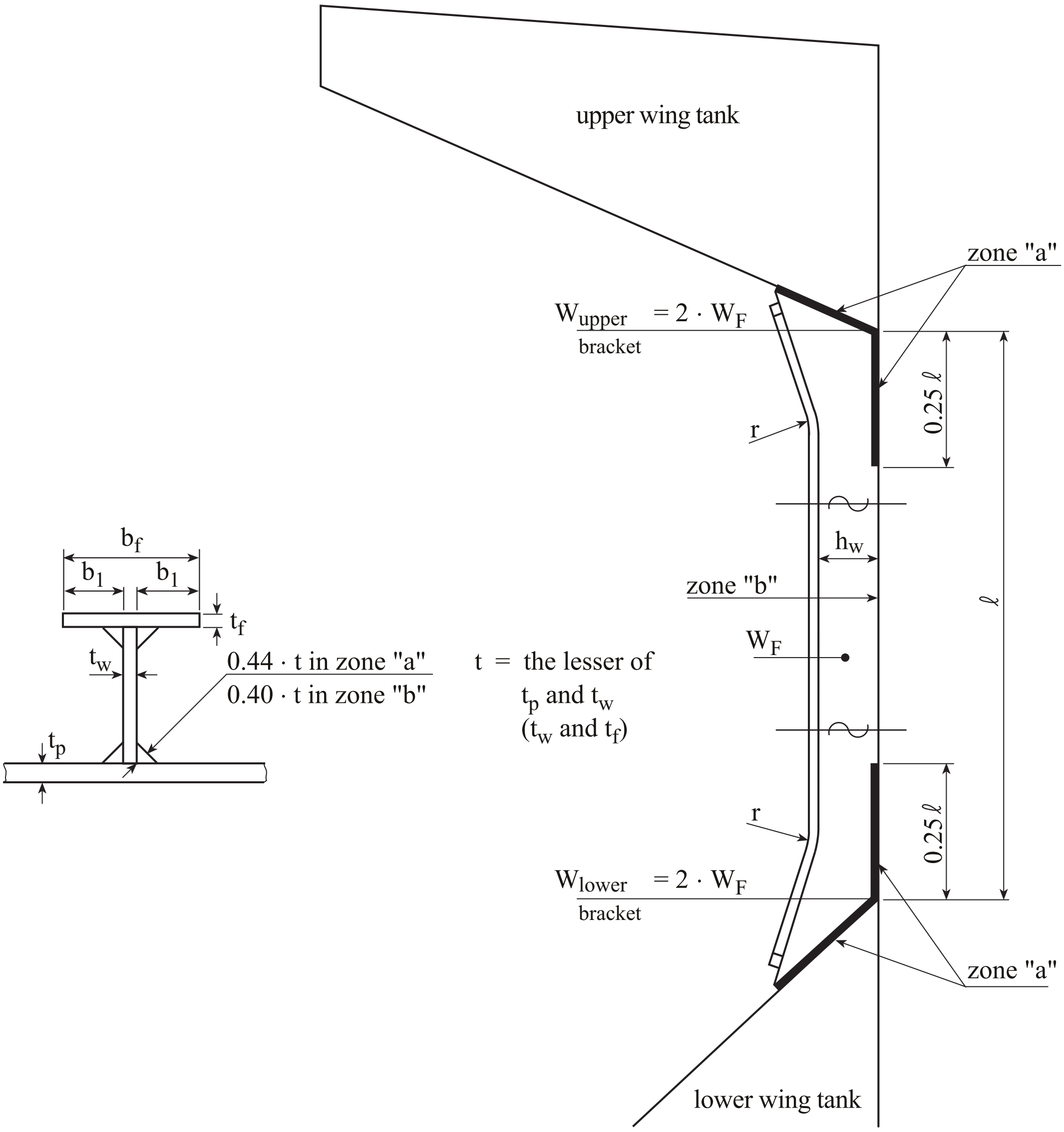


Fig. 23.1 Side frame of single side skin bulk carrier

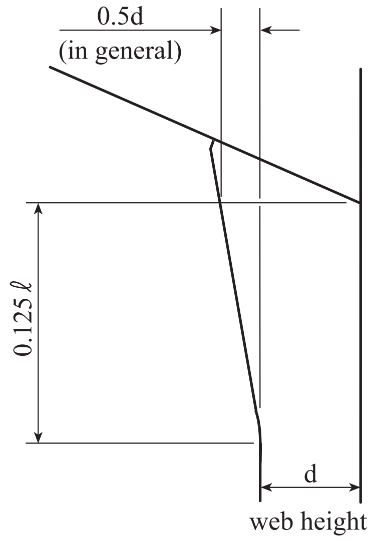


Fig. 23.2 Dimensions of the upper and lower bracket of the side frames

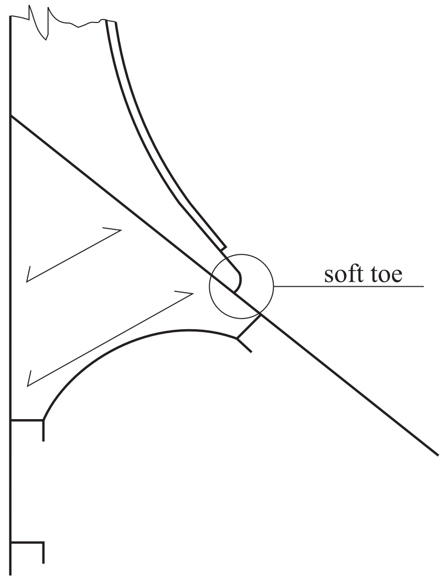


Fig. 23.3 Connecting bracket in the hopper tank

C.5 Topside tanks

C.5.1 The plate thickness of the topside tanks is to be determined according to Section 12.

C.5.2 Where the transverse stiffening system is applied for the longitudinal walls of the topside tanks and for the shell plating in way of the topside tanks, the stiffeners of the longitudinal walls are to be designed according to Section 12, the transverse frames at the shell according to Section 9, B.3.

C.5.3 Sufficient continuity of strength is to be provided for between the structure of the topside tanks and the adjacent longitudinal structure.

C.6 Transverses in the wing tanks

Transverses in the wing tanks are to be determined according to Section 12, B.2 for the load resulting from the head of water or for the cargo load. The greater load is to be considered.

The scantlings of the transverses in the lower wing tanks are also to be examined for the loads according to C.3.3.1.

C.7 Cargo hold bulkheads

C.7.1 The following requirements apply to cargo hold bulkheads on the basis of the loading conditions according to Section 5, B.

For vertically corrugated transverse cargo hold bulkheads on ships according to C.2.2.1 the requirements of F apply in addition, where the strength in the hold flooded condition has to be ensured.

C.7.2 The scantlings of cargo hold bulkheads are to be determined on the basis of the requirements for tank structures according to Section 12, B, where the load p_L is to be used for the load p.

C.7.3 The scantlings are not to be less than those required for watertight bulkheads acc. to Section 11. The plate thickness is in no case to be taken less than 9.0 mm.

C.7.4 The scantlings of the cargo hold bulkheads are to be verified by direct calculations. Permissible stresses are given in Section 11, D.2.1.

C.7.5 Above vertically corrugated bulkheads, transverse girders with double webs are to be fitted below the deck, to form the upper edge of the corrugated bulkheads. They are to have the following scantlings:

- web thickness = thickness of the upper plate strake of the bulkhead
- depth of web ≈ $\mathbf{B} / 22$
- face plate = 1.5 times the thickness of the (thickness) upper plate strake of the bulkhead

See also F.4.1.3.

C.7.6 Vertically corrugated transverse cargo hold bulkheads are to have a plane stiffened strip of plating at the ship's sides. The width of this strip of plating is to be $0.15\ \mathbf{H}$ where the length of the cargo hold is $20\ \mathrm{m}$. Where the length of the cargo hold is greater/smaller, the width of the strip of plating is to be increased/reduced proportionally.

C.8 Hatchway coamings

In way of the hatchway corners full penetration welding by means of double bevel T-joints or single bevel T-joints may be required for connecting the coaming with the deck plating.

See also Section 17.

C.9 Loading information for Bulk Carriers, Ore Carriers and Combination Carriers

C.9.1 General, definitions

C.9.1.1 These requirements are additional to those specified in Section 5, C and apply to Bulk Carriers, Ore Carriers and Combination Carriers of $150\ \mathrm{m}$ length and above and are minimum requirements for loading information.

C.9.1.2 All ships falling into the category of this Section are to be provided with an approved loading manual and an approved computer-based loading instrument.

C.9.1.3 The following definitions apply:

Loading manual is a document which in addition to the definition given in Section 5, C.3.2 describes:

- for bulk carriers, envelope results and permissible limits of still water bending moments and shear forces in the hold flooded condition according to C.2.2.
- which cargo hold(s) or combination of cargo holds 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.
- maximum allowable and minimum mass required of cargo and double bottom contents of each hold as a function of the draught at mid-hold position.
- 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.
- maximum allowable tank top loading together with specification of the nature of cargo for cargoes other than bulk cargoes.
- 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.
- 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.

Loading instrument is an approved computer system which in addition to the requirements given in Section 5, C.4 is to be capable to ascertain that:

- allowable mass of cargo and double bottom contents in way of each cargo hold as a function of the ship's draught at mid-hold position
- allowable mass of cargo and double bottom contents in any two adjacent cargo holds as a function of the mean draught in way of these holds and
- the still water bending moments and shear forces in the hold flooded condition according to C.2.2

are within permissible values.

C.9.2 Conditions of approval of loading manuals

In addition to the requirements given in Section 5, C.3.4 the following loading conditions, subdivided into departure and arrival conditions as appropriate, are to be included in the loading manual:

- alternate light- and heavy cargo loading conditions at maximum draught, where applicable
- homogeneous light- and heavy cargo loading conditions at maximum draught
- ballast conditions including those conditions, where ballast holds are filled when the adjacent top-wing-, hopper- and double bottom tanks are empty.
- short voyage conditions where the vessel is to be loaded to maximum draught but with limited amount of bunkers
- multiple port loading/unloading conditions
- deck cargo conditions, where applicable
- typical loading sequences where the vessel is loaded from commencement of cargo loading to reaching full dead weight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions, where applicable. Typical unloading sequences for these conditions are also to be included. The typical loading/unloading sequences are also to be developed to not exceed applicable strength limitations. The typical loading sequences are also to be developed paying due attention to loading rate and the deballasting capability. Reference is made to IACS Recommendation No. 83 (August 2003), "Notes to Annexes to IACS Unified Requirements S1A on Guidance for Loading/Unloading Sequences for Bulk Carriers.
- typical sequences for change of ballast at sea, where applicable

C.9.3 Approval

For approval of the loading instrument see GL Guidelines for Loading Computer Systems VI-11-7.

D Ore Carriers

D.1 General

Where reduced freeboards according to **ICLL** are to be assigned, the respective requirements of the **ICLL** are to be observed.

D.2 Double bottom

D.2.1 For achieving good stability criteria in the loaded condition the double bottom between the longitudinal bulkheads should be as high as possible.

D.2.2 The strength of the double bottom structure is to comply with the requirements given in C.3.

D.3 Transverse and longitudinal bulkheads

D.3.1 The spacing of transverse bulkheads in the side tanks which are to be used as ballast tanks is to be determined according to Section 24, as for tankers. The spacing of transverse bulkheads in way of the cargo hold is to be determined according to Section 11.

D.3.2 The scantlings of cargo hold bulkheads exposed to the load of the ore cargo are to be determined according to C.7. The scantlings of the side longitudinal bulkheads are to be at least equal to those required for tankers.

E Allowable hold loading, considering flooding

E.1 General

These requirements apply to all bulk carriers, defined in C.2.2.1.

The loading in each hold is not to exceed the allowable loading according to E.4 and is not to exceed the design hold loading in intact condition.

E.2 Load model

E.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 to 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.

E.2.2 Inner bottom flooding head

The flooding head h_f (see Fig. 23.4) is the distance $[m]$, measured vertically with the ship in the upright position, from the inner bottom to a level located at a distance d_f $[m]$, from the baseline:

d_f is in general:

$d_f = 1.00 \cdot \mathbf{H}$ for the foremost hold

$d_f = 0.90 \cdot \mathbf{H}$ for the other holds

For ships less than $50\ 000$ tonnes deadweight with Type B freeboard, d_f is:

$d_f = 0.95 \cdot \mathbf{H}$ for the foremost hold

$d_f = 0.85 \cdot \mathbf{H}$ for the other holds

E.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 Fig. 23.5
- 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.

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, the shear capacity C of double bottom is to be calculated by direct calculations.

In calculating the shear strength, the net thickness of floors and girders is to be used. The net thickness t_{net}, is to be determined by the following formula:

$$t_{net} = t - 2.5 \quad [mm]$$

t : thickness of floors and girders [mm]

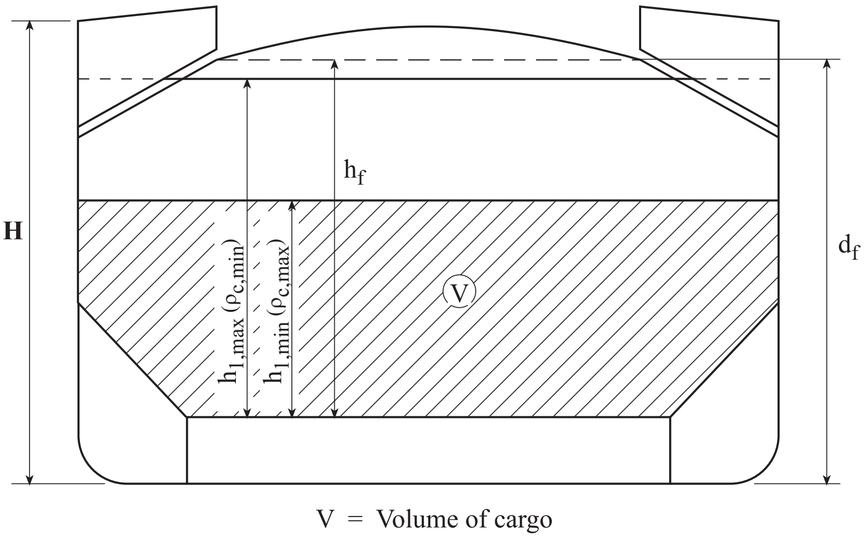


Fig. 23.4 Flooding head h_f of the inner bottom

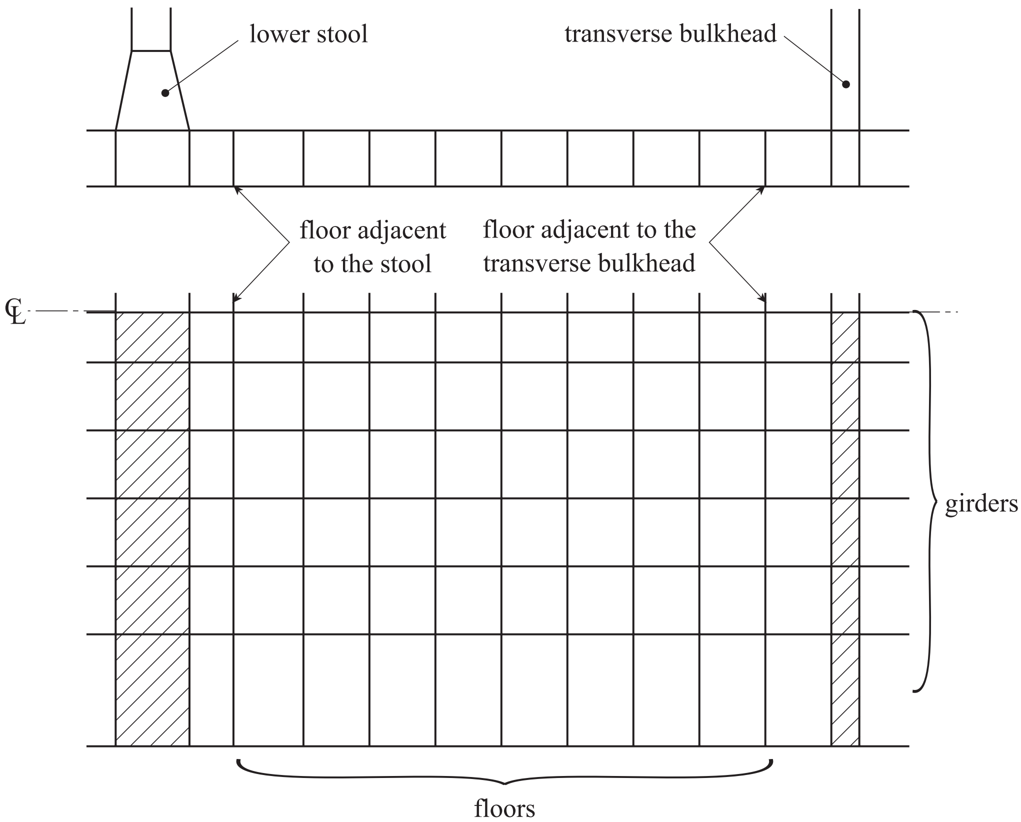


Fig. 23.5 Girders and floors in the double bottom

E.3.1 Floor shear strength

The floor shear strength in way of the floor panel adjacent to hoppers S_{f1}, and the floor shear strength in way of the openings in the outmost bay (i.e. that bay which is adjacent to the hopper) S_{f2}, are to be determined by the following formulae:

$$S_{f1} = A_f \cdot \frac{\tau_a}{\eta_1} \cdot 10^{-3} \quad [\mathrm{kN}]$$

$$S_{f2} = A_{f,h} \cdot \frac{\tau_a}{\eta_2} \cdot 10^{-3} \quad [\mathrm{kN}]$$

A_f : sectional area $[\mathrm{mm}^2]$, of the floor panel adjacent to hoppers

$A_{f,h}$: net sectional area $[\mathrm{mm}^2]$, of the floor panel in way of the openings in the outmost bay (i.e. that bay which is adjacent to the hopper)

τ_a : allowable shear stress $[\mathrm{N/mm}^2]$, defined as:

$$\tau_a = \frac{162 \cdot R_{eH}^{0.6}}{\left(\frac{a}{t_{net}}\right)^{0.8}} \qquad \text{with } \tau_{a,max} = \frac{R_{eH}}{\sqrt{3}}$$

For floors adjacent to the stools or transverse bulkheads, as identified in E.3, τ_a may be taken as

$$\tau_a = \frac{R_{eH}}{\sqrt{3}}$$

a : spacing $[\mathrm{mm}]$ of stiffening members, of panel under consideration

η_1, η_2 : factors, defined as:

$\eta_1 = 1.10$

$\eta_2 = 1.20$ in general

$\eta_2 = 1.10$ where appropriate reinforcements are fitted

E.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}, 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}, are given by

$$S_{g1} = A_g \cdot \frac{\tau_a}{\eta_1} \cdot 10^{-3} \quad [\mathrm{kN}]$$

$$S_{g2} = A_{g,h} \cdot \frac{\tau_a}{\eta_2} \cdot 10^{-3} \quad [\mathrm{kN}]$$

A_g : minimum sectional area $[\mathrm{mm}^2]$, of the girder panel adjacent to stools (or transverse bulkheads, if no stool is fitted)

$A_{g,h}$: net sectional area $[\mathrm{mm}^2]$, of the girder panel in way of the largest opening in the outmost bay (i.e. that bay which is closer to stool, or transverse bulkhead, if no stool is fitted)

τ_a : allowable shear stress $[\mathrm{N/mm}^2]$, as given in E.3.1

η_1, η_2 : factors, defined as:

$\eta_1 = 1.10$

$\eta_2 = 1.15$ inn general

$\eta_2 = 1.10$ where appropriate reinforcements are fitted

E.4 Allowable hold loading

The allowable hold loading HL is to be determined by the following formulae:

$$HL = \min\left[\frac{\rho_c V}{F} \; ; \; HL_{int}\right] \quad [t]$$

HL_{int} : maximum permissible hold loading for intact condition $[t]$

F : factor, defined as:

$F = 1.10$ in general

$F = 1.05$ for steel mill products

ρ_c : cargo density $[t / m^3]$, for bulk cargoes see E.2.1; for steel products, ρ_c is to be taken as the density of steel

V : volume $[m^3]$ occupied by cargo assumed flattened at a level h_1

h_1 : cargo level $[m]$ in hold, defined as:

$$h_1 = \frac{X}{\rho_c \cdot g}$$

X : relative load $[kN / m^2]$, defined as:

$X = \min\left[X_1 \; ; \; X_2\right]$ for bulk cargoes

$X = X_1$ for steel products, X may be taken as X_1 using a value for $perm$ according to the type of products (pipes, flat bars, coils etc.) harmonized with GL.

X_1, X_2 : relative load $[kN / m^2]$, defined as:

$$X_1 = \frac{Z + \rho \cdot g \cdot \left(E - h_f\right)}{1 + \frac{\rho}{\rho_c} \cdot \left(perm - 1\right)}$$

$$X_2 = Z + \rho \cdot g \cdot \left(E - h_f \cdot perm\right)$$

$perm$: cargo permeability (i.e. the ratio between the voids within the cargo mass and the volume occupied by the cargo); need not be taken greater than 0.3.

E : (nominal ship) immersion $[m]$ for flooded hold condition, defined as:

$$E = d_f - 0.1 \cdot \mathbf{H}$$

Z : load $[kN / m^2]$ related to shear capacity, defined as:

$$Z = \min\left[\frac{C_h}{A_{DB,h}} \; ; \; \frac{C_e}{A_{DB,e}}\right]$$

C_h : shear capacity $[kN]$ of the double bottom according to E.3, considering, for each floor, the lesser of the shear strengths S_{f1} and S_{f2} (see E.3.1) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (see E.3.2)

C_e : shear capacity $[kN]$ of the double bottom according to E.3, considering, for each floor, the shear strength S_{f1} (see E.3.1) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (see E.3.2)

$A_{DB,h}$: relative load area $[m^2]$, defined as:

$$A_{DB,h} = \sum_{i=1}^{i=n} S_i \cdot B_{DB,i}$$

$A_{DB,e}$: relative load area $[m^2]$, defined as:

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

n : number of floors between stools (or transverse bulkheads, if no stool is fitted)

S_i : spacing $[m]$ of i^{th}-floor

$B_{DB,i}$: breadth $[m]$ of double bottom related to shear strength calculation of floor, defined as:

$B_{DB,i} = B_{DB} - a_\ell$ for floors whose shear strength is given by S_{f1}, see E.3.1

$B_{DB,i} = B_{DB,h}$ for floors whose shear strength is given by S_{f2}, see E.3.1

B_{DB} : breadth $[m]$ of double bottom between hoppers, see Fig. 23.6

$B_{DB,h}$: distance $[m]$ between the two considered openings, see Fig. 23.6

a_ℓ : spacing $[m]$, of double bottom longitudinals adjacent to hoppers

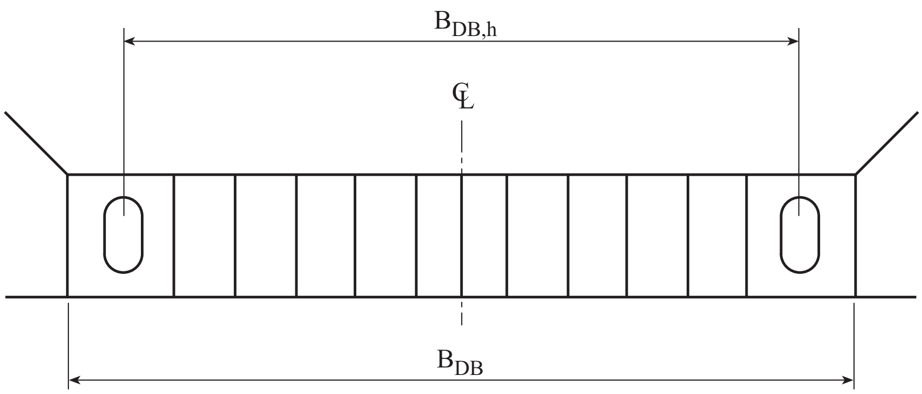


Fig. 23.6 Effective distances B_{DB} and $B_{DB,h}$ for the calculation of shear capacity

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

F.1 Application and definitions

These requirements apply to all bulk carriers with $L \geq 150$ m, intended for the carriage of solid bulk cargoes having bulk density of 1.0 $[t/m^3]$, or above, with vertically corrugated transverse watertight bulkheads.

The net thickness t_{net} is the thickness obtained by applying the strength criteria given in F.4.

The required thickness is obtained by adding the corrosion addition t_K, given in F.6., to the net thickness t_{net}.

In this requirement, homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for each hold, does not exceed 1.20, to be corrected for different cargo densities.

F.2 Load model

F.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 in the loading manual.

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 (e.g. steel products) 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 to or greater than $1.78\ [t/m^3]$, the maximum mass of cargo which may be carried in the hold is also to be considered to fill that hold up to the upper deck level at centre line.

F.2.2 Bulkhead corrugation flooding head

The flooding head h_f (see Fig. 23.7) is the distance $[m]$, measured vertically with the ship in the upright position, from the calculation point to a level located at a distance $d_f\ [m]$, from the baseline.

For ships in general following values can be assumed for d_f:

- in general:

$d_f = 1.00 \cdot \mathbf{H}$	for the aft transverse corrugated bulkhead of the foremost hold
$d_f = 0.90 \cdot \mathbf{H}$	for the other bulkheads

- where the ship is to carry cargoes having bulk density less than $1.78\ t/m^3$ in non-homogeneous loading conditions:

$d_f = 0.95 \cdot \mathbf{H}$	for the aft transverse corrugated bulkhead of the foremost hold
$d_f = 0.85 \cdot \mathbf{H}$	for the other bulkheads

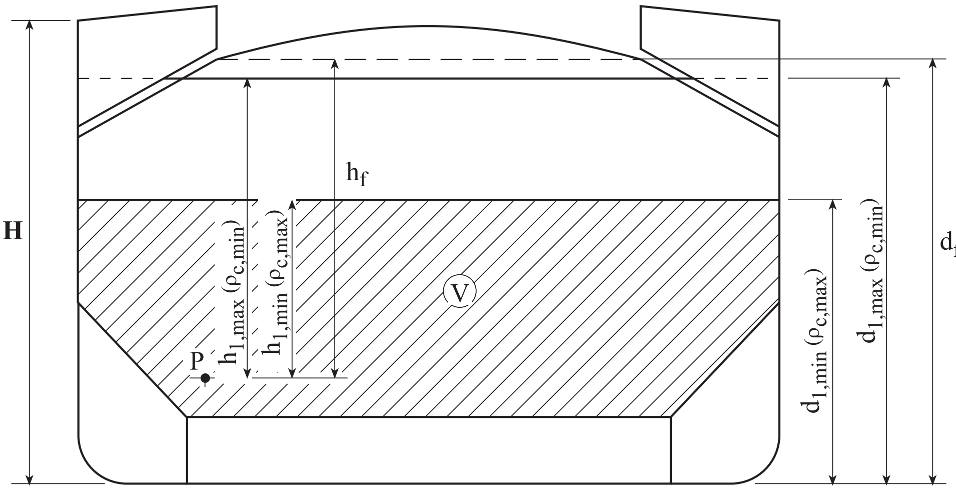
For ships less than $50\,000$ tonnes deadweight with Type B freeboard following values can be assumed for d_f:

- in general:

$d_f = 0.95 \cdot \mathbf{H}$	for the aft transverse corrugated bulkhead of the foremost hold
$d_f = 0.85 \cdot \mathbf{H}$	for the other bulkheads

- where the ship is to carry cargoes having bulk density less than $1.78\ t/m^3$ in non-homogeneous loading conditions:

$d_f = 0.90 \cdot \mathbf{H}$	for the aft transverse corrugated bulkhead of the foremost hold
$d_f = 0.80 \cdot \mathbf{H}$	for the other bulkheads



V = Volume of cargo
P = Calculation point

Fig. 23.7 Flooding head hf of a corrugated bulkhead

F.2.3 Pressure in the non-flooded bulk cargo loaded holds

At each point of the bulkhead, in way of length ℓ according to Fig. 23.8 and Fig. 23.9 the pressure p_c, is to be determined by the following formula:

$$p_c = \rho_c \cdot g \cdot h_1 \cdot n \quad [kN/m^2]$$

ρ_c : bulk cargo density $[t/m^3]$

h_1 : vertical distance $[m]$, from the calculation point to the horizontal plane corresponding to the level height of the cargo (see Fig. 23.7), located at a distance d_1 $[m]$, from the baseline

n : coefficient to take the angle of repose of the cargo into account, defined as:

$$n = \tan^2 \cdot \left(45° - \frac{\gamma}{2}\right)$$

γ : angle $[°]$ of repose of the cargo, defined as:

$\gamma = 35$ may generally be taken for iron

$\gamma = 25$ may generally be taken for cement

F_c : force [kN] acting on a corrugation, defined as:

$$F_c = \rho_c \cdot g \cdot e_1 \cdot \frac{(d_1 - h_{DB} - h_{LS})^2}{2} \cdot n$$

e_1 : spacing $[m]$ of corrugations, see Fig. 23.8

h_{LS} : mean height $[m]$ of the lower stool from the inner bottom

h_{DB} : height $[m]$ of the double bottom

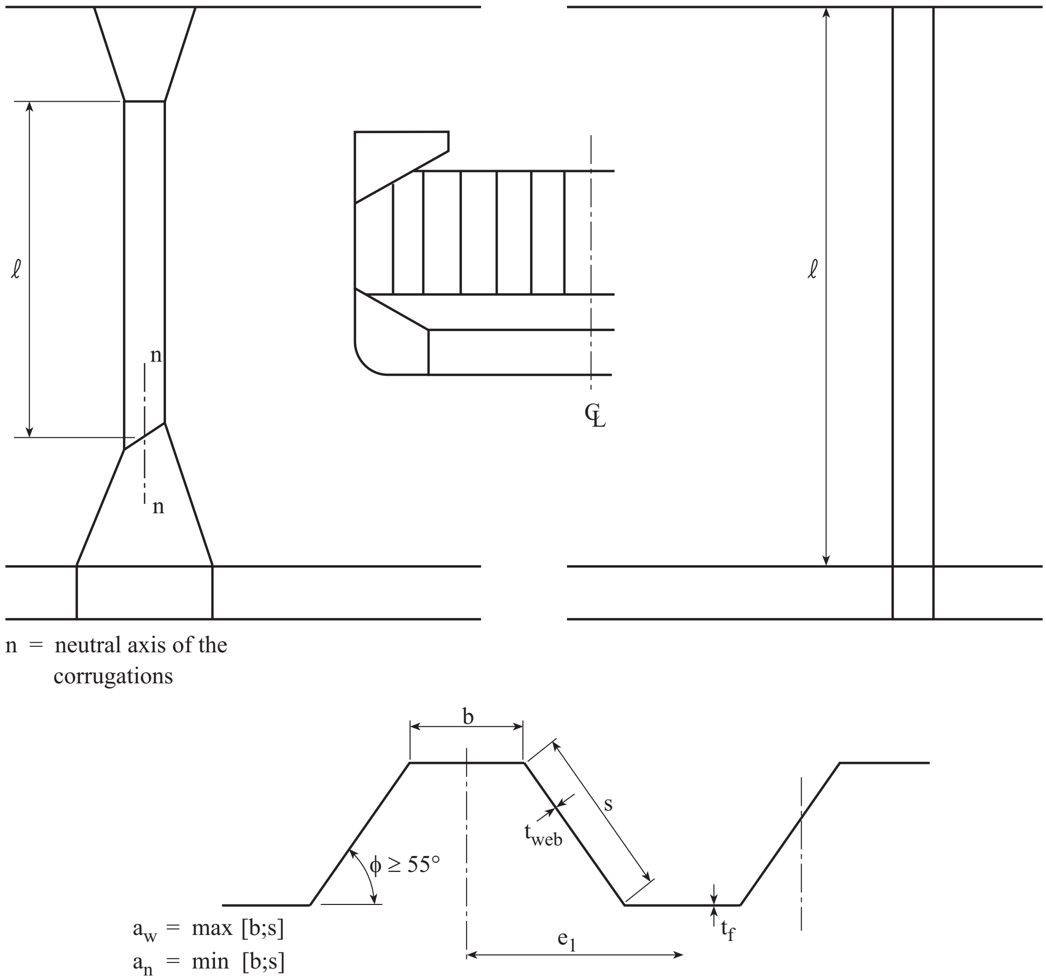
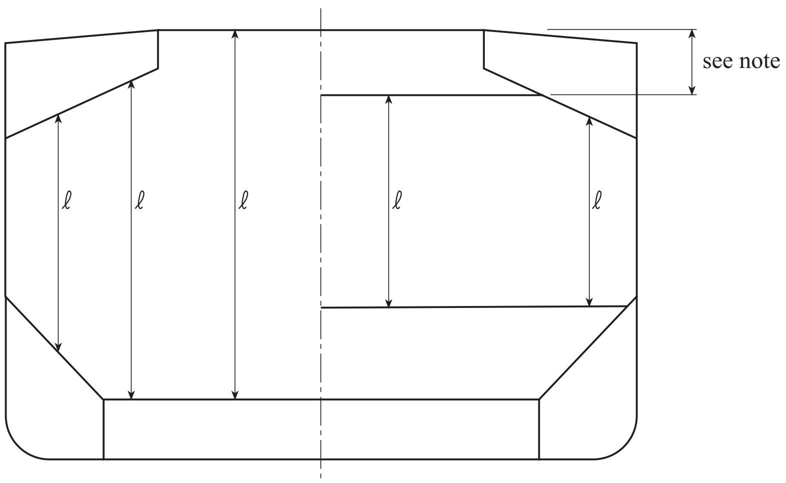


Fig. 23.8 Span ℓ of the corrugation (longitudinal section)



Note

For the definition of ℓ , the internal end of the upper stool is not to be taken more than a distance from the deck at the centre line equal to:

– *3 times the depth of corrugations, in general*

– *2 times the depth of corrugations, for rectangular stool*

Fig. 23.9 Span ℓ of the corrugation (transverse section)

F.2.4 Pressure in the flooded holds

F.2.4.1 Bulk cargo holds

Two cases are to be considered, depending on the values of d_1 and d_f.

1. $d_f \geq d_1$

The pressure $p_{c,f}$ acting on corrugation is to be determined by the following formulae:

$$p_{c,f} = \rho \cdot g \cdot h_f \quad [kN/m^2]$$

at each point of the bulkhead located at a distance between d_1 and d_f from the baseline

$$p_{c,f} = \rho \cdot g \cdot h_f + [\rho_c - \rho \cdot (1 - perm)] \cdot g \cdot h_1 \cdot n$$

at each point of the bulkhead located at a distance lower than d_1 from the baseline, see also Fig. 23.10

$perm$: permeability of cargo, to be taken as 0.3 for ore (corresponding bulk cargo density for iron ore may generally be taken as $3.0\ t/m^3$), coal cargoes and for cement (corresponding bulk cargo density for cement may generally be taken as $1.3\ t/m^3$)

The force $F_{c,f}$ acting on a corrugation is to be determined by the following formula:

$$F_{c,f} = e_1 \cdot \left[\rho \cdot g \cdot \frac{(d_f - d_1)^2}{2} + \frac{\rho \cdot g \cdot (d_f - d_1) + p_{c,f,le}}{2} \cdot (d_1 - h_{DB} - h_{LS}) \right] \quad [kN]$$

$p_{c,f,le}$: pressure $[kN/m^2]$ at the lower end of the corrugation

2. $d_f < d_1$

The pressure $p_{c,f}$ acting on corrugation is to be determined by the following formulae:

$$p_{c,f} = \rho_c \cdot g \cdot h_1 \cdot n \quad [kN/m^2]$$

at each point of the bulkhead located at a distance between d_f and d_1 from the baseline

$$p_{c,f} = \rho \cdot g \cdot h_f + [\rho_c \cdot h_1 - \rho \cdot (1 - perm) \cdot h_f] \cdot g \cdot n \quad [kN/m^2]$$

at each point of the bulkhead located at a distance lower than d_f from the baseline

The force $F_{c,f}$ acting on a corrugation is to be determined by the following formula:

$$F_{c,f} = e_1 \cdot \left[\rho_c \cdot g \cdot \frac{(d_1 - d_f)^2}{2} \cdot n + \frac{\rho_c \cdot g \cdot (d_1 - d_f) \cdot n + p_{c,f,le}}{2} \cdot (d_f - h_{DB} - h_{LS}) \right] \quad [kN]$$

F.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 acting on a corrugation is to be determined by the following formula:

$$F_f = e_1 \cdot \rho \cdot g \cdot \frac{(d_f - h_{DB} - h_{LS})^2}{2} \quad [kN]$$

F.2.5 Resultant pressure and force

F.2.5.1 Homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure p to be considered for the scantlings of the bulkhead is to be determined by the following formula:

$$p = p_{c,f} - 0.8 \cdot p_c \quad [kN/m^2]$$

The resultant force F acting on a corrugation is to be determined by the following formula:

$$F = F_{c,f} - 0.8 \cdot F_c \quad [kN]$$

F.2.5.2 Non homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure p to be considered for the scantlings of the bulkhead is to be determined by the following formula:

$$p = p_{c,f} \quad [kN/m^2]$$

The resultant force F acting on a corrugation is to be determined by the following formula:

$$F = F_{c,f} \quad [kN]$$

F.3 Bending moment and shear force in the bulkhead corrugations

F.3.1 The bending moment M and the shear force Q in the bulkhead corrugations are obtained using the formulae given in F.3.2 and F.3.3. The M and Q values are to be used for the checks in F.4.2.

F.3.2 Bending moment

The design bending moment M for the bulkhead corrugations is to be determined by the following formula:

$$M = \frac{F \cdot \ell}{8} \quad [kNm]$$

F : resultant force according to F.2.5

ℓ : span $[m]$ of the corrugation according to Fig. 23.8 and Fig. 23.9

F.3.3 Shear force

The shear force Q at the lower end of the bulkhead corrugations is to be determined by the following formula:

$$Q = 0.8 \cdot F \quad [kN]$$

F : resultant force according to F.2.5

F.4 Strength criteria

F.4.1 General

The following criteria are applicable to transverse bulkheads with vertical corrugations, see Fig. 23.8. 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. However, if any stools are fitted, they are to comply with the requirements in F.4.1.1 and F.4.1.2. See also C.7.5.

The corrugation angle ϕ shown in Fig. 23.8 is not to be less than $55°$.

Requirements for local net plate thickness are given in F.4.7.

In addition, the criteria as given in F.4.2 and F.4.5 are to be complied with.

The thicknesses of the lower part of corrugations considered in the application of F.4.2 and F.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 $0.15 \cdot \ell$.

The thicknesses of the middle part of corrugations as considered in the application of F.4.2 and F.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 $0.3 \cdot \ell$.

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 strengths.

F.4.1.1 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 according to Section 11, B on the basis of the load model in F.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 d from the edge of the stool top plate to the surface of the corrugation flange is to be not less than the corrugation flange plate thickness, measured from the intersection of the outer edge of corrugation flanges and the centre line of the stool top plate, see Fig. 23.12. The stool bottom is to be installed in line with double bottom floors and is to have a width not less than 2.5 times the mean depth of the corrugation. The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders for effective support of the corrugated bulkhead. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

Where corrugations are cut at the lower stool, corrugated bulkhead plating is to be connected to the stool top plate by full penetration welds. The stool side plating is to be connected to the stool top plate and the inner bottom plating by either full penetration or deep penetration welds, see Fig. 23.13. The supporting floors are to be connected to the inner bottom by either full penetration or deep penetration welds, see Fig. 23.13.

F.4.1.2 Upper stool

The upper stool, where fitted, is to have a height generally between 2 and 3 times the depth of corrugations. Rectangular stools are to have a height generally equal to 2 times the depth of corrugations, measured from the deck level and at hatch side girder. The upper stool is to be properly supported by girders or deep brackets between the adjacent hatch-end beams.

The width of the stool bottom plate is generally to be the same as that of the lower stool top plate. The stool top of non rectangular stools is to have a width not less then 2 times the depth of corrugations. The thickness and material of the stool bottom plate are to be the same as those of the bulkhead plating below. The thickness of the lower portion of stool side plating is not to be less than 80 % of that required for the upper part of the bulkhead plating where the same material is used. The thickness of the stool side plating and the section modulus of the stool side stiffeners is not to be less than required according to Section 11, B on the basis of the load model in F.2. The ends of stool side stiffeners are to be attached to brackets at the upper and lower ends of the stool. Diaphragms are to be fitted inside the stool in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders for effective support of the corrugated bulkhead. Scallops in the brackets and diaphragms in way of the connection to the stool bottom plate are to be avoided.

F.4.1.3 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 Fig. 23.13. 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.

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.

F.4.2 Bending capacity and shear stress τ

The bending capacity is to comply with the following relationship:

$$\frac{M}{0.5 \cdot W_{le} \cdot \sigma_{a,le} + W_m \cdot \sigma_{a,m}} \cdot 10^3 \le 0.95$$

M : bending moment according to F.3.2

W_{le} : section modulus of one half pitch corrugation $[cm^3]$, at the lower end of corrugations, to be calculated according to F.4.3

W_m : section modulus of one half pitch corrugation $[cm^3]$, at the mid-span of corrugations, to be calculated according to F.4.4

$\sigma_{a,le}$: allowable stress according to F.4.5 for the lower end of corrugations

$\sigma_{a,m}$: allowable stress according to F.4.5 for the mid-span of corrugations

In no case is W_m to be taken greater than the lesser of $1.15 \cdot W_{le}$ and $1.15 \cdot W'_{le}$ for calculation of the bending capacity, W'_{le} being defined below.

In case shedders plates are fitted which:

- are not knuckled
- are welded to the corrugations and the top of the lower stool by one side penetration welds or equivalent
- are fitted with a minimum slope of $45\,°$ and their lower edge is in line with the stool side plating
- have thicknesses not less than $75\ \%$ of that provided by the corrugation flange
- and material properties at least equal to those provided by the flanges

or gusset plates are fitted which:

- are in combination with shedder plates having thickness, material properties and welded connections in accordance with the above requirements
- have a height not less than half of the flange width
- are fitted in line with the stool side plating
- are generally welded to the top of the lower stool by full penetration welds, and to the corrugations and shedder plates by one side penetration welds or equivalent
- have thickness and material properties at least equal to those provided for the flanges

the section modulus W_{le} is to be taken not larger than the value W'_{le} which is to be determined by the following formula:

$$W'_{le} = W_g + \frac{Q \cdot h_g - 0.5 \cdot h_g^2 \cdot e_1 \cdot p_g}{\sigma_a} \cdot 10^3 \quad [cm^3]$$

W_g : section modulus of one half pitch corrugation $[cm^3]$, of the corrugations calculated, according to F.4.4, in way of the upper end of shedder or gusset plates, as applicable

Q : shear force according to F.3.3

h_g : height of shedders or gusset plates $[m]$, as applicable (see Fig. 23.10 and Fig. 23.11)

e_1 : spacing $[m]$ of corrugations, see Fig. 23.8

p_g : resultant pressure according to F.2.5, calculated in way of the middle of the shedders or gusset plates, as applicable

σ_a : allowable stress according to F.4.5

Stresses τ are obtained by dividing the shear force Q by the shear area. The shear area is to be reduced in order to account for possible non-perpendicularity between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multi- plying the web sectional area by ($\sin\phi$), ϕ being the angle between the web and the flange (see Fig. 23.8).

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 F.4.3 and F.4.4.

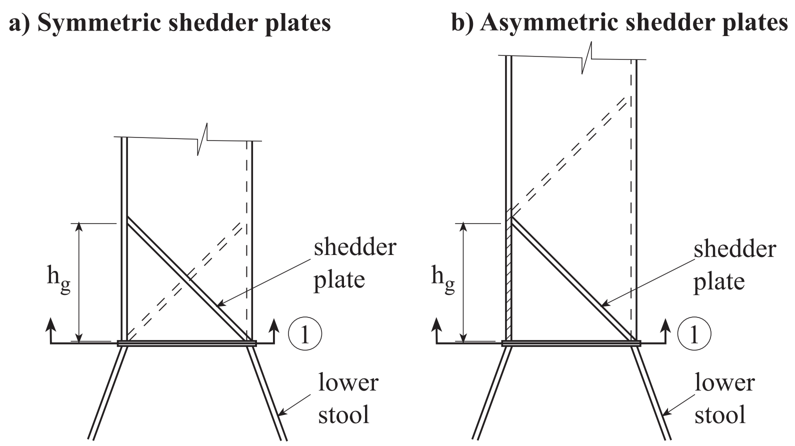


Fig. 23.10 Shedder plates

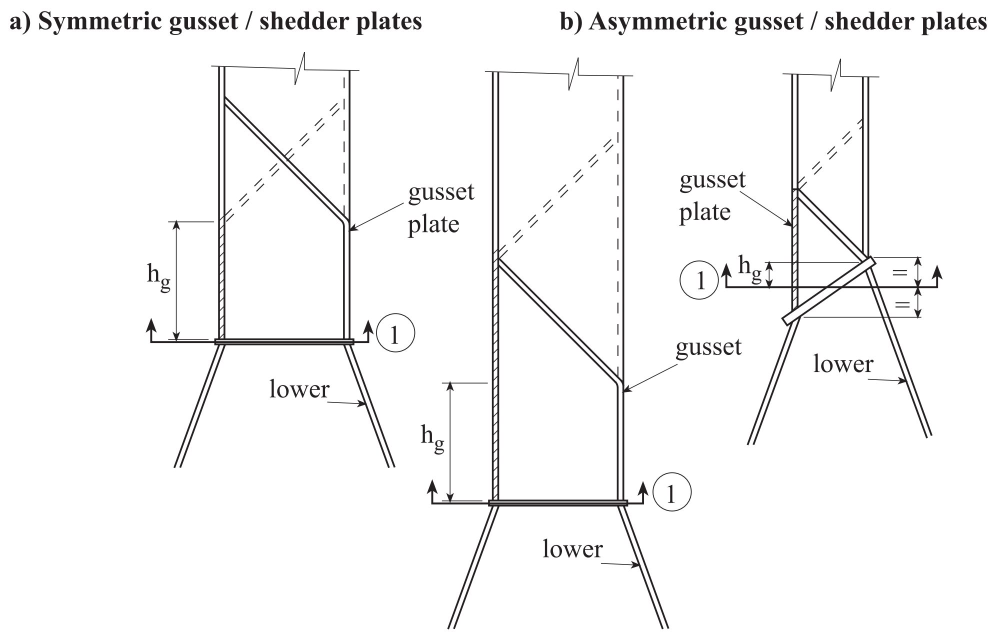


Fig. 23.11 Gusset plates and shedder plates

F.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 F.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.

1. Provided that effective shedder plates, as defined in F.4.2, are fitted (see Fig. 23.10), when calculating the section modulus of corrugations at the lower end (cross-section 1 in Fig. 23.10), the area of flange plates ΔA_f may be increased by

$$\Delta A_f = 2.5 \cdot b \cdot \sqrt{t_f \cdot t_{sh}} \quad [\mathrm{cm}^2] \qquad \text{with } \Delta A_f \le 2.5 \cdot b \cdot t_f \quad [\mathrm{cm}^2]$$

b : width [m] of the corrugation flange, see Fig. 23.8

t_{sh} : net shedder plate thickness [mm]

t_f : net flange thickness [mm]

2. Provided that effective gusset plates, as defined in F.4.2, are fitted (see Fig. 23.11), when calculating the section modulus of corrugations at the lower end (cross-section 1 in Fig. 23.11), the area of flange plates ΔA_f may be increased by

$$\Delta A_f = 7 \cdot h_g \cdot t_f \quad [cm^2]$$

h_g : height [m] of gusset plate, see Fig. 23.11, with:

$$h_g \leq \frac{10}{7} \cdot a_{gu}$$

a_{gu} : width [m] of the gusset plates, defined as:

$$a_{gu} = 2 \cdot e_1 - b$$

t_f : net flange thickness [mm] based on the as built condition

3. If the corrugation webs are welded to a sloping stool top plate which has 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 1. 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 °.

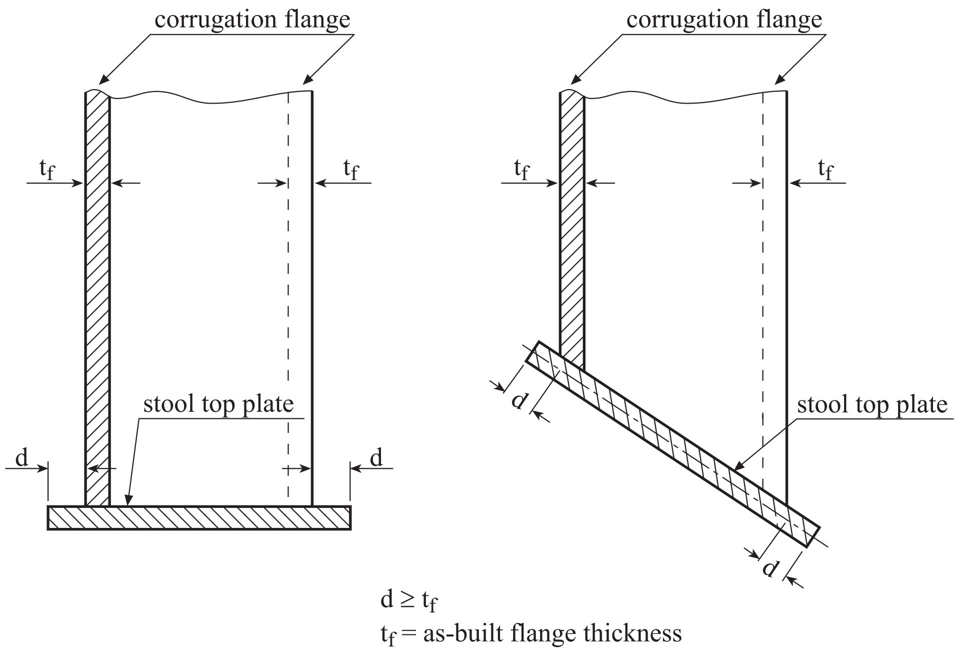
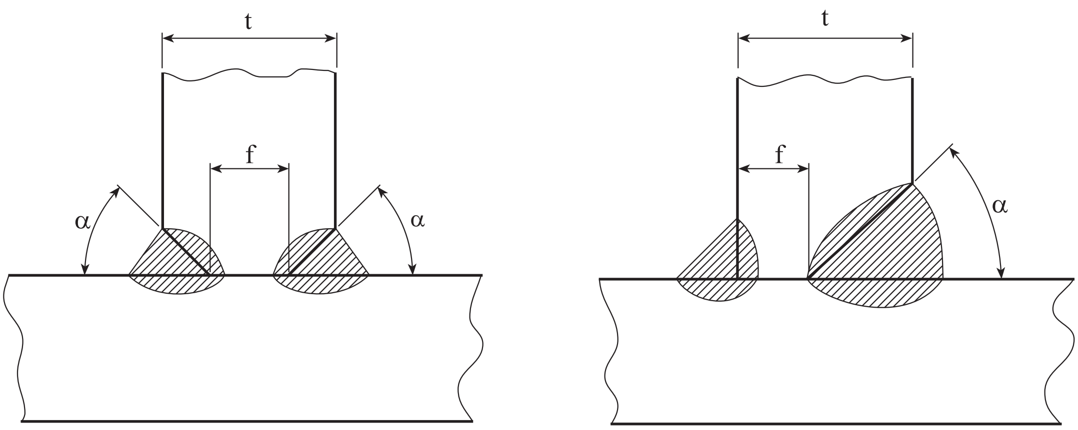


Fig. 23.12 Excess end d of the stool top plate



Root face f : 3 mm to t/3 mm

Groove angle α : 40° to 60°

Fig. 23.13 Connection by deep penetration welds

F.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 F.4.6.1.

F.4.5 Allowable stress check

The normal and shear stresses σ and τ are not to exceed the allowable values σ_a and τ_a which are defined as:

$$\sigma_a = R_{eH}$$

$$\tau_a = 0.5 \cdot R_{eH}$$

F.4.6 Effective compression flange width and shear buckling check

F.4.6.1 Effective width of the compression flange of corrugations

The effective width b_{ef} [m], of the corrugation flange is calculated according to Section 3, D.

F.4.6.2 Shear buckling

The buckling check for the web plates at the corrugation ends is to be performed according to Section 3, D. The buckling factor is to be taken as follows:

$$K = 6.34 \cdot \sqrt{3}$$

The shear stress τ has to be taken according to F.4.2 and the safety factor S is 1.05.

F.4.7 Local net plate thickness

The bulkhead local net plate thickness t_{net}, is to be determined by the following formula:

$$t_{net} = 14.9 \cdot a_w \cdot \sqrt{\frac{1.05 \cdot p}{R_{eH}}} \quad [\text{mm}]$$

a_w : plate width [m], to be taken equal to the width of the corrugation flange or web, whichever is the greater, see Fig. 23.8

p : resultant pressure [kN / m²], as defined in F.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

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 $t_{net,n}$ is to be determined by the following formula:

$$t_{net,n} = 14.9 \cdot a_n \cdot \sqrt{\frac{1.05 \cdot p}{R_{eH}}} \quad [\mathrm{mm}]$$

a_n : width [m] of the narrower plating, see Fig. 23.8

The net thickness t_w of the wider plating is to be determined by the following formulae:

$$t_w = \max\left[t_{w1} \,;\, t_{w2}\right]$$

$$t_{w1} = 14.9 \cdot a_w \cdot \sqrt{\frac{1.05 \cdot p}{R_{eH}}}$$

$$t_{w2} = \sqrt{\frac{440 \cdot a_w^2 \cdot 1.05 \cdot p}{R_{eH}} - t_{np}^2}$$

t_{np} : actual net thickness [mm] of the narrower plating, with:

$$t_{np} \le t_{w1}$$

F.5 Shedder and gussed plates

The thickness and stiffening of effective gusset and shedder plates, as defined in F.4.3, is to determined according to Section 12, B on the basis of the load model in F.2.

F.6 Corrosion addition and steel renewal

The corrosion addition t_K is to be taken equal to 3.5 mm.

G Harmonised Notations and Corresponding Design Loading Conditions for Bulk Carriers

G.1 Application

G.1.1 These requirements are applicable to bulk carriers as defined in A.3 having a length $\mathbf{L}$ of 150 m or above. The consideration of the following requirements is recommended for ships having a length $\mathbf{L} < 150$ m.

G.1.2 The loading conditions listed under G.3 are to be checked regarding longitudinal strength as required by Section 5, local strength, capacity and disposition of ballast tanks and stability. The loading conditions listed under G.4 are to be checked regarding local strength.

G.1.3 For the loading conditions given in this document, maximum draught is to be taken as moulded summer load line draught.

G.1.4 These requirement are not intended to prevent any other loading conditions to be included in the loading manual for which calculations are to be submitted see Section 5, nor is it intended to replace in any way the required loading manual/instrument.

G.1.5 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.

G.2 Harmonized notations and annotations

G.2.1 Notations

Bulk Carriers are to be assigned one of the following notations.

BC-C: for bulk carriers designed to carry dry bulk cargoes of cargo density less than $1.0\ \mathrm{t/m^3}$.

BC-B: for bulk carriers designed to carry dry bulk cargoes of cargo density of $1.0\ \mathrm{t/m^3}$ and above with all cargo holds loaded in addition to **BC-C** conditions.

BC-A: for bulk carriers designed to carry dry bulk cargoes of cargo density of $1.0\ \mathrm{t/m^3}$ and above with specified holds empty at maximum draught in addition to **BC-B** conditions.

G.2.2 Additional Notations

The following additional Notations 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:

- **{maximum cargo density ... t/m3}** for Notations **BC-A** and **BC-B** if the maximum cargo density is less than $3.0\ \mathrm{t/m^3}$
- **{no MP}** for all Notations when the vessel has not been designed for loading and unloading in multiple ports in accordance with the conditions specified in G.5.3
- **{holds, a, b, ... may be empty}** for Notation **BC-A**

G.3 Design loading conditions (general)

G.3.1 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.

G.3.2 BC-B

As required for **BC-C**, plus:

Homogeneous cargo loaded condition with cargo density $3.0\ \mathrm{t/m^3}$, and the same filling ratio (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 $3.0\ \mathrm{t/m^3}$, the maximum density of the cargo that the vessel is allowed to carry is to be indicated with the additional Notation **{maximum cargo density ... $\mathbf{t/m^3}$}**.

G.3.3 BC-A

As required for **BC-B**, plus:

At least one cargo loaded condition with specified holds empty, with cargo density $3.0\ \mathrm{t/m^3}$, and the same filling ratio (cargo mass/hold cubic capacity) in all loaded cargo holds at maximum draught with all ballast tanks empty.

The combination of specified empty holds is to be indicated with the additional Notation **{holds a, b, ... may be empty}**.

In such cases where the design cargo density applied is less than $3.0\ \mathrm{t/m^3}$, the maximum density of the cargo that the vessel is allowed to carry is to be indicated within the additional Notation, e.g. **{holds a, b, ... may be empty; maximum cargo density $\mathbf{t/m^3}$}**.

G.3.4 Ballast conditions (applicable to all Notations)

G.3.4.1 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 for normal and heavy ballast condition:

Normal ballast condition for the purpose of these requirements is a ballast (no cargo) condition where:

- the ballast tanks may be full, partially full or empty. Where partially full option is exercised, the conditions in Section 5, B.4 are to be complied with
- any cargo hold or holds adapted for the carriage of water ballast at sea are to be empty
- the propeller is to be fully immersed
- the trim is to be by the stern and is not to exceed $0.015\ L$, where L is 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.

Heavy ballast condition for the purpose of these requirements is a ballast (no cargo) condition where:

- the ballast tanks may be full, partially full or empty. Where partially full option is exercised, the conditions in Section 5, B.4 are to be complied with,
- at least one cargo hold adapted for carriage of water ballast at sea, where required or provided, is to be full,
- the propeller immersion I / D is to be at least $60\ \%$ where:
- the trim is to be by the stern and is not to exceed $0.015\ L$, where L is the length between perpendiculars of the ship, and
- the moulded forward draught in the heavy ballast condition is not to be less than the smaller of $0.03\ L$ or $8\ m$.

I : distance from propeller centreline to the waterline

D : propeller diameter

G.3.4.2 Strength requirements

All bulk carriers are to meet the following strength requirements:

Normal ballast condition:

- the structures of bottom forward are to be strengthened in accordance with the GL Rules against slamming for the condition at the lightest forward draught,
- the longitudinal strength requirements according to Section 5, E are to be met for the condition of G.3.41 for normal ballast, and
- in addition, the longitudinal strength requirements of according to Section 5, E are to be met with all ballast tanks $100\ \%$ full.

Heavy ballast condition:

- the longitudinal strength requirements according to Section 5, E are to be met for the condition of G.3.4.1 for heavy ballast
- in addition, the longitudinal strength requirements according to Section 5, E are to be met with all ballast tanks $100\ \%$ full and any one cargo hold adapted for the carriage of water ballast at sea, where provided, $100\ \%$ full
- 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.

G.4 Departure and arrival conditions

Unless otherwise specified, each of the design loading conditions defined in G.3.1 to G.3.4 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

G.5 Design loading conditions (for local strength)

G.5.1 Definitions

The maximum allowable or minimum required cargo mass in a cargo hold, or in two adjacently loaded holds, is related to the net load on the double bottom. The net load on the double bottom is a function of draft, cargo mass in the cargo hold, as well as the mass of fuel oil and ballast water contained in double bottom tanks.

The following definitions apply:

M_H : the actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught

M_{Full} : the cargo mass in a cargo hold corresponding to cargo with virtual density (homogeneous mass/hold cubic capacity, minimum $1.0\ t/m^3$) filled to the top of the hatch coaming. M_{Full} is in no case to be less than M_H.

M_{HD} : the maximum cargo mass allowed to be carried in a cargo hold according to design loading condition(s) with specified holds empty at maximum draught

G.5.2 General conditions applicable for all Notations

G.5.2.1 Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being $100\ \%$ full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught.

G.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.

G.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.

G.5.3 Condition applicable for all Notations, except when Notation {no MP} is assigned

G.5.3.1 Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being $100\ \%$ full and ballast water tanks in the double bottom in way of the cargo hold being empty, at $67\ \%$ of maximum draught.

G.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.

G.5.3.3 Any two adjacent cargo holds are to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being $100\ \%$ full and ballast water tanks in the double bottom in way of the cargo hold being empty, at $67\ \%$ of the maximum draught. This requirement to the mass of cargo and fuel oil in double bottom tanks in way of the cargo hold applies also to the condition where the adjacent hold is fitted with ballast, if applicable.

G.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.

G.5.4 Additional conditions applicable for BC-A Notation only

G.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.

G.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 is to be limited to M_{HD}.

G.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 is to be limited to the maximum cargo load according to the design loading conditions.

G.5.5 Additional conditions applicable for ballast hold(s) only

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 is to be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty.

G.5.6 Additional conditions applicable during loading and unloading in harbour only

G.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.

G.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.

G.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 is not to exceed the mass allowed at maximum draught in the sea-going condition.

The minimum required mass may be reduced by the same amount.

G.5.7 Hold mass curves

Based on the design loading criteria for local strength, as given in G.5.2 to G.5.6 (except G.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 C.9.

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.

H Fitting of a Forecastle for Bulk Carriers, Ore Carriers and Combination Carriers

H.1 Application

All bulk carriers, ore carriers and combination carriers are to be fitted with an enclosed forecastle on the freeboard deck.

The structural arrangements and scantlings of the forecastle are to comply with the requirements of Section 16.

(IACS UR S28.1)

H.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 (see Fig. 23.14).

The forecastle height, H_F [m], above the main deck is not to be less than the greater of:

H_F = the standard height of a superstructure as specified in the **ICLL**, or

$$H_F = H_c + 0.5$$

H_c : height $[m]$ of the forward transverse hatch coaming of cargo hold No. 1

In order to use the reduced design loads for the forward transverse hatch coaming (see Section 17, B.2) and hatch cover stoppers (see Section 17, B.5.5) of the foremost cargo hold, the distances between all points of the aft edge of the forecastle deck and the hatch coaming plate, ℓ_F [m], are to comply with the following (see Fig. 23.14):

$$\ell_F = 5 \cdot \sqrt{H_F - H_c} \quad [m]$$

A breakwater is not to be fitted on the forecastle deck for the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, the distance between its upper edge at centre line and the aft edge of the forecastle deck, ℓ_B [m], is to comply with the following (see Fig. 23.14):

$$\ell_B \geq 2.75 \cdot H_B \quad [m]$$

H_B : height $[m]$ of the breakwater above the forecastle

(IACS UR S28.2)

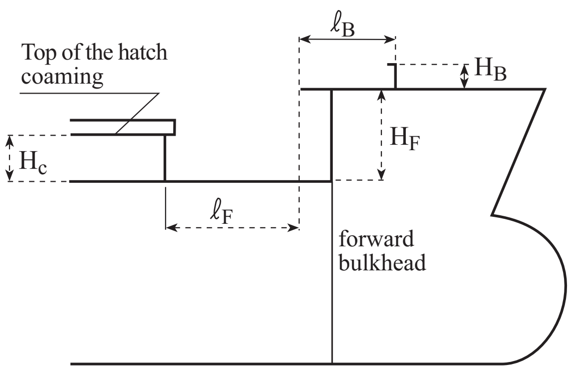


Fig. 23.14 Dimensions of the forecastle

I Transport of Steel Coils in Multi-Purpose Dry Cargo Ships

I.1 General

I.1.1 The requirements of this section are valid for ships with longitudinal framing and vertical longitudinal bulkheads. Ships with other construction are to be considered separately.

I.1.2 The equations for calculation of the distance between the outermost patch loads within a plate field c, the number of steel coils within one row athwartships n_5 and the number of tiers n_1 in I.2 and I.3 may be used, if a direct determination based on stowing arrangement plans is not possible.

I.1.3 The "Code of Safe Practice for Cargo Stowage und Securing" (IMO Res. A714(17) as amended) has to be observed for the stowage of steel coils in seagoing ships. Especially sufficient supporting of coils by means of dunnages laid athwartships has to be observed.

I.2 Inner bottom plating

The plate thickness t of inner bottom is not to be less than determined by the following formula:

$$t = 1.15 \cdot K_1 \cdot \sqrt{\frac{P}{\sigma_{pl}}} + t_k \quad [mm]$$

K_1 : coefficient, defined as:

$$K_1 = \sqrt{\frac{1.7 \cdot a \cdot b \cdot K_2 - 0.73 \cdot a^2 \cdot K_2^2 - (b-c)^2}{2 \cdot c \cdot (2 \cdot a + 2 \cdot b \cdot K_2)}}$$

K_1 : coefficient, defined as:

$$K_2 = -\frac{a}{b} + \sqrt{\left(\frac{a}{b}\right)^2 + 1.37\left(\frac{b}{a}\right)^2 \cdot \left(1 - \frac{c}{b}\right)^2 + 2.33}$$

c : distance $[m]$ between outermost patch loads in a plate field, defined as:

$$c = (n_2 - 1) \cdot \frac{\ell_c}{n_3} + c_d \cdot \ell_c \cdot (n_4 - 1)$$

n_1 : number of tiers of coils, defined as:

$n_1 = 1.4$ for one tier, secured with key coils

n_2 : number of patch loads per plate field, see also Fig. 23.15, defined as:

$$n_2 = n_3 \cdot \left(\frac{b}{\ell_c} - c_d \cdot (n_4 - 1)\right)$$ in general

$$n_2 = n_3 \cdot n_4$$ for $(n_3 - 1) \cdot \frac{\ell_c}{n_3} < b - (1 + c_d) \cdot \ell_c \cdot (n_4 - 1)$

n_2 has to be rounded up to the next integer

n_3 : number of dunnages per coil, see Fig. 23.15

n_4 : number of coils per plate field, see Fig. 23.15, whereat

$$n_4 = \frac{b}{(1 + c_d) \cdot \ell_c}$$

n_4 has to be rounded up to the next integer

P : mass force $[N]$ including acceleration addition, defined as:

$$P = F_p \cdot (1 + a_v)$$

F_p : mass force $[N]$ acting on one plate field $[N]$, defined as:

$$F_p = 9.81 \cdot \frac{W \cdot n_1 \cdot n_2}{n_3}$$

$\sigma_{p\ell}$: permissible local design stress $[N/mm^2]$, defined as:

$$\sigma_{pl} = \sqrt{\sigma_{perm}^2 - 0.786 \cdot \sigma_{perm} \cdot \sigma_{LI} - 3 \cdot \tau_L^2} - 0.062 \cdot \sigma_{LI}$$

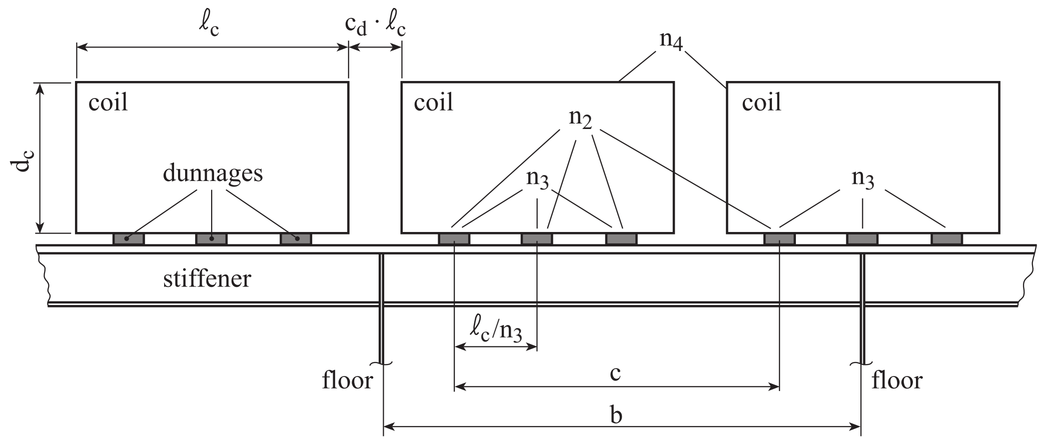


Fig. 23.15 Exemplary arrangement for determination of n_2, n_3 and n_4

Note

As a first approximation σ_{LI} and τ_L may be taken as follows:

$$\sigma_{LI} = \frac{12{,}6\sqrt{\mathbf{L}}}{k} \quad [N/mm^2] \quad \text{for } \mathbf{L} < 90\ m$$

$$= \frac{120}{k} \quad [N/mm^2] \quad \text{for } \mathbf{L} \geq 90\ m$$

$$\tau_L = 0 \quad [N/mm^2]$$

I.3 Plating of longitudinal bulkhead

The plate thickness of the longitudinal bulkhead at least to a height of one frame distance above the highest possible contact line with the steel coil loading is not to be less than determined by the following formula:

$$t = K_1 \cdot \sqrt{\frac{P^*}{\sigma_{pl}}} + t_k \quad [mm]$$

K_1 : coefficient according to I.2

P^* : mass force [N] including acceleration addition, defined as:

$$P^* = F_p^* \cdot \left(a_y - \mu \cdot \cos\varphi\right)$$

$F_P{}^*$: mass force [N] acting on one plate field, defined as:

$$F_P^* = 9.81 \cdot \frac{W \cdot n_2 \cdot n_5}{n_3}$$

n_2 : number of patch loads per plate field according to I.2

n_3 : number of dunnages per coil, see Fig. 23.15

n_5 : number of coils in one row athwardships, defined as:

$$n_5 = \frac{B_H}{d_c} + n_6$$

n_6 relative number of steel coils in upper rows, defined as:

$n_6 = 0$ for $n_1 = 1$

n_6 = number of key coils for $n_1 = 1.4$

$n_6 = B_H / d_c - 1$ for $n_1 = 2$

$n_6 = 2 \cdot B_H / d_c - 3$ for $n_1 = 3$

B_H / d_c has to be rounded up to the next integer for determination of n_5 and n_6

$\sigma_{p\ell}$: permissible local design stress $[N / mm^2]$, defined as:

$$\sigma_{pl} = \sqrt{\sigma_{perm}^2 - 0.786 \cdot \sigma_{perm} \cdot \sigma_{LL} - 3 \cdot \tau_L^2} - 0.062 \cdot \sigma_{LL}$$

For sloping plates (e.g. Hopper plates) additional forces have to be observed for the calculation of P^*. Furthermore the force components rectangular to the plate have to be determined.

Note

As a first approximation σ_{LI} and τ_L may be taken as follows:

$\sigma_{LL} = 0{,}76 \cdot \sigma_{LI}$

$\tau_L = \dfrac{55}{k} \quad [N/mm^2]$

σ_{LI} = *see 2.*

I.4 Scantlings of longitudinal stiffeners

I.4.1 Analysis model

The scantlings of the longitudinals of inner bottom and side structure have to be determined by using simple beam theory.

For this purpose the beams have to be loaded according to the possible load combinations for the coils.

Boundary conditions for the beam model have to be selected with respect to the intersection details at floors and web frames.

I.4.2 Loads

The forces have to be determined with respect to the expected load combinations of coils. If this is not known, estimations according to I.2 and I.3 can be made as follows:

Inner bottom:

- Acting mass per dunnage = F_p / n_2, accelerated by a_v according to Section 4, A.3.

Side structure:

- Acting mass per dunnage = F_P^* / n_2, accelerated by $(ay - \mu \cdot \cos\varphi)$, see also I.3

The stresses caused by global ship deflections have to be superposed.

I.4.3 Permissible stresses

The permissible stresses of Section 9, C.3 have to be observed.

The permissible shear stress is $100 / k \; [N / mm^2]$.

Sufficient shear area at intersections between longitudinals and floors or web frames has to be considered. Furthermore sufficient strength of heel stiffeners has to be observed.

I.4.4 Strengthening of side structure

Appropriate reinforcement has to be arranged in way of the contact line of the steel coils with the longitudinal bulkhead e.g. a longitudinal stiffener or stringer.

J Strengthening within the working range of grabs

J.1 General

To assign the Notation **G** to the Certificate behind the Character of Classification the requirements in J.2 – J.4 are to be fulfilled.

J.2 Horizontal plate fields and tank side slopes

The plate thickness t_G of horizontal plate fields and tank side slopes are to be determined by the following formula:

$$t_G = (0.1 \cdot \mathbf{L} + 5) \cdot \sqrt{k} \quad [\text{mm}] \qquad \text{with } t_G \leq 30 \text{ mm}$$

Note

The stressing of horizontal plate fields depends mainly on the use of grabs, therefore, damage of plating cannot be excluded, even in case of compliance with the above recommendation.

J.3 Hatchway coamings

The scantlings of the hatchway coaming plates are to be determined such as to ensure efficient protection against mechanical damage by grabs.

Wire rope grooving in way of cargo holds openings is to be prevented by fitting suitable protection such as half-round bar on the hatch side girders (i.e. upper portion of top side tank plates), hatch end beams in cargo hold and upper portion of hatch coamings.

The coaming plates are to have a minimum thickness of 15 mm. Stays are to be fitted at every alternate frame. The longitudinal hatchway coamings are to be extended in a suitable manner beyond the hatchway corners.

J.4 Longitudinal bulkheads

Longitudinal bulkheads exposed to grabs have got a general corrosion addition according to Section 3, G of $t_K = 2.5$ mm.

Section 24 Tankers

A General

A.1 Application

A.1.1 Ships intended to get the Notation **OIL TANKER** (as engaged to carry “oil” as defined in A.3) or **PRODUCT TANKER** (as engaged to carry oil other than “crude oil” as defined in A.3) are to be in compliance with this section.

A.1.2 Ships intended to get Notations for "tankers for special cargoes" like **SPECIAL TANKER**, **ASPHALT TANKER**, **EDIBLE OIL TANKER**, **WINE TANKER** or **FRUIT JUICE CARRIER** are to be in compliance with this section.

A.1.3 Ships intended to get the Notation **BC / OIL TANKER**, **ORE CARRIER / OIL TANKER** or **ORE CARRIER / PRODUCT TANKER** are to be in compliance with M.

A.1.4 Unless specially mentioned in this Section the requirements of Sections 1 to 22 and 27 apply.

For ships of 5 000 GT and more intended to get the Notation **OIL TANKER** the stability requirements of MARPOL 73/78 apply. For all other ships intended to get one oh the Notations mentioned in A.1.1 – A.1.3 the stability requirements of Section 28 apply.

A.1.5 The following requirements apply to tankers which are intended to carry oil in bulk having a flashpoint (closed cup test) not exceeding 60 °C and whose Reid vapour pressure is below that of atmospheric pressure and other liquid products having a similar fire hazard.

A.1.6 Products listed in the Product List 2 (at the end of this Section) are permitted to be carried in tankers complying with the requirements of this Section. Products whose Reid vapour pressure is above that of atmospheric pressure may only be carried where the cargo tank vents are fitted with pressure/vacuum relief valves (see the GL Rules for Machinery Installations (I-1-2), Section 15) and the tanks have been dimensioned for the set pressure of the pressure relief valves.

Note

1. *In accordance with the provisions of **MARPOL 73/78**, Annex II the carriage in bulk of category Z products is permitted only on vessels holding an "International Pollution Prevention Certificate for the Carriage of Noxious Liquid Substances in Bulk" issued by the Flag Administration.*

2. *The petrochemicals listed in the list of products of the IBC-Code, Chapter 17, and products of similar hazard are not subject to the provisions of this Section.*

A.1.7 For tankers intended to carry liquids in bulk having a flashpoint (closed cup test) above 60 °C only, the requirements of this Section concerning safety, e.g. according to B.3.3, B.4.5, D.3 etc., need not be complied with.

Where, however, these products are heated to a temperature above 15 °C below their flashpoint the vessels will be specially considered.

Note

*It is assumed that the provisions of Annex I and, as far as applicable, of Annex II of **MARPOL 73/78** will be complied with.*

*Upon application a declaration confirming the compliance with the provisions **of MARPOL 73/78** will be issued.*

*Tankers not complying with the Annex I provisions will not be assigned the notation **OIL TANKER** or **PRODUCT TANKER**.*

*For a type "A" ship, if over 150 m length, to which a freeboard less than type "B" has been assigned the **ICLL** Regulation 27.3 has to be considered.*

A.2 References

A.2.1 Where cargo is intended to be heated Section 12, I is also to be observed.

A.2.2 The requirements of this Section include the provisions of Chapter II-2 of **SOLAS 74** applicable to tankers as far as provisions affecting the lay-out and structural design of the vessels are concerned.

For the remaining fire safety measures of the above mentioned provisions, see Section 22, F and the GL Rules for Machinery Installations (I-1-2), Section 12 and 15.

A.3 Definitions

Accommodation spaces

Accommodation spaces are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, barber shops, pantries containing no cooking appliances and similar spaces. Public spaces are those portions of the accommodation spaces which are used for halls, dining rooms, lounges and similar permanently enclosed spaces.

Control stations

Control stations are those spaces in which ship's radio or main navigating equipment or the emergency source of power is located or where the fire-recording or fire-control equipment is centralized. This does not include special fire-control equipment which can be most practically located in the cargo area.

Cofferdam

Cofferdam is the isolating space between two adjacent steel bulkheads or decks. This space may be a void space or a ballast space.

The following spaces may also serve as cofferdams: oil fuel tanks as well as cargo pump rooms and pump rooms not having direct connection to the machinery space, passage ways and accommodation spaces. The clear spacing of cofferdam bulkheads is not to be less than 600 mm.

Cargo service spaces

Cargo service spaces are spaces within the cargo area used for workshops, lockers and storerooms of more than 2 m^2 in area used for cargo handling equipment.

Cargo deck

Cargo deck means an open deck within the cargo area, which forms the upper crown of a cargo tank; or above which cargo tanks, tank hatches, tank cleaning hatches, tank gauging openings and inspection holes as well as pumps, valves and other appliances and fittings required for loading and discharging are fitted.

Cargo pump room

Cargo pump room is a space containing pumps and their accessories for the handling of products covered by this Section.

Cargo area

Cargo area is that part of the ship that contains cargo tanks, slop tanks, cargo pump rooms including pump rooms, cofferdams, ballast or void spaces adjacent to cargo tanks or slop tanks and also deck areas throughout the entire length and breadth of the part of the ship over the above-mentioned spaces.

Where independent tanks are installed in hold spaces, cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forward most hold space are excluded from the cargo area.

Crude oil

For the purpose of this Section crude oil means any liquid hydrocarbon mixture occurring naturally in the earth whether or not treated to render it suitable for transportation and includes:

- crude oil from which certain distillate fractions may have been removed, and
- crude oil to which certain distillate fractions may have been added

Flashpoint

Flashpoint is the temperature in degrees Celsius [°C] at which a product will give off enough flammable vapour to be ignited.

Hold space

Hold space is a space enclosed by the ship's structure in which an independent cargo tank is situated.

Machinery spaces

Machinery spaces are all machinery spaces of Category A and all other spaces containing propelling machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces; and trunks to such spaces.

Machinery spaces of Category A

Machinery spaces of Category A are those spaces and trunks to such spaces which contain:

- internal combustion machinery used for main propulsion; or
- internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
- any oil-fired boiler or oil fuel unit

Oil

For the purpose of this Section oil means petroleum in any form including crude oil, refined products, sludge and oil refuse (see also Product List 1 at the end of this Section).

Oil fuel unit

Oil fuel unit is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 1.8 bar (gauge).

Pump room

Pump room is a space, located in the cargo area, containing pumps and their accessories for the handling of ballast and oil fuel.

Service spaces

Service spaces are those spaces used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, store-rooms, workshops other than those forming part of machinery spaces and similar spaces and trunks to such spaces.

Slop tank

Slop tank is a tank for the retention of oil residues and oily wash water residues according to Reg. 1.15 of Annex I of **MARPOL 73/78**.

Void space

Void space is an enclosed space in the cargo area external to a cargo tank other than a hold space, ballast space, oil fuel tank, cargo pump room, pump room, or any space in normal use by personnel.

Symbols

k : material factor according to Section 2, A.2

p_{T1}, p_{T2} : loads on filled tanks according to Section 4, D.1

p_{T3} : load on partial filled tanks according to Section 4, D.2

p_v : pressure [bar] according to Section 4, A.3

B Arrangement

B.1 General

Oil or other flammable liquids are not permitted to be carried in the fore- or afterpeak.

B.2 Cargo tank arrangement

B.2.1 General

B.2.1.1 Every oil tanker of 600 tdw and above is to comply with the double hull requirements of MARPOL 73/78, Annex I, Reg. 19.

B.2.1.2 Tanks or spaces within the double hull required in accordance with the provisions of B.2.2 and B.2.3 are not to be used for the carriage of cargo and fuel oil.

B.2.1.3 For access to spaces in the cargo area F is to be observed.

B.2.1.4 Concerning the definition of "deadweight" (tdw) reference is made to MARPOL 73/78, Annex I, Reg. 1.23

Note

*The aggregate capacity of wing tanks, double bottom tanks, forepeak tanks and afterpeak tanks is not to be less than the capacity of segregated ballast tanks necessary to meet the requirements of **MARPOL 73/78**, Annex I, Regulation 18. Wing tanks, spaces and double bottom tanks used to meet the requirements of **MARPOL 73/78**, Annex I, Regulation 18 are to be located as uniformly as practicable along the cargo tank length. For inerting, ventilation and gas measurement see the GL Rules for Machinery Installations (I-1-2), Section 15.*

B.2.2 Double hull requirements for oil tankers of 5 000 tdw and above

B.2.2.1 The entire cargo tank length is to be protected by a double side (wing tanks or spaces) and double bottom tanks or spaces as outlined in the following paragraphs.

B.2.2.2 Double side

Wing tanks or spaces are to extend either for the full depth of the ship's side or from the top of the double bottom to the uppermost deck, disregarding a rounded gunwale where fitted. They are to be arranged such that the cargo tanks are located inboard of the moulded line of the side shell plating, nowhere less than the distance w which is measured at every cross-section at right angles to the side shell as specified below:

$$w = 0.5 + \frac{tdw}{20\,000} \quad [m] \qquad \text{with } 1.0 \le w \le 2.0 \text{ m}$$

B.2.2.3 Double bottom

At any cross-section the depth of each double bottom tank or space is to be such that the distance h between the bottom of the cargo tanks and the moulded line of the bottom shell plating measured at right angles to the bottom shell plating is not less than:

$$h = \frac{\mathbf{B}}{15} \quad [m] \qquad \text{with } 1.0 \le h \le 2.0 \text{ m}$$

In the turn of bilge area or at locations without a clearly defined turn of bilge, where the distances h and w are different, the distance w is to have preference at levels exceeding $1.5\ h$ above the baseline. For details see **MARPOL 73/78**, Annex I, Reg. 19.3.3.

B.2.2.4 Suction wells in cargo tanks

Suction wells in cargo tanks may protrude into the double bottom below the boundary line defined by the distance h provided that such wells are as small as practicable and the distance between the well bottom and the bottom shell plating is not less than $0.5\ h$.

B.2.2.5 Alternative cargo tank arrangements

Double bottom tanks or spaces as required above may be dispensed with, if the provisions of **MARPOL 73/78**, Annex I, Reg. 19.4 or 19.5 are complied with.

B.2.2.6 Double bottom in pump room

The cargo pump room is to be provided with a double bottom, the distance h of which above the ship's base line is not less than the distances required in B.2.2.3.

Note

For pump rooms, the bottom plate of which is above this minimum height, see 22.3 of ***MARPOL 73/78****, Annex I.*

B.2.3 Double hull requirements for oil tankers of less than 5 000 tdw

B.2.3.1 Double bottom

Oil tankers of less than $5\,000$ tdw are at least to be fitted with double bottom tanks or spaces having such a depth that the distance h specified in B.2.2.3 complies with the following:

$$h = \frac{\mathbf{B}}{15} \quad [m] \qquad \text{with } h \ge h_{min}$$

h_{min} : minimum distance $[m]$, defined as:

$$h_{min} = 0.76$$

In the turn of bilge area and at locations without a clearly defined turn of bilge the tank boundary line is to run parallel to the line of the midship flat bottom.

For suction wells in cargo tanks, the provisions of B.2.2.4 apply accordingly.

B.2.3.2 Limitation of cargo tank capacity

The capacity of each cargo tank of ships less than $5\,000$ tdw is not to exceed $700\ m^3$, unless wing tanks or spaces are arranged in accordance with B.2.2.2 complying with:

$$w = 0.4 + \frac{2.4 \cdot tdw}{20\,000} \quad [m] \qquad \text{with } w_{min} = 0.76\,m$$

B.2.4 Limitation of cargo tank length

B.2.4.1 For oil and product tankers of less than $5\,000$ tdw, the length of cargo tanks measured between oil tight bulkheads is not to exceed 10 m or the values listed in Table 24.1, whichever is greater.

Table 24.1 Permissible length of cargo tanks

Number of longitudinal bulkheads within the cargo tanks	Permissible length	
–	$\ell_{ct} = \left(\frac{b_i}{2 \cdot \mathbf{B}} + 0.1\right) \cdot \mathbf{L_c}$	with $\ell_{ct,max} = 0.2 \cdot \mathbf{L_c}$
1	$\ell_{ct} = \left(\frac{b_i}{4 \cdot \mathbf{B}} + 0.15\right) \cdot \mathbf{L_c}$	with $\ell_{ct,max} = 0.2\,\mathbf{L_c}$
2 and more	Centre tanks:	
	$\ell_{ct} = 0.2 \cdot \mathbf{L_c}$	If $\frac{b_i}{\mathbf{B}} \ge 0.2$
	$\ell_{ct} = \left(\frac{b_i}{2 \cdot \mathbf{B}} + 0.1\right) \cdot \mathbf{L_c}$	if $\frac{b_i}{\mathbf{B}} < 0.2$ and no centreline longitudinal bulkhead is provided
	$\ell_{ct} = \left(\frac{b_i}{4 \cdot \mathbf{B}} + 0.15\right) \cdot \mathbf{L_c}$	If $\frac{b_i}{\mathbf{B}} < 0.2$ and a centreline longitudinal bulkhead is provided
	Wing cargo tanks: $\ell_{ct} = 0.2 \cdot \mathbf{L_c}$	
b_i = minimum distance from the ship's side to inner hull of the tank in question measured inboard at right angles to the centreline at the level corresponding to the summer load line.		

B.2.4.2 Where the tank length exceeds $0.1\ \mathbf{L}$ and/or the tank breadth exceeds $0.6\ \mathbf{B}$ calculations have to be carried out in accordance with Section 12, C.1. to examine if the motions of liquids in partially filled tanks will be in resonance with the pitching or heeling motions of the vessel.

Note

*Reference is also made to **MARPOL 73/78**, Annex I, Reg. 23 concerning limitation of cargo tank sizes.*

B.3 Ship arrangement

B.3.1 General

The requirements according to B.3.2.2 – B.3.2.4, B.3.2.8 – B.3.2.10 and B.3.3.1 – B.3.3.3 apply to ships of 500 t gross tonnage and over.

B.3.2 Location and separation of spaces

B.3.2.1 Cargo tanks are to be segregated by means of cofferdams from all spaces which are situated outside the cargo area (see also B.3.2.5 – B.3.2.7).

A cofferdam between the forward cargo tank and the forepeak may be dispensed with if the access to the forepeak is direct from the open deck, the forepeak air and sounding pipes are led to the open deck and portable means are provided for gas detection and inerting the forepeak.

B.3.2.2 Machinery spaces are to be positioned aft of cargo tanks and slop tanks; they are also to be situated aft of cargo pump-rooms and cofferdams, but not necessarily aft of the oil fuel tanks. Any machinery space is to be isolated from cargo tanks and slop tanks by cofferdams, cargo pump-rooms, oil fuel tanks or ballast tanks. Pump-rooms containing pumps and their accessories for ballasting those spaces situated adjacent to cargo tanks and slop tanks and pumps for oil fuel transfer may be considered as equivalent to a cargo pump-room within the context of this regulation, provided that such pump-rooms have the same safety standard as that required for cargo pump-rooms. However, the lower portion of the pump-room may be recessed into machinery spaces of Category A to accommodate pumps, provided that the deck head of the recess is in general not more than one third of the moulded depth above the keel, except that in the case of ships of not more than 25 000 tdw, where it can be demonstrated that for reasons of access and satisfactory piping arrangements this is impracticable, a recess in excess of such height, but not exceeding one half of the moulded depth above the keel may be permitted.

B.3.2.3 Accommodation spaces, main cargo control stations and service spaces (excluding isolated cargo handling gear lockers) are to be positioned aft of all cargo tanks, slop tanks and spaces which isolate cargo or slop tanks from machinery spaces but not necessarily aft of the oil fuel bunker tanks and ballast tanks, but are to be arranged in such a way that a single failure of a deck or bulkhead will not permit the entry of gas or fumes from the cargo tanks or slop tanks into an accommodation space, main cargo control station, control station, or service space. A recess provided in accordance with B.3.2.2 need not be taken into account when the position of these spaces is being determined.

B.3.2.4 However, where deemed necessary, accommodation spaces, main cargo control stations, control stations and service spaces may be permitted forward of the cargo tanks, slop tanks and spaces which isolate cargo and slop tanks from machinery spaces but not necessarily forward of oil fuel bunker tanks or ballast tanks. Machinery spaces, other than those of Category A, may be permitted forward of the cargo tanks and slop tanks provided they are isolated from the cargo tanks and slop tanks by cofferdams, cargo pump-rooms, oil fuel bunker tanks or ballast tanks and subject to an equivalent standard of safety and appropriate availability of fire-extinguishing arrangements being provided. Accommodation spaces, main cargo control spaces, control stations and service spaces are to be arranged in such a way that a single failure of a deck or bulkhead will not permit the entry of gas or fumes from the cargo tanks or slop tanks into such spaces. In addition, where deemed necessary for the safety or navigation of the ship, machinery spaces containing internal combustion machinery not being main propulsion machinery having an output greater than 375 kW may be permitted to be located forward of the cargo area provided the arrangements are in accordance with the provisions of this paragraph.

B.3.2.5 Where a corner-to-corner situation occurs between a safe space and a cargo tank, the safe space is to be protected by a cofferdam. Subject to agreement by the owners this protection may be formed by an angle bar or a diagonal plate across the corner. Such cofferdam if accessible is to be capable of being ventilated and if not accessible is to be filled with a suitable compound.

B.3.2.6 Where it is intended to carry products with a flashpoint (closed cup test) above 60 °C only, the cofferdams according to B.3.2.1 – B.3.2.5 need not be arranged (see also A.1.7).

B.3.2.7 On special tankers cofferdams may be required between cargo tanks and oil fuel tanks on account of the hazards presented by the special products intended to be carried.

B.3.2.8 Where the fitting of a navigation position above the cargo area is shown to be necessary, it is allowed for navigation purposes only and it is to be separated from the cargo tanks deck by means of an open space with a height of at least 2 m. The fire protection of such a navigation position is in addition to be as required for control spaces in Section 22, F.4 and other provisions, as applicable, of Section 22.

B.3.2.9 Means are to be provided to keep deck spills away from the accommodation and service areas. This may be accomplished by provision of a permanent continuous coaming of a suitable height (approximately 150 mm, however, not less than 50 mm above upper edge of sheer strake) extending from side to side. Special consideration is to be given to the arrangements associated with stern loading.

Note

Furthermore the corresponding rules of the respective national administrations are to be observed.

B.3.2.10 For exterior boundaries of superstructures, see Section 22, F.2.1.

B.3.3 Arrangement of doors, windows and air inlets

B.3.3.1 Entrances, air inlets and outlets and openings to accommodation spaces, service spaces, control stations and machinery spaces are not to face the cargo area. They are to be located on the transverse bulkhead not facing the cargo area and/or on the outboard side of the superstructure or deckhouse at a distance of at least 4 % of the length of the ship $\mathbf{L_c}$ but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. This distance, however, need not exceed 5 m.

B.3.3.2 Access doors may be permitted in boundary bulkheads facing the cargo area or within the limits specified in B.3.3.1, to main cargo control stations and to such service spaces as provision rooms, store rooms and lockers, provided they do not give access directly or indirectly, to any other space containing or provided for accommodation, control stations or service spaces such as galleys, pantries or workshops, or similar spaces containing sources of vapour ignition. The boundaries of such space are to be insulated to "A-60" standard, with the exception of the boundary facing the cargo area. Bolted plates for removal of machinery may be fitted within the limits specified in B.3.3.1. Wheelhouse doors and wheelhouse windows may be located within the limits specified in B.3.3.1 so long as they are designed to ensure that the wheelhouse can be made rapidly and efficiently gas and vapour tight.

B.3.3.3 Windows and side scuttles facing the cargo area and on the sides of the superstructures and deckhouses within the limits specified in B.3.3.1 are to be of the fixed (non-opening) type. Such windows and side scuttles, except wheelhouse windows, are to be constructed to "A-60" class standard and are to be of an approved type.

B.3.4 Pipe tunnels in double bottoms

Where pipe tunnels are arranged in double bottoms the following is to be observed:

- Pipe tunnels are not permitted to have direct connections with machinery spaces neither through openings nor through piping.
- At least two access openings with watertight covers are to be fitted and are to be spaced at maximum practicable distance. One of these openings may lead into the cargo pump room. Other openings are to lead to the open deck.
- Adequate mechanical ventilation is to be provided for a pipe tunnel for the purpose of venting prior to entry (see also the GL Rules for Machinery Installations (I-1-2), Section 15).

B.4 Bow or stern loading and unloading arrangements

B.4.1 Subject to special approval, cargo piping may be fitted to permit bow or stern loading or unloading. Portable piping is not permitted.

B.4.2 Outside the cargo area bow and stern loading and unloading lines are to be arranged on the open deck.

B.4.3 When stern loading and unloading arrangements are in use, openings and air inlets to enclosed spaces within a distance of 10 metres from the cargo shore connection are to be kept closed.

B.4.4 The provisions of B.3.2.9, B.3.3.1, B.3.3.2 and B.3.3.3 apply to the exterior boundaries of superstructures and deckhouses enclosing accommodation spaces, main cargo control stations, control stations, service spaces and machinery spaces which face the cargo shore connection, the overhanging decks which support such spaces, and the outboard sides of the superstructures and deckhouses for the specified distances from the boundaries which face the cargo shore connection.

B.4.5 Tankers equipped for single point offshore mooring and bow loading arrangements should in addition to the provision of B.4.1 to B.4.4 comply with the following:

- Where a forward bridge control position is arranged on the fore deck, provisions are to be made for emergency escape from the bridge control position in the event of fire.
- An emergency quick release system is to be provided for cargo hose and mooring chain. Such systems are not to be installed within the fore ship.
- The mooring system is to be provided with a tension meter continuously indicating the tension in the mooring system during the bow loading operation. This requirement may be waived if the tanker has

in operation equivalent equipment, e.g. a dynamic positioning system ensuring that the permissible tension in the mooring system is not exceeded.

- An operation manual describing emergency procedures such as activation of the emergency quick release system and precautions in case of high tension in the mooring system, should be provided on board.

B.4.6 For piping details and for the fire extinguishing systems the provisions of the GL Rules for Machinery Installations (I-1-2), Section 15 apply.

C Superstructures

C.1 According to Regulation 39 of **ICLL**, a minimum bow height above the waterline is required at the forward perpendicular.

C.2 Machinery and boiler casings are to be protected by an enclosed poop or bridge of not less than standard height, or by a deckhouse of not less than standard height and equivalent strength. Details are to be taken from **ICLL**, Reg. 26.

The end bulkheads are to have scantlings as required in Section 16.

C.3 Openings in superstructure end bulkheads are to be provided with weather tight closing appliances. Their sills are not to be less than 380 mm in height. Reference is made to the respective requirements of the **ICLL**.

D Equipment

D.1 Gangways, bulwarks

D.1.1 Either a permanent and continuous walkway on the freeboard deck or a corresponding gangway of substantial strength (e.g. at the level of the superstructure deck) is to be provided between the deckhouse and the forecastle on or near the centre line of the ship.

For these the following conditions are to be observed:

- The clear width is to be between 1 m and 1.5 m. For ships of less than 100 m in length the width may be reduced to 0.6 m.
- If the length of the deck to be traversed exceeds 70 m shelters of sufficient strength at intervals not exceeding 45 m are to be provided. Each shelter is to be capable of accommodating at least one person and be so constructed as to afford weather protection on the forward, port and starboard side.
- They are to be fitted with guard rails and a footstop on either side. The guard rails are to have a height of not less than 1 m and are to be fitted with two courses and with a handrail. The intermediate opening to the lowest course is not to exceed 230 mm and between the other courses it is not to exceed 380 mm. Stanchions are to be fitted at intervals of not more than 1.5 m. Every third stanchion is to be fitted with a support.
- At all the working areas, but at least every 40 m, there is to be access to the deck.
- The construction of the gangway is to be of suitable strength, is to be fire resistant and the surface is to be of non-slip material.

Ships with hatches may be fitted with two walkways as specified above on the port and starboard side of the hatch, located as close as practicable to the ship's centre line.

Alternatively a well-lit and sufficiently ventilated passageway of at least 800 mm width and 2 000 mm height can be constructed below the weather deck, as close as possible to the freeboard deck.

Note

The respective regulations of the competent national authorities are to be observed.

D.1.2 Type "A" ships with bulwarks are to have open rails fitted for at least half the length of the weather deck or other equivalent freeing arrangements. A freeing port area, in the lower part of the bulwarks, of 33 % of the total area of the bulwarks, is an acceptable equivalent freeing arrangement. The upper edge of the sheer strake is to be kept as low as practicable.

Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

D.2 Ventilators

D.2.1 Ventilators for spaces under the freeboard deck are to be of strong construction, or to be efficiently protected by superstructures or other equivalent means.

D.2.2 Pump rooms, cofferdams and other rooms adjacent to cargo tanks are to be fitted with ventilation arrangements, as per GL Rules for Machinery Installations (I-1-2), Section 15.

D.2.3 The dangerous zones as per GL Rules for Electrical Installations (I-1-3), Section 14, B. are to be observed.

D.3 Anchor equipment

D.3.1 The anchor windlass and the chain locker are considered a source of ignition. Unless located at least 2.4 m above the cargo deck the windlass and the openings of chain pipes leading into the chain locker are to be fitted at a distance of not less than 3 m from the cargo tank boundaries, if liquids having a flashpoint (closed cup test) not exceeding 60 °C are intended to be carried.

D.3.2 For distances from cargo tank vent outlets etc. the relevant requirements of the GL Rules for Machinery Installations (I-1-2), Section 15 are to be observed.

D.4 Emergency towing arrangements

D.4.1 Purpose

Under regulation II-1/3-4 of the 1974 **SOLAS** Convention, as amended in 2000 by Resolution MSC.99(73), new and existing tankers of 20 000 t deadweight and above are to be fitted with an emergency towing arrangement in the bow and stern areas of the upper deck

D.4.2 Requirements for the arrangements and components

D.4.2.1 General

The emergency towing arrangements are to be so designed as to facilitate salvage and emergency towing operations on tankers primarily to reduce the risk of pollution. The arrangements are at all times to be capable of rapid deployment in the absence of main power on the ship to be towed and of easy connection to the towing vessel. Fig. 24.1 shows typical arrangements which may be used as reference.

D.4.2.2 Documents to be submitted

The following documents have to be submitted for approval:

- general layout of the bow and stern emergency towing arrangements
- drawings of the bow and stern strong points and fairleads including material specifications and strength calculations
- drawings of the local ship structures supporting the loads from the forces applied to the emergency towing equipment
- operation manual for the bow and stern emergency towing equipment

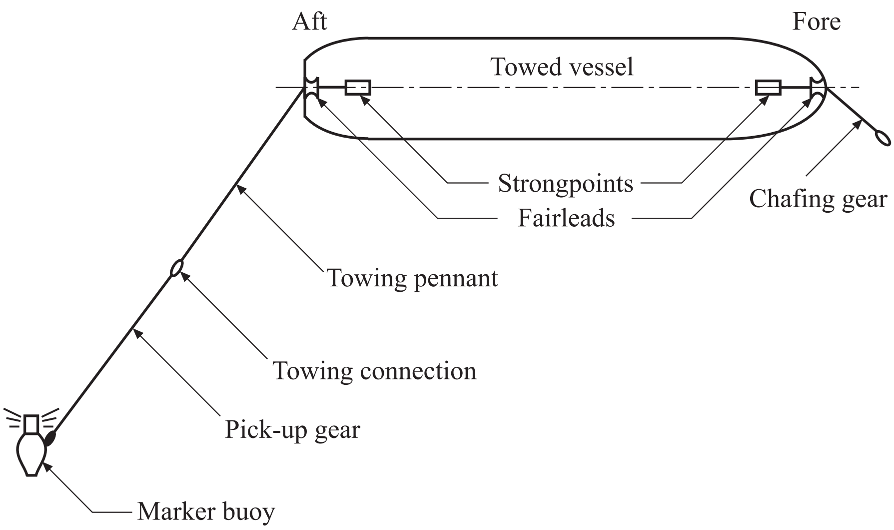


Fig. 24.1 Typical emergency towing arrangements

D.4.2.3 Strength of the towing components

Towing components are to have a safe working load (SWL) of at least 1 000 kN for tankers of 20 000 t deadweight and over but less than 50 000 t deadweight, and at least 2 000 kN for tankers of 50 000 t deadweight and over. The SWL is defined as one half of the minimum breaking load of the towing pennant. The strength is to be sufficient for all relevant angles of towline, i.e. up to 90 ° from the ship's centerline to port and starboard and 30 ° vertical downwards.

D.4.2.4 Length of towing pennant

The towing pennant is to have a length of at least twice the lightest seagoing ballast freeboard at the fairlead plus 50 m.

D.4.2.5 Location of strongpoint and fairlead

The strong points and fairleads are each to be located in the bow and stern areas at the centerline.

D.4.2.6 Strongpoint

The inboard end fastening is to be a chain cable stopper or towing bracket or other fitting of equivalent strength. The strongpoint can be designed integral with the fairlead. The scantlings of the strong points and the supporting structures are to be determined on the basis of the ultimate strength of the towing pennant.

D.4.2.7 Fairleads

The bending ratio (towing pennant bearing surface diameter to towing pennant diameter) of the fairlead is not to be less than 7 to 1. Otherwise a chafing gear (stud link chain) is required.

D.4.2.8 Chafing gear

D.4.2.8.1 The chafing gear is to be long enough to ensure that the towing pennant remains outside the fairlead during the towing operation. A chain extending from the strongpoint to a point at least 3 m beyond the fairlead is to meet this criterion.

D.4.2.8.2 One end of the chafing chain is to be suitable for connection to the strongpoint. The other end is to be fitted with a standard pear-shaped open link allowing connection to a standard bow shackle.

D.4.2.9 Towing connection

The towing pennant is to have a hard eye-formed termination allowing connection to a standard bow shackle.

D.4.2.10 Testing

The breaking load of the towing pennant is to be demonstrated. All components such as chafing gear, shackles and standard pear-shaped open links are to be tested in the presence of a GL surveyor under a proof load of 1 420 kN or 2 640 kN respectively, corresponding to a SWL of 1 000 kN or 2 000 kN (see D.4.2.3).

The strong points of the emergency towing arrangements are to be prototype tested before the installation on board under a proof load of 2 x SWL.

On board, the rapid deployment in accordance with D.4.3 is to be demonstrated.

D.4.3 Ready availability of towing arrangements

Emergency towing arrangements are to comply with the following criteria:

D.4.3.1 The aft emergency towing arrangement is to be pre-rigged and be capable of being deployed in a controlled manner in harbour conditions in not more than 15 minutes.

D.4.3.2 The pick-up gear for the aft towing pennant is to be designed at least for manual operation by one person taking into account the absence of power and the potential for adverse environmental conditions that may prevail during such emergency towing operations. The pick-up gear is to be protected against the weather and other adverse conditions that may prevail.

D.4.3.3 The forward emergency towing arrangement is to be capable of being deployed in harbour conditions in not more than one hour.

D.4.3.4 All emergency towing arrangements are to be clearly marked to facilitate safe and effective use even in darkness and poor visibility.

E Corrosion Protection

E.1 General

The requirements of Section 35 apply, as far as applicable.

E.2 Cathodic protection

E.2.1 Impressed current systems and magnesium or magnesium alloy anodes are not permitted in oil cargo tanks. There is no restriction on the positioning of zinc anodes.

E.2.2 When anodes are fitted in tanks they are to be securely attached to the structure. Drawings showing their location and the attachment are to be submitted.

E.2.3 Aluminium anodes are only permitted in cargo tanks of tankers in locations where the potential energy does not exceed 275 Nm. The height of the anode is to be measured from the bottom of the tank to the centre of the anode, and its weight is to be taken as the weight of the anode as fitted, including the fitting devices and inserts. However, where aluminium anodes are located on or closely above horizontal surfaces such as bulkhead girders and stringers not less than 1 metre wide and fitted with an upstanding flange or face flat projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured from this surface. Aluminium anodes are not to be located under tank hatches or Butterworth openings (in order to avoid any metal parts falling on the fitted anodes) unless protected by the adjacent structure.

E.2.4 The anodes should have cores of hull structural steel or other weldable steel and these should be sufficiently rigid to avoid resonance in the anode support and be designed so that they retain the anode even when it is wasted.

The steel inserts are to be attached to the structure by means of a continuous weld of adequate section. Alternatively, they may be attached to separate supports by bolting, provided a minimum of two bolts with lock-nuts are used. When anode inserts or supports are welded to the structure, they should be arranged so that the welds are clear of stress risers.

The supports at each end of an anode should not be attached to separate items which are likely to move independently.

However, approved mechanical means of clamping will be accepted.

E.3 Aluminium paints

Aluminium paints are not to be applied in cargo tanks, on tank decks in way of cargo tanks, in pump rooms, cofferdams or any other spaces where inflammable cargo gas may accumulate.

F Access to Spaces in the Cargo Area

F.1 Access to cofferdams, ballast tanks, cargo tanks and other spaces in the cargo area is to be direct from the open deck and such as to ensure their complete inspection. Access to double bottom spaces may be through a cargo pump room, pump room, deep cofferdam, pipe tunnel or similar compartments, subject to consideration of ventilation aspects.

Note

Access to double bottom tanks located under cargo tanks through manholes in the inner bottom may be permitted in special cases where non-dangerous liquid substances only are carried in the cargo tanks and subject to approval by the Administration, however, not to oil fuel double bottom tanks.

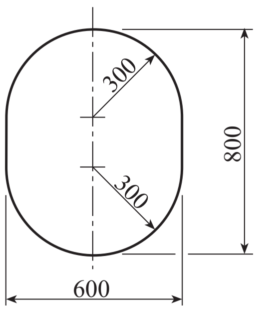
F.2 For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained, airbreathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is to be not less than 600 mm by 600 mm.

F.3 For access through vertical openings, or manholes providing passage through the length and breadth of the space, the minimum clear opening is to be not less than 600 mm by 800 mm at a height of not more than 600 mm from the bottom shell plating unless gratings or other footholds are provided.

Note

For the purpose of F.2 and F.3 the following applies:

1. The term “minimum clear opening of not less than *600 mm x 600 mm*“ means that such openings may have corner radii up to *100 mm* maximum.
2. *The term "minimum clear opening of not less than 600 mm x 800 mm" includes also an opening of the following size:*



F.4 For oil tankers of less than 5 000 t deadweight smaller dimensions may be approved by the Administration in special circumstances, if the ability to transverse such openings or to remove an injured person can be proved to the satisfaction of the Administration.

F.5 With regard to accessibility for survey purposes of cargo and ballast tanks see also Section 27, D.6 and the GL Rules for Classification and Surveys (I-0), Section 4, A.

F.6 Any tank openings, e.g. tank cleaning openings, ullage plugs and sighting ports are not to be arranged in enclosed spaces.

F.7 Ullage plugs and sighting ports are to be fitted as high as possible, for instance in the hatchway covers. The openings are to be of the self-closing type capable of being closed oil tight upon completion of the sounding operation. Covers may be of steel, bronze or brass, however, aluminium is not an acceptable material. Where the covers are made of glass fibre reinforced plastic or other synthetic materials, K is to be observed.

F.8 Where deck openings for scaffolding wire connections are provided, the following requirements are to be observed:

- The number and position of holes in the deck are to be approved.
- The closing of holes may be by screwed plugs of steel, bronze, brass or synthetic material, however, not of aluminium. The material used is to be suitable for all liquids intended to be carried.
- Metal plugs are to have fine screw threads. Smooth transitions of the threads are to be maintained at the upper and lower surface of the deck plating.
- Where synthetic material is used, the plugs are to be certified to be capable of maintaining an effective gastight seal up to the end of the first 20 minutes of the standard fire test as defined in Regulation II-2/3.2, **SOLAS 74**, the test being applied to the upper side which would in practice be exposed to the flames.
- The number of spare plugs to be kept on board is to cover at least 10 % of the total number of holes.

G Minimum Plate Thicknesses in Cargo and Ballast Tanks within the Cargo Area

G.1 In cargo and ballast tanks within the cargo area the thickness of longitudinal strength members, primary girders, bulkheads and associated stiffeners is not to be less than determined by the following formula:

$$t_{min} = 6.5 + 0.02 \cdot \mathbf{L}_{250} \quad [mm]$$

with $t_{min} \le 9.0$ mm for secondary structures such as local stiffeners and

with $t_{min} \le 11.0$ mm for pump rooms, cofferdams and void spaces within the cargo area as well as for fore peak tanks the requirements for ballast tanks according to Section 12, B.1.3 apply

$\mathbf{L}_{250}$: corresponds to the length of the ship as $\mathbf{L}$, but $\mathbf{L}_{250}$ is not to be taken greater than 250 m

For aft peak tanks the requirements of Section B.1.3 apply.

G.2 In way of cargo tanks the thickness of side shell is not to be taken less than determined by the following formula:

$$t_{min} = \sqrt{\mathbf{L} \cdot k} \quad [mm]$$

G.3 If the berthing zone is stiffened longitudinally and the transverse web frame spacing exceeds circa 3.3 m the side shell plating in way of the berthing zone is to be increased by $10 \cdot a$ [%]. The berthing zone extends from 0.3 m below the ballast waterline to 0.3 m above the load waterline. In ship's longitudinal direction it is the area of the side shell which breadth is larger than $0.95 \cdot \mathbf{B}$.

H Strength of Girders and Transverses in the Cargo Tank Area

H.1 General

H.1.1 Girders and transverses may be pre-designed according to Section 12, B.2. Subsequently a stress analysis according to H.2 is to be carried out.

H.1.2 Brackets fitted in the corners of transverses and tripping brackets fitted on longitudinals are to have smooth transitions at their toes.

H.1.3 Well rounded drain holes for oil and air holes are to be provided, they are not to be larger than required for facilitating efficient drainage and for venting of vapours. No such holes and no welding scallops are to be placed near the constraint points of stiffeners and girders and near the toes of brackets.

H.1.4 Transverses are to be effectively supported to resist loads acting vertically on their webs.

H.2 Stress analysis

A three-dimensional stress analysis is to be carried out for the primary structural numbers in way of the cargo tank area by applying the FE calculation method. The analysis is to be based on the loading conditions ac-cording to Fig. 24.2 and Fig. 24.3 for double hull oil tankers with one or two longitudinal oil-tight bulkheads. Tankers with deviating cargo tank arrangements and loading conditions will be separately considered. Consideration of additional load cases may be required if deemed necessary by GL.

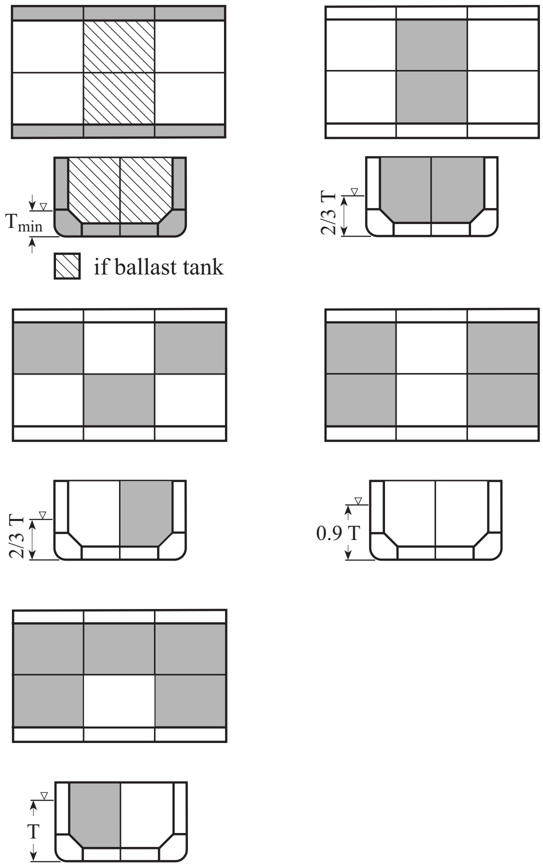


Fig. 24.2 Loading conditions for tankers with one centreline longitudinal bulkhead

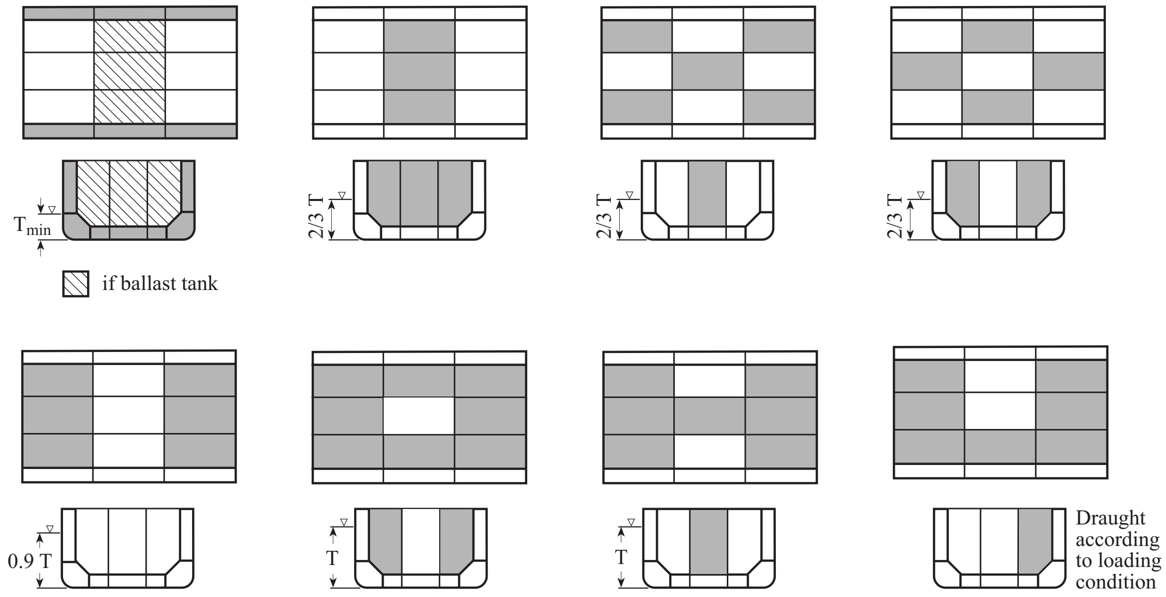


Fig. 24.3 Loading conditions for tankers with two longitudinal bulkheads

H.2.1 Structural modelling

The longitudinal extent of the FE model is determined by the geometry of the structure as well as the local load distribution according to inner and outer pressures and the global load distribution according to the section forces obtained from the longitudinal strength calculation.

Regarding assessment of fatigue strength, GL reserve the right to require examination of structural details by means of local FE models.

H.2.2 Loads

Local static and dynamic loads are to be determined according to Section 4; global static and dynamic loads according to Section 5. Also the heeling condition determined by the angle φ is to be considered.

The internal pressure in the cargo tanks is to be determined in accordance with the formula for p_{T1}.

H.2.3 Permissible stresses

H.2.3.1 Transverse members

Under the given load assumptions the following stress values are not to be exceeded in the transverses and in the bulkhead girders:

$$\sigma_x = \frac{150}{k} \quad [\mathrm{N/mm^2}]$$ for bending and axial stresses

$$\tau = \frac{100}{k} \quad [\mathrm{N/mm^2}]$$ for shear stresses

$$\sigma_v = \sqrt{\sigma_x^2 + 3 \cdot \tau^2} = \frac{180}{k} \quad [\mathrm{N/mm^2}]$$ for equivalent stresses

σ_x : stress in longitudinal direction of the girder

The stress values according to Section 12, B.2.3.1 are not to be exceeded when the load p_{T2} is applied.

H.2.3.2 Longitudinal members

In the longitudinal girders at deck and bottom, the combined stress resulting from local bending of the girder and longitudinal hull girder bending of the ship's hull under sea load is not to exceed $230 / k$ [N/mm^2].

H.2.4 Fatigue strength

A fatigue strength analysis according to Section 20 is to be carried out. Analogously it is to be based on Section 20, Table 20.1 whereas loading due to different draught, i.e. ship in ballast and ship fully laden respectively may be considered according to service life, see Section 20, B.2.

H.2.5 Cross ties

The cross sectional area of the cross ties exposed to compressive loads is not to be less than determined by the following formula:

$$A_k = \frac{P}{9.5 - 4.5 \cdot 10^{-4} \cdot \lambda^2} \quad [cm^2] \qquad \text{for } \lambda \le 100$$

$$A_k = \frac{P \cdot \lambda^2}{5.0 \cdot 10^4} \quad [cm^2] \qquad \text{for } \lambda > 100$$

λ : degree of slenderness, defined as:

$$\lambda = \ell / i$$

ℓ : unsupported span $[cm]$

i : radius $[cm]$ of gyration, defined as:

$$i = \sqrt{I/A_k}$$

I : smallest moment of inertia $[cm^4]$

For the first approximation:

P : load $[kN]$ on cross tie, for first approximation defined as:

$$P = A \cdot p$$

A : area $[m^2]$ supported by one cross tie

p : design pressure $[kN/m^2]$ on cross tie, defined as:

$$p = p_{T1} \text{ or } p_{T3}$$

Finally the sectional area A_k is to be checked for the load P resulting from the transverse strength calculation.

I Oiltight Longitudinal and Transverse Bulkheads

I.1 Scantlings

I.1.1 The scantlings of bulkheads are to be determined according to Section 12. The thicknesses are not to be less than the minimum thickness according to G. For stress analysis the requirements of H.1.1 apply.

I.1.2 The top and bottom strakes of the longitudinal bulkheads are to have a width of not less than $0.1\ \mathbf{H}$, and their thickness is not to be less than:

$t_{min} = 0.75$ x deck thickness — for top strake of plating

$t_{min} = 0.75$ x bottom thickness — for bottom strake of plating

I.1.3 The section modulus of horizontal stiffeners of longitudinal bulkheads is to be determined as for longitudinals according to Section 9, C, however, it is not to be less than W_2 according to Section 12, B.2.

I.1.4 The stiffeners are to be continuous in way of the girders. They are to be attached to the webs of the girders in such a way that the support force can be transmitted observing $\tau_{perm} = 100 / k$ [N/mm^2].

I.2 Cofferdam bulkheads

Cofferdam bulkheads forming boundaries of cargo tanks are to have the same strength as cargo tank bulkheads. Where they form boundaries of ballast tanks or tanks for consumables the requirements of Section 12 are to be complied with. Where they form boundaries of pump-room or machinery spaces the scantlings for watertight bulkheads as required by Section 11 are sufficient.

J Wash Bulkheads

J.1 General

J.1.1 The total area of perforation in wash bulkheads is to be approximately 20 % of the bulkhead area.

J.1.2 The scantlings of the top and bottom strakes of plating of a perforated centreline bulkhead are to be as required by I.1.2. Large openings are to be avoided in way of these strakes.

The centreline bulkhead is to be constructed in such a way as to serve as shear connection between bottom and deck.

J.2 Scantlings

J.2.1 The plate thickness of the transverse wash bulkheads is to be determined in such a way as to support the forces induced by the side shell, the longitudinal bulkheads and the longitudinal girders. The shear stress is not to exceed $100 / k$ [N/mm^2]. The plate thickness is not to be less than the minimum thickness according to G.

J.2.2 The stiffeners and girders are to be determined as required for an oil tight bulkhead. The pressure p_{T3} but disregarding p_v is to be taken for p.

K Hatches

K.1 Tank hatches

K.1.1 Oil tight tank hatches are to be kept to the minimum number and size necessary for access and venting.

K.1.2 Openings in decks are to be elliptical and with their major axis in the longitudinal direction, wherever this is practicable. Deck longitudinals in way of hatches should be continuous within $0.4\,\mathbf{L}$ amidships. Where this is not practicable, compensation is to be provided for lost cross sectional area.

K.1.3 Coaming plates are to have a minimum thickness of 10 mm.

K.1.4 Hatch covers are to be of steel with a thickness of not less than 12.5 mm. Where their area exceeds 1.2 m^2, the covers are to be stiffened. The covers are to close oil tight.

K.1.5 Other types of oiltight covers may be approved if found to be equivalent.

K.2 Other access arrangements

Hatchways to spaces other than cargo tanks situated on the strength deck, on a trunk or on the forecastle deck, also inside open superstructures, are to be fitted with weather tight steel covers, the strength of which is to be in accordance with Section 17, C.

L Structural Details at the Ship's End

L.1 General

L.1.1 The following requirements are based on the assumption that the bottom forward of the forward cofferdam and abaft the aft cofferdam bulkhead is framed transversely. Approval may be given for other systems of construction if these are considered equivalent.

L.1.2 For the fore- and after peak, the requirements of Section 9, B.5 apply.

L.2 Fore body

L.2.1 Floor plates are to be fitted at every frame. The scantlings are to be determined according to Section 8, B.1.2.2.

L.2.2 Every alternate bottom longitudinal is to be continued forward as far as practicable by an intercostal side girder of same thickness and at least half the depth of the plate floors. The width of their flange is not to be less than 75 mm.

L.2.3 The sides may be framed transversely or longitudinally in accordance with Section 9.

L.3 Aft body

L.3.1 Between the aft cofferdam bulkhead and the after peak bulkhead the bottom structure is to comply with Section 8.

L.3.2 The sides may be framed transversely or longitudinally in accordance with Section 9.

M Ships for the Carriage of Dry Cargo or Oil in Bulk

M.1 General

M.1.1 For ships intended to carry dry cargo or oil in bulk, the regulations of this Section apply as well as the relevant regulations for the carriage of the respective dry cargo. For ships intended to also carry dry cargo in bulk the regulations of Section 23 apply also.

M.1.2 Dry cargo and liquid cargo with a flashpoint (closed cup test) of 60 °C and below are not to be carried simultaneously, excepting cargo oil-contaminated water (slop) carried in slop tanks complying with M.3.

M.1.3 Prior to employing the ship for the carriage of dry cargo the entire cargo area is to be cleaned and gas freed. Cleaning and repeated gas concentration measurements are to be carried out to ensure that dangerous gas concentrations do not occur within the cargo area during the dry cargo voyage.

M.1.4 In way of cargo holds for oil, hollow spaces in which explosive gases may accumulate are to be avoided as far as possible.

M.1.5 Openings which may be used for cargo operations when bulk dry cargo is carried are not permitted in bulkheads and decks separating oil cargo spaces from other spaces not designed and equipped for the carriage of oil cargoes unless equivalent approved means are provided to ensure segregation and integrity.

M.2 Reinforcements

M.2.1 In cargo holds for dry cargo in bulk or oil the following reinforcements are to be carried out.

M.2.2 Framing

M.2.2.1 The scantlings of frames in the oil cargo spaces are to be determined according to Section 12, B.3.

Tripping brackets according to Section 9, B.5.5 are to be fitted at suitable intervals.

M.2.2.2 In cargo holds which may be partly filled frames may be required to be strengthened, depending on the filling ratio.

M.2.3 Cargo hold bulkheads

M.2.3.1 The scantlings of cargo hold bulkheads are to be determined according to Section 23, C.7. and according to the requirements for oil tankers according to I.

M.2.3.2 In cargo holds which may be partly filled the bulkheads may be required to be strengthened, depending on the filling ratio.

M.2.4 Hatchways

M.2.4.1 The scantlings of the hatch covers are to be determined according to Section 17.

M.2.4.2 Where cargo holds are intended to be partly filled the hatchway covers may be required to be strengthened depending on the filling ratio and the location in the ship.

M.2.4.3 The scantlings of the hatchway coamings are to be checked for the load according to Section 17, C.

M.2.4.4 The form and size of hatchway covers and the sealing system are to be adapted to each other in order to avoid leakages caused by possible elastic deformations of the hatchways.

M.3 Slop tanks

M.3.1 The slop tanks are to be surrounded by cofferdams except where the boundaries of the slop tanks where slop may be carried on dry cargo voyages are the hull, main cargo deck, cargo pump room bulkhead or oil fuel tank. These cofferdams are not to be open to a double bottom, pipe tunnel, pump room or other enclosed space. Means are to be provided for filling the cofferdams with water and for draining them. Where the boundary of a slop tank is the cargo pump room bulkhead the pump room is not to be open to the double bottom, pipe tunnel or other enclosed space, however, openings provided with gastight bolted covers may be permitted.

M.3.2 Hatches and tank cleaning openings to slop tanks are only permitted on the open deck and are to be fitted with closing arrangements. Except where they consist of bolted plates with bolts at watertight spacing, these closing arrangements are to be provided with locking arrangements which are to be under the control of the responsible ship's officer.

N Product List 1

List of Oils*

Asphalt solutions	**Gasoline blending stocks**
Blending stocks	Alkylates - fuel
Roofers flux	Reformates
Straight run residue	Polymer - fuel

Oils

Clarified

Crude oil

Mixtures containing crude oil

Diesel oil

Fuel oil no. 4

Fuel oil no. 5

Fuel oil no. 6

Residual fuel oil

Road oil

Transformer oil

Aromatic oil (excluding vegetable oil)

Lubricating oils and blending stocks

Mineral oil

Motor oil

Penetrating oil

Spindle oil

Turbine oil

Distillates

Straight run

Flashed feed stocks

Gas oil

Cracked

Gasolines

Casinghead (natural)

Automotive

Aviation

Straight run

Fuel oil no. 1 (kerosene)

Fuel oil no. 1-D

Fuel oil no. 2

Fuel oil no. 2-D

Jet fuels

JP-1 (kerosene)

JP-3

JP-4

JP-5 (kerosene, heavy)

Turbo fuel

Kerosene

Mineral spirit

Naphtha

Solvent

Petroleum

Heartcut distillate oil

* This list of oils is not necessarily to be considered as comprehensive.

O Product List 2

Explanatory Notes

Product name: (column **a**) The product names are identical with those given in Chapter 18 of the **IBC Code**.

UN number: (column **b**) The number relating to each product shown in the recommendations proposed by the (column b) United Nations Committee of Experts on the Transport of Dangerous Goods. UN numbers, where available, are given for information only.

Category: (column **c**)
Z = pollution category assigned under **MARPOL 73/78**, Annex II
I = Product to which a pollution category X, Y, or Z has not been assigned.

Flashpoint: (column **e**)
Values in ( ) are "open cup values", all other values are "closed cup values".
– = non-flammable product

Remarks:

*In accordance with Annex II of **MARPOL 73/78** an "International Pollution Prevention Certificate for the Carriage of Noxious Liquid Substances in Bulk" (NLS-Certificate) issued by the Flag Administration is required for the carriage in bulk of category Z products.*

Columns d and e are for guidance only. The date included therein have been taken from different publications.

Product name	UN-number	Category	Density [kg/m³]	Flashpoint [°C]
a	b	c	d	e
Acetone	1 090	Z	790	-18
Alcoholic beverages, n.o.s.	3 065	Z	< 1 000	> 20
Apple juice		I	< 1 000	–
n-Butyl alcohol	1 120	Z	810	29
sec-Butyl alcohol	1 120	Z	810	24
Butyl stearate		I	860	160
Clay slurry		I	≈ 2 000	–
Coal slurry		I	≈ 2 000	–
Diethylene glycol		Z	1 120	143
Ethyl alcohol	1 170	I	790	13
Ethylene carbonate		I	1 320	143
Glucose solution		I	1 560	–
Glycerine		Z	1 260	160
Glycerol monooleate		Z	950	224
Hexamethylenetetramine solutions		Z	≈ 1 200	–
Hexylene glycol		Z	920	96

Isopropyl alcohol	1 219	Z	790	22
Kaolin slurry		I	1 800 – 2 600	–
Magnesium hydroxide slurry		Z	≈ 1530	–
N-Methylglucamine solution (70 % or less)		Z	1 150	> 95
Molasses		I	1 450	> 60
Non-noxious liquid, n.o.s. (12) (trade name ..., contains ...) Cat. OS		I		
Noxious liquid, n.o.s. (11) (trade name ..., contains ...) Cat. Z		Z		
Polyaluminium chloride solution		Z	1 190 – 1 300	–
Potassium formate solutions		Z	≈ 1 570	> 93
Propylene carbonate		Z	1 190	135
Propylene glycol		Z	1 040	99
Sodium acetate solutions		Z	1 450	
Sodium sulphate solutions		Z		> 60
Tetraethyl silicate monomer/oligomer (20 % in ethanol)		Z		
Triethylene glycol		Z	1 130	166
Water		I	1 000	–

P Additional Requirements for Tankers in Shuttle Service

P.1 General requirements and instructions

P.1.1 General

P.1.1.1 Scope

These requirements apply to tankers employed in shuttle service between offshore ports and terminals (single point moorings, SPM), floating storage units (FSU), submerged turret loading (STL) and regular ports and terminals. The requirements herein provide minimum safety standards for the intended service and are to be applied in addition to A. to J. National regulations for such operations are to be observed, if any. In respect of layout and arrangement of such systems, the applicable guidelines and recommendations issued by the Oil Companies International Marine Forum (OCIMF) have been considered as far as necessary.

P.1.1.2 Reference to other Rules and Guidelines

The following GL Rules are to be applied in addition:

- Section 1 to Section 22
- Chapter 2 – Machinery Installations
- Chapter 3 – Electrical Installations
- Chapter 15 – Dynamic Positioning Systems

P.1.2 Exemptions

Any kind of new or different design may be accepted by GL provided that an equivalent level of safety is demonstrated.

P.1.3 Notations affixed to the Character of Classification

The following Notations may be assigned within the scope of these requirements to the general Character of Classification:

- SPM, SPM1, SPM2 or SPM3
- STL

SPM installations are grouped into four classes as defined in P.1.4 and have to comply with the requirements set out in P.2.

For further Notations refer to the GL Rules for Dynamic Positioning Systems (I-1-15).

P.1.4 Definitions

SPM

Single point mooring arrangement of basic design, fitted with local control for mooring to single point moorings complying with P.2.1.1.

SPM1

Single point mooring arrangement of basic design, fitted with local control for mooring and cargo loading manifold complying with P.2.1, P.2.3.1 to P.2.3.4 and P.2.4.1.3 to P.2.4.1.4.

SPM2

Single point mooring arrangement of advanced design, fitted with bow control station and provided with automatic and remote control for cargo transfer and ship manoeuvring complying with P.2.1, P.3.5 and P.2.4.1.

SPM3

Single point mooring arrangement of advanced design, fitted with bow control station automatic and remote control for cargo transfer and equipped with a dynamic positioning system (DPS) complying with P.2.1, P.2.3, P.2.4 and the GL Rules for Dynamic Positioning Systems (I-1-15)

STL

Submerged turret loading arrangement of specific design combined with a dynamic positioning system (DPS) complying with P.2.2 and the GL Rules for Dynamic Positioning Systems (I-1-15)

P.2 System requirements

P.2.1 Requirements for single point mooring (SPM)

P.2.1.1 Bow chain stoppers and fairleads

P.2.1.1.1 One or two bow chain stoppers are to be fitted, capable to accept a standard 76 mm stud-link chain (chafing chain, as defined in the OCIMF "Recommendations for Equipment Employed in the Bow Mooring of Conventional Tankers at Single Point Moorings"). The number of chain stoppers is to be chosen in accordance with Table 24.2. For ships of a size of up to 150 000 tdw two bow chain stoppers may be fitted to ensure full range terminal acceptance. The capacity of bow chain stoppers is to be according to P.2.1.1.5.

P.2.1.1.2 The design of the chain stopper is to be of an approved type, in accordance with the GL Rules for Machinery Installations (I-1-2), Section 14, D. The chafing chain is to be secured when the chain engaging pawl or bar is in closed position. When in open position, the chain and associated fittings are to be capable to pass freely.

P.2.1.1.3 Stoppers are to be fitted as close as possible to the deck structure and are to be located 2.7 m to 3.7 m inboard of the fairleads. Due consideration is to be given to proper alignment of the stopper between the fairlead and pedestal lead or drum of the winch or capstan.

P.2.1.1.4 For the structural strength of the supporting structure underneath the chain stoppers the following permissible stresses are to be observed:

$$\sigma_x = \frac{200}{k} \quad [\mathrm{N/mm^2}]$$ for bending and axial stresses

$$\tau = \frac{120}{k} \quad [N/mm^2]$$ for shear stresses

$$\sigma_v = \sqrt{\sigma_x^2 + 3 \cdot \tau^2} = \frac{220}{k} \quad [N/mm^2]$$ for equivalent stresses

For strength assessment using FEM the following permissible equivalent v. Mises stress is to be observed:

$$\sigma_v = \frac{230}{k} \quad [N/mm^2]$$

The acting forces are to be twice the SWL according to Table 24.2.

P.2.1.1.5 Upon installation, bow stoppers are to be load tested to the equivalent safe working load (SWL). A copy of the installation test certificate has to be available for inspection on board the ship.

Alternatively, the ship has to hold a copy of the manufacturer's type approval certificate for the bow chain stoppers, confirming that bow chain stoppers are constructed in strict compliance with the SWL given in Table 24.2. This certificate must also indicate the yield strength of the bow chain stoppers. Loads that induce this yield stress is not to be less than twice the SWL.

Applicable strength of the supporting structures underneath the chain stoppers is to be documented by adequate analyses. GL will issue a declaration confirming

Table 24.2 Arrangement and capacity for SPM

Vessel size	Chafe chain size	Number of bow fairleads (recommended)	Number of bow stoppers	SWL
[tdw]	[mm]			[kN]
$\leq$ 100 000	76	1	1	2 000
> 100 000 $\leq$ 150 000	76	1	1	2 500
> 150 000	76	2	2	3 500

that an evaluation verifying sufficient support strength has been carried out. A copy of the declaration has to be available for inspection on board the ship. Bow chain stoppers and supporting structures underneath the chain stoppers are to be subject to periodic class survey.

P.2.1.1.6 Bow fairleads are to have minimum dimensions of 600 x 450 mm and are to be of oval or rounded shape. The design force for the fairleads as well as permissible design stresses for their supporting structures are to be taken according to P.2.1.1.4. The design force is to be considered at angles of 90 ° to the sides and 30 ° upwards or downwards.

P.2.1.1.7 Single fairleads should be arranged at the centreline, where two fairleads are fitted they should be arranged 1 to 1.5 m from the centreline on either side. Two bow fairleads are recommended for ships fitted with two bow chain stoppers.

P.2.1.1.8 Winches or capstans are to be positioned to enable a pull in direct straight lead with the bow fairleads and chain stoppers. Alternatively a pedestal roller is to be positioned between stopper and winch or capstan. Winches or capstans are to be capable of lifting at least 15 tonnes.

P.2.1.1.9 If a winch storage drum is used to stow the pick-up rope, it is to be capable to accommodate at least 150 m rope of 80 mm in diameter.

P.2.1.1.10 The design force for substructures of pedestal rollers is to be not less than 1.25 times the force exerted by the winch or capstan when lifting with maximum capacity. The permissible design stresses are to be taken according to P.2.1.1.4.

P.2.1.1.11 The SWL according to Table 24.2 is to be marked (by weld bead or equivalent) on the chain stoppers and fairleads.

P.2.1.2 Bow loading arrangements

P.2.1.2.1 Bow loading cargo piping is to be permanently fitted and is to be arranged on the open deck. Outside the cargo area and in way of the bow area only welded connections, except at the bow loading connection, are permitted.

P.2.1.2.2 Within the cargo area the bow piping is to be separated from the main cargo system by at least two valves fitted with an intermediate drain or spool piece. Means for draining towards the cargo area as well as purging arrangements with inert gas are to be provided.

P.2.1.2.3 The bow loading connection is to be equipped with a shut-off valve and a blank flange. Instead of the blank flange a patent hose coupling may be fitted. Spray shields are to be provided at the connection flange and collecting trays are to be fitted underneath the bow loading connection area.

P.2.1.2.4 Materials and pipe scantlings are to be in compliance with the GL Rules for Machinery Installations (I-1-2), Section 11.

P.2.1.3 Fire fighting arrangements

P.2.1.3.1 The following foam fire-extinguishing equipment is to be provided for bow loading arrangement:

- one or more dedicated foam monitor(s) for protecting the bow loading area complying with the requirements in the GL Rules for Machinery Installations (I-1-2), Section 12, K.
- one portable foam branch pipe for protecting the cargo line forward of the cargo area

P.2.1.3.2 A fixed water spray system is to be provided covering the areas of chain stoppers and bow loading connection, having a capacity of:

$$10 \cdot \frac{\text{litre}}{\text{m}^2 \cdot \text{min}}$$

The system is to be capable of being manually operated from outside the bow loading area and may be connected to the forward part of the fire water main line.

P.2.1.4 Electrical equipment

Electrical equipment in hazardous areas and spaces as well as within a radius of 3 m from the cargo loading connection/manifold or any other vapour outlet are to be of certified safe type, meeting the requirements stated in the GL Rules for Electrical Installations (I-1-3), Section 15.

P.2.2 Requirements for submerged turret loading (STL)

P.2.2.1 The STL room with mating recess is to be arranged in the fore body, but within the cargo area. The hull structural design (scantlings of mating recess, mating ring locking device, brackets etc.) is to take into account the design loads caused by the cargo transfer system with due consideration to environmental and operational loads. The designer has to provide sufficient information about the design loads.

P.2.2.2 Access to the STL room is only permitted from open deck.

P.2.2.3 A permanent mechanical extraction type ventilation system providing at least 20 changes of air per hour is to be fitted. Inlets and outlets are to be arranged at least 3 m above the cargo tank deck, and the horizontal distance to safe spaces is not to be less than 10 m. Design of fans has to conform to the GL Rules for Machinery Installations (I-1-2), Section 15. The air inlet is to be arranged at the top of the STL room. Exhaust trunks are to be arranged having:

- one opening directly above the lower floor and one opening located 2 m above this position
- one opening above the deepest waterline

The openings are to be equipped with dampers capable of being remotely operated from outside the space.

P.2.2.4 A fixed fire extinguishing system in accordance with the GL Rules for Machinery Installations (I-1-2), Section 12, D.1.4 is to be provided.

P.2.2.5 A connection for the supply of inert gas (IG) is to be fitted. The connection may be arranged fixed or portable. If fixed, the connection to the IG-System inlet is to be provided with a blank flange.

P.2.2.6 Electrical equipment is to be of certified safe type in compliance with the GL Rules for Electrical Installations (I-1-3), Section 15. Where equipment needs to be installed for submerged use, the protection class is to be IP 68; otherwise, the installation is to be located well above the deepest waterline. Electric lighting of the STL room is to be interlocked with the ventilation such that lights can only be switched on when the ventilation is in operation.

Failure of ventilation is not to cause the lighting to extinguish. Emergency lighting is not to be interlocked.

P.2.2.7 A fixed gas detection system is to be fitted with sampling points or detector heads located at the lower portions of the room. At least one sampling point/detector is to be fitted above the deepest waterline. Visual and audible alarms are to be triggered in the cargo control station and on the navigation bridge if the concentration of flammable vapours exceeds $10\ \%$ of the lower explosive limit (LEL).

P.2.3 Arrangement of forward spaces

P.2.3.1 General

Hazardous zones, areas and spaces are to be defined on basis of the GL Rules for Electrical Installations (I-1-3), Section 15.

P.2.3.2 Air vent pipes from fore peak tanks are to be located as far as practicable away from hazardous areas.

P.2.3.3 Access openings, air inlets and outlets or other openings to service, machinery and other gas safe spaces are not to face the bow loading area and are to be arranged not less than $10\ \mathrm{m}$ away from the bow loading connection. These spaces are to have no connection to gas dangerous spaces and are to be equipped with fixed ventilation systems.

P.2.3.4 Spaces housing the bow loading connection and piping are to be considered as gas dangerous spaces and are preferably to be arranged semi-enclosed. In case of fully enclosed spaces, a fixed extraction type ventilation providing 20 changes of air per hour is to be fitted. Design of fans is to be according to GL Rules for Machinery Installations (I-1-2), Section 15.

P.2.3.5 A bow control station for SPM or STL loading operations may be arranged. Unless agreed otherwise and approved, this space is to be designed as gas safe and is to be fitted with fixed overpressure ventilation with inlets and outlets arranged in the safe area. The access opening is to be arranged outside the hazardous zones. If the access opening is located within the hazardous zone, an air lock is to be provided. Emergency escape routes are to be considered during design. Fire protection standards according to "A–60" class are to be applied for bulkheads, decks, doors and windows in relation to adjacent spaces and areas.

P.2.4 Functional requirements for bow and STL loading systems

P.2.4.1 Control systems, communication

P.2.4.1.1 General

The bow control station, if fitted, may include the ship manoeuvring controls as well as the SPM / STL mooring and cargo transfer control instrumentation. In case the ship manoeuvring controls are provided on the navigation bridge only, a fixed means of communication is to be fitted in both locations. Similar arrangements apply to the bow control station and the cargo control room (CCR), where main cargo loading controls are provided in the CCR only.

P.2.4.1.2 Essential instrumentation and controls in the bow control station

- Ship manoeuvring:
  - main propulsion controls
  - steering gear, thruster controls
  - radar, log
- Bow mooring:

  - mooring chain traction controls. This requirement may be waived if the tanker is fitted and operating with dynamic positioning system.
  - chain stopper controls
  - data recorder for mooring and load parameters
- Bow / STL loading:
  - manifold connector/coupling indicator
  - cargo valves position indicator / controls
  - cargo tank level and high alarm indicators
  - cargo pumps controls

P.2.4.1.3 Emergency release

The bow loading arrangements are to be provided with a system for emergency release operation based on a logical sequence to ensure safe release of the vessel. The system is to be capable of the following functions:

- stopping of main cargo pumps or tripping of shore transfer facilities if a ship to shore link is provided
- closing manifold and hose coupling valves
- opening the hose coupling
- opening the chain stopper

In addition to the automatic functions, individual release of hose coupling and chain stoppers are to be provided.

P.2.4.1.4 Communication

Means of communication between ship and offshore loading terminal is to be provided, certified as "Safe for use in gas dangerous atmosphere". Procedures for emergency communication are to be established.

P.2.4.2 Operation manual

The tanker is to have on board an operation manual containing the following information:

- arrangement drawings of the SPM / STL cargo transfer arrangement, bow / STL loading connection, mooring system, fire fighting systems and instrumentation
- safety instructions with regard to fire fighting and extinction, emergency release procedures and escape routes
- operational procedures for mooring, connecting/ disconnecting loading arrangements and communication

P.3 Surveys and tests

P.3.1 Tests of components

Couplings/connectors intended for bow or STL loading operations are to be of approved design. Approvals or test reports issued by recognised institutions may be submitted for review/acceptance. Materials for steel structure, piping, electrical equipment and cables are in general to be in compliance with the current GL Rules as applicable, see P.1.1.2. Cargo transfer hoses and hoses used in hydraulic or other systems are to be type approved.

P.3.2 Tests after installation

All systems and equipment used for SPM, bow loading and STL are to be function tested at the shipyard prior to commissioning. During the first offshore loading operation, an inspection is to be carried out by a local Surveyor. The inspection is to include all relevant operational procedures and verification of the operation manual.

P.3.3 Periodical inspections

To maintain the Class Notations assigned for the SPM and STL installations, annual/intermediate and renewal surveys are to be carried out in conjunction with regular class surveys. The scope of surveys is to be based on the principles laid down in the GL Rules for Classification and Surveys (I-0), Section 4, A.

Section 25 Tugs

A General

A.1 Application

Ships intended to get the Notations **TUG** and/or **ACTIVE ESCORT TUG** are to be in compliance with this section. Unless specially mentioned in this Section, the requirements of Sections 1 – 22 apply.

A.2 References

A.2.1 Paragraphs of this section are based on the following international convention(s) and / or code(s):

- IACS UR A1 Rev.5

At the end of each relevant paragraph, the corresponding paragraphs of the international convention(s) and / or code(s) are given in brackets.

A.2.2 For instructions regarding towing operations in general, see the GL Guidelines for Ocean Towage (VI-11-1).

A.3 Definitions

z_h : vertical distance $[m]$ between the working point of the towrope and the centre of the propeller

φ : heeling angle $[°]$

D : loading condition displacement $[t]$

B Materials

GL material certificates will generally be required for:

- towing hook and attached load transmitting elements, including slip device
- towing winch, including frame, drum shaft(s), couplings, brakes and gear(s)
- towrope(s), including certification of breaking force

Material certificates according to DIN 50049-3.1B may be accepted for standard items, if the manufacturer is recognised by GL.

C Hull Structures

C.1 Scantlings, general

For the determination of hull structure scantlings the draught $\mathbf{T}$ is not to be taken less than $0.85\ \mathbf{H}$.

C.2 Deck structure

C.2.1 On tugs for ocean towage, the deck, particularly in the forward region, shall be suitably protected or strengthened against sea impact.

C.2.2 Depending on the towrope arrangement, the deck in the aft region may have to be strengthened (beams, plate thickness), if considerable chafing and/or impact is to be expected. See also D.1.5.

C.3 Fore body, bow structure

C.3.1 On tugs for ocean towage, strengthening in way of the fore body (stringers, tripping brackets etc.) shall generally conform to the indications given in Section 9. The stringers shall be effectively connected to the collision bulkhead. Depending on the type of service expected, additional strengthening may be required.

C.3.2 For (harbour) tugs frequently engaged in berthing operations, the bow is to be suitably protected by fendering and be structurally strengthened.

C.3.3 The bulwark is to be arranged with an inward inclination in order to reduce the probability and frequency of damages. Square edges are to be chamfered.

C.3.4 The bow structure of pusher tugs for sea service will be specially considered. For pusher tugs for inland navigation see the GL Rules for Additional Requirements for Notations (I-2-4), Section 2, E.

C.4 Stern frame

The cross sectional area of a solid stern frame is to be $20\ \%$ greater than required according to Section 13, C.2.1. For fabricated stern frames, the thickness of the propeller post plating is to be increased by $20\ \%$ compared to the requirements of Section 13, C.2.2. The section modulus W_Z of the sole piece is to be increased by $20\ \%$ compared to the modulus determined according to Section 13, C.4.

C.5 Side structure

C.5.1 The side structure of areas frequently subjected to impact loads is to be reinforced by increasing the section modulus of side frames by $20\ \%$. Besides, fendering may be necessary to reduce indenting damages of the shell plating.

C.5.2 A continuous and suitable strong fender is to be arranged along the upper deck.

C.6 Engine room casing, superstructures and deckhouses

C.6.1 The plate thickness of the casing walls and casing tops is not to be less than $5\ \text{mm}$. The thickness of the coamings is not to be less than $6\ \text{mm}$. The coamings are to extend to the lower edges of the beams.

C.6.2 The stiffeners of the casing are to be connected to the beams of the casing top and are to extend to the lower edge of the coamings.

C.6.3 The following requirements have to be observed for superstructures and deckhouses of tugs assigned for the restricted services areas **RSA (50)** and **RSA (200)** or for unlimited range of service:

- The plate thickness of the external boundaries of superstructures and deckhouses is to be increased by $1\ \text{mm}$ above the thickness as required in Section 16, E.2.1.

- The section modulus of stiffeners is to be increased by 50 % above the values as required in Section 16, E.2.2.

C.7 Foundations of towing gear

C.7.1 The substructure of the towing hook attachment and the foundations of the towing winch, and of any guiding elements such as towing posts or fairleads, where provided, are to be thoroughly connected to the ship's structure, considering all possible directions of the towrope, see D.3.5.

C.7.2 The stresses in the foundations and fastening elements are not to exceed the permissible stresses shown in Table 25.2, assuming a load equal to the test load of the towing hook in case of hook arrangements, and a load of the winch holding capacity in case of towing winches, see also D.3.5 and D.5.3.

D Towing Gear / Towing Arrangement

D.1 General design requirements

D.1.1 The towing gear is to be arranged in such a way as to minimise the danger of capsizing; the towing hook / working point of the towing force is to be placed as low as practicable, see G .

D.1.2 With direct-pull (hook-towrope), the towing hook and its radial gear are to be designed such as to permit adjusting to any foreseeable towrope direction.

D.1.3 The attachment point of the towrope is to be arranged closely behind the centre of buoyancy.

D.1.4 On tugs equipped with a towing winch, the arrangement of the equipment is to be such that the towrope is led to the winch drum in a controlled manner under all foreseeable conditions (directions of the towrope).

D.1.5 Towrope protection sleeves or other adequate means are to be provided to prevent the directly pulled towropes from being damaged by chafing / abrasion.

D.2 Definition of loads

D.2.1 The design force T corresponds to the towrope pull (or the bollard pull, if the towrope pull is not defined) stipulated by the owner. The design force may be verified by a bollard pull test, see the GL Guidelines for Ocean Towage (VI-11-1).

D.2.2 The test force PL is used for dimensioning as well as for testing the towing hook and connected elements. The test force is related to the design force as shown in Table 25.1.

Table 25.1 Design force T and test force PL

Design force T [kN]	Test force PL [kN]
$T \leq 500$	$2.00 \cdot T$
$500 < T \leq 1\,500$	$T + 500$
$1\,500 < T$	$1.33 \cdot T$

D.2.3 The minimum breaking force of the towrope is based on the design force, see D.4.3.

D.2.4 The winch holding capacity is to be based on the minimum breaking force, see D.5.3, the rated winch force is the hauling capacity of the winch drive when winding up the towrope, see D.6.1.3.3.

D.2.5 For forces at the towing hook foundation see D.3.5.4.

D.3 Towing hook and slip device

D.3.1 The towing hook is to be fitted with an adequate device guaranteeing slipping (i.e., quick release) of the towrope in case of an emergency. Slipping must to be possible from the bridge as well as from at least one other place in the vicinity of the hook itself, from where in both cases the hook can be easily seen.

D.3.2 The towing hook has to be equipped with a mechanical, hydraulic or pneumatic slip device. The slip device is to be designed such as to guarantee that unintentional slipping is avoided.

D.3.3 A mechanical slip device is to be designed such that the required release force under test force PL does not exceed neither $150\ N$ at the towing hook nor $250\ N$ when activating the device on the bridge. In case of a mechanical slip device, the releasing rope is to be guided adequately over sheaves. If necessary, slipping should be possible by downward pulling, using the whole body weight.

D.3.4 Where a pneumatic or hydraulic slip device is used, a mechanical slip device has to be provided additionally.

D.3.5 Dimensioning of towing hook and towing gear

D.3.5.1 The dimensioning of the towing gear is based on the test force PL, see D.2.2.

D.3.5.2 The towing hook, the towing hook foundation, the corresponding substructures and the slip device are to be designed for the following directions of the towrope:

- For a test force $PL \leq 500\ kN$:
  - in the horizontal plane, directions from abeam over astern to abeam
  - in the vertical plane, from horizontal to $60\ °$ upwards
- For a test force $PL > 500\ kN$:
  - in the horizontal plane, as above
  - in the vertical plane, from horizontal to $45\ °$ upwards

D.3.5.3 Assuming the test force PL acting in any of the directions described in D.3.5.2, the permissible stresses in the towing equipment elements defined above are not to exceed the values shown in Table 25.2.

D.3.5.4 For the towing hook foundation it has to be additionally proven that the permissible stresses given in Table 25.2 are not exceeded assuming a load equal to the minimum breaking force F_{min} of the towrope.

Table 25.2 Permissible stresses

Type of stress	Permissible stress
Axial and bending tension and axial and bending compression with box type girders and tubes	$\sigma = 0.83 \cdot R_{eH}$
Axial and bending compression with girders of open cross sections or with girders consisting of several members	$\sigma = 0.72 \cdot R_{eH}$
Shear	$\tau = 0.48 \cdot R_{eH}$
Equivalent stress	$\sigma_v = 0.85 \cdot R_{eH}$

D.4 Towropes

D.4.1 Towrope materials are to correspond to the GL Rules for Equipment (II-1-4). All wire ropes should have as far as possible the same lay.

D.4.2 The length of the towrope is to be chosen according to the tow formation (masses of tug and towed object), the water depth and the nautical conditions. Regulations of flag state authorities have to be observed. For length of towrope for bollard pull test, see the GL Guidelines for Ocean Towage (VI-11-1).

D.4.3 The required minimum breaking force F_{min} of the towrope is to be determined by the following formula:

$$F_{min} = K \cdot T \quad [kN]$$

K : utility factor, defined as:

$K = 2.5$ for $T \le 200$ kN

$K = 2.0$ for $T \ge 1\,000$ kN

For T between 200 and 1 000 kN, K may be interpolated linearly.

T : design force [kN]

D.4.4 For ocean towages, at least one spare towrope with attachments has be available on board.

D.4.5 The required minimum breaking force F_{min} of the tricing rope is to be calculated on the basis of the holding capacity of the tricing winch and a utility factor $K = 2.5$.

D.5 Towing winches

D.5.1 Arrangement and control

D.5.1.1 The towing winch, including towrope guiding equipment, has to be arranged such as to guarantee safe guiding of the towrope in all directions according to D.3.5.2.

D.5.1.2 The winch is to be capable of being safely operated from all control stands. Apart from the control stand on the bridge, at least one additional control stand has to be provided on deck. From each control stand the winch drum has to be freely visible; where this is not ensured, the winch is to be provided with a self-rendering device.

D.5.1.3 Each control stand has to be equipped with suitable operating and control elements. The arrangement and the working direction of the operating elements have to be analogous to the direction of motion of the towrope.

D.5.1.4 Operating levers have to, when released, return into the stop position automatically. They are to be capable of being secured in the stop position.

D.5.1.5 It is recommended that, on vessels for ocean towage, the winch is fitted with equipment for measuring the pulling force in the towrope.

D.5.1.6 If, during normal operating conditions, the power for the towing winch is supplied by a main engine shaft generator, another generator has to be available to provide power for the towing winch in case of main engine or shaft generator failure.

D.5.2 Winch drum

D.5.2.1 The towrope is to be fastened on the winch drum by a breaking link.

D.5.2.2 The winch drum is to be capable of being declutched from the drive.

D.5.2.3 The diameter of the winch drum is to be not less than 14 times the towrope diameter.

D.5.2.4 The length of the winch drum is to be such that at least $50\ m$ of the towrope can be wound up in the first layer.

D.5.2.5 To ensure security of the rope end fastening, at least 3 dead turns have to remain on the drum.

D.5.2.6 At the ends, drums are to have disc sheaves whose outer edges have to surmount the top layer of the rope at least by 2.5 rope diameters, if no other means is provided to prevent the rope from slipping off the drum.

D.5.2.7 If a multi-drum winch is used, then each winch drum is to be capable of independent operation.

D.5.2.8 D.5.2.3 to D.5.2.5 are not applicable to towropes of austenitic steels and fibre ropes. In case these towrope materials are utilized, dimensioning of the winch drum is subject to GL approval.

D.5.3 Holding capacity / dimensioning

D.5.3.1 The holding capacity of the towing winch (towrope in the first layer) has to correspond to $80\ \%$ of the minimum breaking load F_{min} of the towrope.

D.5.3.2 When dimensioning the towing winch components, which - with the brake engaged - are exposed to the pull of the towrope (rope drum, drum shaft, brakes, foundation frame and its fastening to the deck), a design tractive force equal to the holding capacity is to be assumed. When calculating the drum shaft the dynamic stopping forces of the brakes have to be considered. The drum brake is not to give way under this load.

D.5.4 Brakes

D.5.4.1 If the drum brakes are power-operated, manual operation of the brake is to be provided additionally.

D.5.4.2 Drum brakes are to be capable of being quickly released from the control stand on the bridge, as well as from any other control stand. The quick release has to be possible under all working conditions, including failure of the power drive.

D.5.4.3 The operating levers for the brakes are to be secured against unintentional operation.

D.5.4.4 Following operation of the quick release device, normal operation of the brakes are to be restored immediately.

D.5.4.5 Following operation of the quick release device, the winch driving motor are not to start again automatically.

D.5.4.6 Towing winch brakes are to be capable of preventing the towrope from paying out when the vessel is towing at the design force T and are not to be released automatically in case of power failure.

D.5.5 Tricing winches

D.5.5.1 Control stands for the tricing winches have to be located at safe distance off the sweep area of the towing gear. Apart from the control stands on deck, at least one other control stand have to be available on the bridge.

D.5.5.2 Tricing winches have to be suitably dimensioned depending on F_{min} of the tricing rope. For operation of the tricing winch, perfect transmission of orders has to be safeguarded. For tricing ropes, see D.4.5.

D.6 Testing

D.6.1 Workshop testing

D.6.1.1 Towing hook and slip device

D.6.1.1.1 Towing hooks with a mechanical slip device, the movable towing arm and other load transmitting elements have to be subjected to a test force PL with the aid of an approved testing facility. In connection with this test, the slip device is to be tested likewise; the release force has to be measured and is not to exceed $150\ N$, see D.3.3.

D.6.1.1.2 When towing hooks are provided with a pneumatic slip device, both the pneumatic and the mechanical slip device required by D.3.4 are to be tested according to D.6.1.1.1.

D.6.1.1.3 Also towing hooks with a hydraulic slip device have to be tested according to D.6.1.1.1, but the slip device itself need not be subjected to the test load. If a cylinder tested and approved by GL is employed as a loaded gear component, during the load test the cylinder may be replaced by a load transmitting member not pertaining to the gear, the operability of the gear being restored subsequently. The operability of the slip device has to be proved with the towrope loosely resting on the hook.

D.6.1.2 Certification and stamping of towing hook

Following each satisfactory testing at manufacturer's, a Certificate (F 186) will be issued by the attending surveyor and is to be handed on board, together with the towing hook.

D.6.1.3 Towing winches

D.6.1.3.1 The winch power unit has to be subjected to a test bed trial at the manufacturer's. A works test certificate has to be presented on the occasion of the final inspection of the winch, see D.6.2.3

D.6.1.3.2 Components exposed to pressure are to be pressure-tested to a test pressure PD of

$$PD = 1.5 \cdot p$$

p : admissible working pressure or opening pressure of the safety valves $[b]$. However, with working pressures exceeding 200, the test pressure need not be higher than $p + 100$.

Tightness tests are to be carried out at the relevant components.

D.6.1.3.3 Upon completion, towing winches have to be subjected to a final inspection and an operational test to the rated load. The hauling speed has to be determined during an endurance test under the rated tractive force. During these trials, in particular the braking and safety equipment is to be tested and adjusted.

The brake has to be tested to a test load equal to the rated holding capacity**,** but at least equal to the bollard pull.

If manufacturers do not have at their disposal the equipment required, a test confirming the design winch capacity, and including adjustment of the overload protection device, may be carried out after installation on board, see D.6.2.4.

In that case only the operational trials without applying the prescribed loads will be carried out at the manufacturers.

D.6.1.4 Accessory towing gear components and towropes

D.6.1.4.1 Accessories subjected to towing loads, where not already covered by D.6.1.1.1, are generally to be tested to test force PL at the manufacturer.

D.6.1.4.2 For all accessories Test Certificates, Form LA 3, and for the towrope, Form LA 4, have to be submitted.

D.6.1.4.3 GL reserve the right of stipulating an endurance test to be performed at towing gear components, where considered necessary for assessment of their operability.

D.6.2 Initial testing

D.6.2.1 Towing gear on board

The installed towing gear is to be tested on the tug using the bollard pull test to simulate the towrope pull.

D.6.2.2 Bollard pull test

In general a bollard pull test will be carried out before entering into service of the vessel. The test can be witnessed and certified by GL, see VI – Additional Rules and Guidelines, Part 11 – Other Operations and Systems, Chapter 1 – Guidelines for Ocean Towage.

D.6.2.3 Towing hooks

For all towing hooks (independent of the magnitude of the test force PL), the slip device has to be tested with a towrope direction of $60\,°$ towards above against the horizontal line, under the towrope pull T.

The Surveyor certifies the initial board test by an entry into the Test Certificate for Towing Hooks (Form F 186).

D.6.2.4 Towing winches on board

After installation on board, the safe operation of the winch(es) from all control stands has to be checked; it has to be proved that in both cases, with the drum braked and during hauling and releasing, the respective quick-release mechanism for the drum operates well. These checks may be combined with the Bollard Pull Test, see D.6.2.2.

The towing winch has to be subjected to a trial during the bollard pull test to a test load corresponding to the holding power of the winch.

D.6.3 Recurrent testing

D.6.3.1 General

The following tests will be applied to all tugs classed by GL unless otherwise required by the Administration.

The Surveyor certifies the satisfactory recurrent test in Part C of Form F 186.

D.6.3.2 Towing hooks

D.6.3.2.1 The functional safety of towing hook and slip device is to be checked by the ship's master at least once a month.

D.6.3.2.2 Following initial testing on board, towing hooks with mechanical and/or pneumatic slip devices have to be removed every 2.5 years, thoroughly examined and exposed to test force PL on a recognised testing facility. Upon reinstallation of the hook on the tug, the slip device has to be subjected to an operational trial by releasing the hook without load. The release forces at the hook and at the bridge have to be measured.

For avoiding dismounting of these towing hooks, the test force PL can also be produced by fastening in front of the first tug towed to the bollard, the hook of which is intended to be tested, another tug with a design force T which is sufficient to jointly reach the required test force PL according to Table 25.1. Slipping has to be effected whilst both tugs are pulling with full test force.

D.6.3.2.3 Following initial testing on board, towing hooks with hydraulic slip device are to be subjected to a functional test on board every 2.5 years. They are ready for operation with the towrope loosely resting on the hook. The release forces required at the hook and at the bridge have to be measured. Additionally all components are to be thoroughly examined. Every 5 years the towing hook has to be pulled against a bollard.

D.6.3.2.4 Particular attention has to be paid to the proper functioning of all gear components.

E Steering Gear / Steering Arrangement

E.1 Steering stability

Steering stability, i.e. stable course maintaining capability of the tug, is to be ensured under all normally occurring towing conditions. Rudder size and rudder force are to be suitable in relation to the envisaged towing conditions and speed.

E.2 Rudder movement

Regarding the time to put the rudder from one extreme position to the other, the requirements of the GL Rules for Machinery Installations (I-1-2), Section 14, A. are to be observed for tugs exceeding 500 gross tons. Special rudder arrangements may be considered in the particular case, see also E.4.

E.3 Tugs operating as pusher units

For tugs operating as pusher units, the steering gear is to be designed so as to guarantee satisfying steering characteristics in both cases, tug alone and tug with pushed object.

E.4 Special steering arrangements

Steering units and arrangements not explicitly covered by the Rules mentioned above, and combinations of such units with conventional rudders, will be considered from case to case.

F Anchoring / Mooring Equipment

F.1 Equipment numeral

The equipment with anchors and chains as well as the recommended towropes of tugs for unrestricted service is to be determined according to Section 18, B. However, for the determination of the equipment numeral the term $2 \cdot h \cdot \mathbf{B}$ may be substituted by the term:

$$2 \cdot \left(a \cdot \mathbf{B} + \Sigma h_i \cdot b_i\right)$$

$a, \sum h_i$: distance and heights according to Section 18, B.1

b_i : breadth of the superstructure tier "$_i$", considering only tiers with a breadth greater than $\mathbf{B} / 4$.

(IACS UR A1.3.1)

F.2 General requirements

F.2.1 The equipment of tugs for restricted service areas is to be determined as for vessels in the **RSA (20)** or **RSA (50)** range, see Section 18, A.1.3. For tugs in the service range **RSA (SW)**, see Section 30, F.

(IACS UR A1.3.1)

F.2.2 For tugs engaged only in berthing operations, one anchor is sufficient, if a spare anchor is readily available on land.

F.2.3 The stream anchor specified in Section 18, Table 18.2 is not required for tugs.

F.3 Tugs operating as pusher units

The anchoring equipment for tugs operating as pusher units will be considered according to the particular service. Normally, the equipment is intended to be used for anchoring the tug alone, the pushed unit being provided with its own anchoring equipment.

G Weather tight integrity and stability

G.1 Weather deck openings

G.1.1 Openings (skylights) above the machinery space are to be arranged with coamings not less than 900 mm high, measured from the upper deck. Where the height of the coaming is less than 1.8 m, the casing covers are to be of specially strong construction, see also H.1.

G.1.2 The head openings of ventilators and air pipes are to be arranged as high as possible above the deck.

G.1.3 For companionways to spaces below deck to be used while at sea, sills with a height not less than 600 mm are to be provided. Watertight steel doors are to be provided which can be opened / closed from either side.

G.1.4 Deck openings are to be avoided in the sweep area of the towing gear, or else be suitably protected.

G.2 Stability

G.2.1 The intact stability is to comply with the following requirements:

- the intact stability requirement of Section 28
- alternatively if applicable, the intact stability requirement of the 2008 IS Code, Chapter B.2.4

G.2.2 Additionally, the intact stability is to comply with one of the following requirements:

- The residual area between a righting lever curve and a heeling lever curve developed from 70 % of the maximum bollard pull force acting in 90 ° to the ship-length direction should not be less than 0.09 mrad. The area has to be determined between the first interception of the two curves and the second interception or the angle of down flooding whichever is less.
- Alternatively, the area under a righting lever curve should not be less than 1.4 times the area under a heeling lever curve developed from 70 % of the maximum bollard pull force acting in 90 ° to ship-length direction. The areas to be determined between 0° and the 2nd interception or the angle of down flooding whichever is less.

G.2.3 The curve of heeling levers b_h should be determined by the following formula:

$$b_h = \frac{0.071 \cdot T \cdot z_h \cdot \cos\varphi}{D} \quad [m]$$

T : maximum bollard pull [kN]

H Escape routes and safety measures

H.1 Engine room exit

In the engine room an emergency exit is to be provided on or near the centerline of the vessel, which can be used at any inclination of the ship. The cover is to be weather tight and is to be capable of being opened easily from outside and inside. The axis of the cover is to run in athwart ship direction.

H.2 Companionways

Companionways to spaces below deck see G.1.3.

H.3 Rudder compartment

Where, for larger ocean going tugs, an emergency exit is provided from the rudder compartment to the upper deck, the arrangement, sill height and further details are to be designed according to the requirements of G.1, particularly G.1.4.

H.4 Access to bridge

Safe access to the bridge is to be ensured for all anticipated operating and heeling conditions, also in heavy weather during ocean towage.

H.5 Fire safety

H.5.1 Structural fire protection measures are to be as outlined in Section 22, as applicable according to the size of the vessel. The fire fighting equipment has to conform to the GL Rules for Machinery Installations (I-1-2), Section 12, as applicable.

H.5.2 Additional or deviating regulations of the competent Administration may have to be observed.

I Additional Requirements for Active Escort Tugs

I.1 General

I.1.1 The following escort characteristics are to be determined by approved full scale trials:

- maximum steering force TEy [kN] at a test speed of advance V_t [kn], normally 8 to 10 kn
- manoeuvring time t [s]
- manoeuvring coefficient $K = 31 / t$ or 1, whichever is less

I.1.2 A test certificate indicating the escort characteristics is issued on successful completion of such trials.

I.2 Definitions

I.2.1 Active Escort Tug is a tug performing the active escort towing.

I.2.2 Assisted vessel is the vessel being escorted by an Active Escort Tug.

I.2.3 Indirect towing is a typical manoeuvre of the Active Escort Tug where the maximum transverse steering force is exerted on the stern of the assisted vessel while the Active Escort Tug is at an oblique angular position. The steering force TEy [kN] is provided by the hydrodynamic forces acting on the Active Escort Tug's hull, see Fig. 25.1.

I.2.4 Test speed V_t [kn] is the speed of advance (through the water) of the assisted vessel during full scale trials.

I.2.5 The manoeuvring time t [s] is the time needed for the Active Escort Tug to shift in indirect towing from an oblique angular position at the stern of the assisted vessel to the mirror position on the other side, see Fig. 25.1. The length of the towline during such a manoeuvre should not be less than 50 m and the towline angle need not be less than 30 °.

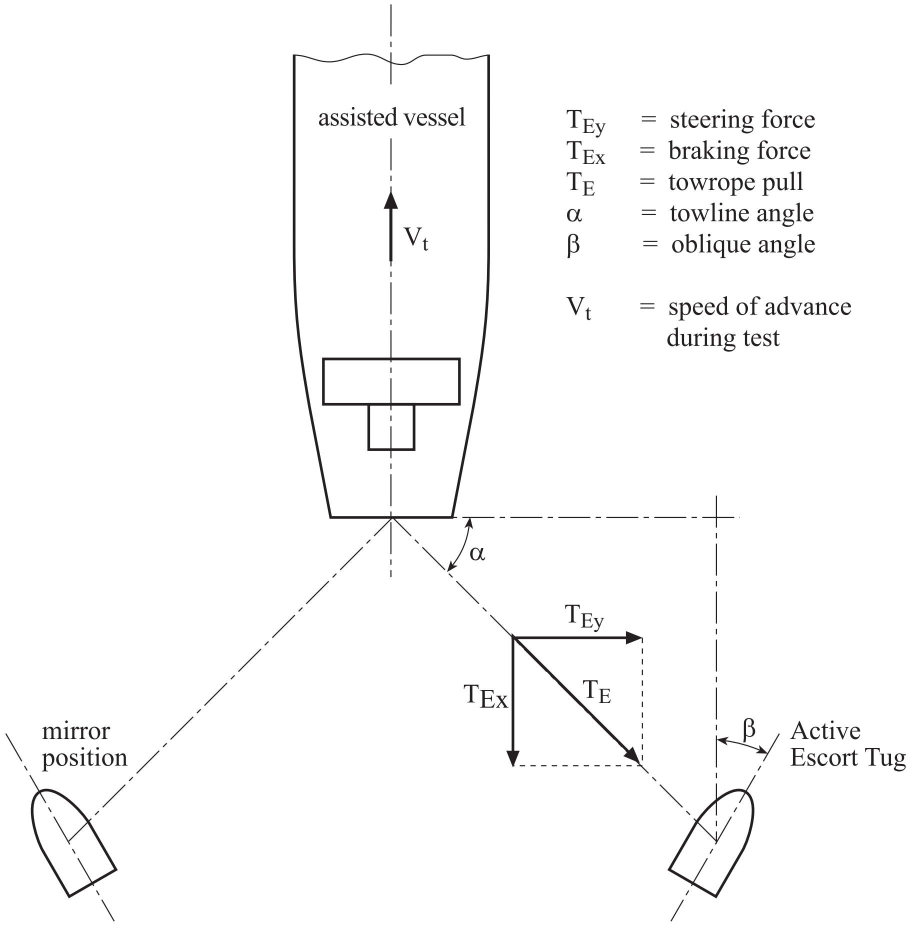


Fig. 25.1 Typical working mode of an Active Escort Tug

I.3 Arrangement and Design

I.3.1 Hull

I.3.1.1 The hull of the Active Escort Tug is to be designed to provide adequate hydrodynamic lift and drag forces when in indirect towing mode. Hydrodynamic forces, towline pull and propulsion forces are to be in balance during active escort towing thereby minimising the required propulsion force itself.

I.3.1.2 Freeboard is to be provided in such a way, that excessive trim at higher heeling angles is avoided.

I.3.1.3 A bulwark is to be fitted all around the weather deck.

I.3.2 Towing winch

I.3.2.1 The equipment for measuring the pulling force in the towrope, recommended in D.5.1.5, is to be provided in any case for towing winches of Active Escort Tugs.

I.3.2.2 In addition to the requirements given in D.5 towing winches of escort tugs are to be fitted with a load damping system which prevents overload caused by dynamic impacts in the towrope.

The towing winch has to pay out the towrope controlled when the towrope pull exceeds 50 % of the minimum breaking force F_{min} of the towrope. Active escort towing is always carried out via the towing winch, without using the brake on the towing winch's rope drum.

I.3.2.3 The towing winch has to automatically spool a slack towrope. The requirement D.5.2.4 may be waived, if an impeccable spooling of the towrope under load is guaranteed by design measures (e.g. spooling device).

I.3.3 Propulsion

In case of loss of propulsion during indirect towing the remaining forces are to be so balanced that the resulting turning moment will turn the Active Escort Tug to a safer position with reduced heel.

I.4 Stability of Active Escort Tugs

Proof of stability has to be shown by using the curve of heeling levers b_h calculated by the following formula:

$$b_h = \frac{T_E \cdot z_h \cdot \cos\varphi}{9.81 \cdot D} \quad [m]$$

T_E : maximum towrope pull $[kN]$

I.5 Full Scale Trials

I.5.1 Procedure

I.5.1.1 A documented plan, describing all parts of the trial is to be submitted for approval before commencement of the trials, including:

- towage arrangement plan
- data of assisted vessel including SWL of the strong points
- intended escort test speed
- calculated maximum steering force TEy $[kN]$

I.5.1.2 Full scale trials are to be carried out in favourable weather and sea conditions which will not significantly influence the trial results.

I.5.1.3 The size of the assisted vessel is to be sufficiently large to withstand the transverse steering forces of the tug without using too large rudder angles.

I.5.2 Recordings

At least the following data are to be recorded continuously during the trial for later analysis:

- Assisted vessel:
  - position
  - speed over ground and through the water
  - heading
  - rudder angle
  - angle of towline
  - wind (speed and direction), sea-state
- Active Escort Tug:
  - position and speed over ground
  - heading
  - length, angle β and pull of towrope T_E
  - heeling angle

Section 26 Passenger Ships

A General

A.1 Application

A.1.1 Ships intended to get the Notation **PASSENGER SHIP**, **PASSENGER SHIP EU** and **PASSENGER SHIP N** are to be in compliance with this section. Unless specially mentioned in this Section, the requirements of Sections 1 – 22 and 27 and the stability requirements of SOLAS apply.

A.1.2 Exemptions from these requirements may be granted only within the framework of options given therein and are subject of approval by the competent Administration.

Note

For ships subject to the supervision of the BG Verkehr Dienststelle Schiffssicherheit (BG Verkehr Ship Safety Division), the additional regulations of the valid Schiffssicherheitsverordnung (SSV) and Unfallverhütungsvorschriften (UVV) are to be observed.

B Superstructure

B.1 In general the requirements of Section 16 have to be observed. If a corresponding weight calculation can be provided, the deck load p_{AD} in cabin areas according to Section 4, C.3 may be reduced to:

$$p_{AD} = 2.5 \cdot (1 + a_v) \quad [kN/m^2]$$

a_v : acceleration addition according to Section 4, A.3

B.2 The following minimum thicknesses t_{min} for accommodation and superstructure decks have to be observed:

$t_{min} = 5.0$ mm for decks inside

$t_{min} = 5.5$ mm for decks exposed to weather, if effective sheathing is provided.

C Materials for Closures of Openings

Appropriate materials are to be used only. Materials with at least 10 % breaking elongation are to be used for the closures of openings in the shell plating, in watertight bulkheads, in boundary bulkheads of tanks, and in watertight decks. Lead and other heat sensitive materials are not to be used for structural parts whose destruction would impair the watertightness of the ship and/or the bulkheads.

D Pipe Lines

D.1 Where pipes are carried through watertight bulkheads, Chapter II-1 Reg. 12 and 13 of SOLAS as amended is to be observed.

D.2 Where the ends of pipes are open to spaces below the bulkhead deck or to tanks, the arrangements are to be such as to prevent other spaces or tanks from being flooded in any damage condition. Arrangements will be considered to provide safety against flooding if pipes which are led through two or more watertight compartments are fitted inboard of a line parallel to the subdivision load line drawn at $0.2\ \mathbf{B}$ from the ship's side ($\mathbf{B}$ is the greatest breadth of the ship at the subdivision load line level).

D.3 Where the pipe lines cannot be placed inboard of the line $0.2\ \mathbf{B}$ from the ship's side, the bulkhead is to be kept intact by the means stated in D.4 – D.6.

D.4 Bilge lines have to be fitted with a non-return valve at the watertight bulkhead through which the pipe is led to the section or at the section itself.

D.5 Ballast water and fuel lines for the purpose of emptying and filling tanks have to be fitted with a shutt-off valve at the watertight bulkhead through which the pipe leads to the open end in the tank. These shut-off valves are to be capable of being operated from a position above the bulkhead deck which is accessible at all times and are to be equipped with indicators.

D.6 Where overflow pipes from tanks which are situated in various watertight compartments are connected to a common overflow system, they are either to be led well above the bulkhead deck before they are connected to the common line, or means of closing are to be fitted in the individual overflow lines. The means of closing is to be capable of being operated from a position above the bulkhead deck which is accessible at all times. These means of closing are to be fitted at the watertight bulkhead of the compartment in which the tank is fitted and are to be sealed in the open position.

These means of closing may be omitted, if pipe lines pass through bulkheads at such a height above base line and so near the centre line that neither in any damaged condition nor in case of maximum heeling occurring in intermediate conditions, they will be below the water line.

D.7 The means of closing described in D.4 and D.5 should be avoided where possible by the use of suitably installed piping. Their fitting may only be approved by GL in exceptional circumstances.

E Side Scuttles and Windows

E.1 Depending on the arrangement of side scuttles and windows, the following tests are to be performed.

E.1.1 Ship safety relevant areas, such as all tiers of front walls of superstructures, wheelhouse and others as may be defined.

- tests according to ISO 1751 and ISO 3903 as appropriate. Window sizes not covered by ISO standards are to be tested at four times design pressure.

E.1.2 Side walls and aft facing walls of superstructures from the 2^{nd} to the 4^{th} tier above freeboard deck.

- no test requirements regarding weathertightness
- test for structural strength according ISO 1751 and ISO 3903 as appropriate at four times design pressure.

E.1.3 Side walls and aft facing walls of superstructures 5^{th} tier and upwards above freeboard deck.

- no test requirements regarding weathertightness

- test for structural strength according ISO 1751 and ISO 3903 as appropriate at two times design pressure.

All design pressures for the dimensioning of side scuttles and windows on the basis of ISO 1751, ISO 3903 and ISO 21005 are to be in accordance with Section 21, D.2. However, the design pressure for the 5^{th} tier and higher for all areas, except unprotected fronts, can be set to $3.6\ kN / m^2$.

Section 27 General Arrangement

A General

A.1 Application

Unless expressly provided otherwise in the subsections, the requirements of this section apply to cargo ships and to passenger ships.

A.2 References

International conventions and codes

Paragraphs of this section are based on the following international convention(s) and/or code(s):

SOLAS including all amendments up to 1st July 2012

ICLL containing all amendments up to 1st July 2010

At the end of each relevant paragraph, the corresponding paragraphs of the international convention(s) and/or code(s) are given in brackets.

A.3 Definitions

Machinery Space of category A

Machinery spaces of category A are those spaces and trunks to such spaces which contain:

1. internal combustion machinery used for main propulsion;
2. internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
3. any oil-fired boiler or oil fuel unit.

Moulded depth D_1

The moulded depth is the vertical distance measured from the top of the keel to the top of the freeboard deck beam at side. In wood and composite ships the distance is measured from the lower edge of the keel rabbet. Where the form at the lower part of the midship section is of a hollow character, or where thick garboards are fitted, the distance is measured from the point where the line of the flat of the bottom continued inwards cuts the side of the keel.

In ships having rounded gunwales, the moulded depth is to be measured to the point of intersection of the moulded lines of deck and sides, the lines extending as though the gunwale were of angular design.

Where the freeboard deck is stepped and the raised part of the deck extends over the point at which the moulded depth is to be determined, the moulded depth is to be measured to a line of reference extending from the lower part of the deck along a line parallel with the raised part.

B Subdivision

B.1 General

B.1.1 All ships are to have a collision bulkhead, a stern tube bulkhead and one watertight bulkhead at each end of the engine room. In ships with machinery aft, the stern tube bulkhead may substitute the aft engine room bulkhead (see also B.4).

B.1.2 Number and location of transverse bulkheads fitted in addition to those specified in B.1.1 are to be so selected as to ensure sufficient transverse strength of the hull.

B.2 References

For ships which require proof of survival capability in damaged conditions, the watertight subdivision will be determined by damage stability calculations.

- In general see Section 28
- for liquefied gas carriers see the Liquefied Gas Carriers (I-1-6), Section 2
- for chemical tankers see the Chemical Tankers (I-1-7), Section 2.

B.3 Collision bulkhead

B.3.1 A collision bulkhead is to be fitted which is to be watertight up to the bulkhead deck. This bulkhead is to be located at a distance from the forward perpendicular of not less than $0.05 \cdot \mathbf{L_c}$ or 10 m, whichever is the less, and, except as may be permitted by the Administration, not more than $0.08 \cdot \mathbf{L_c}$ or $0.05 \cdot \mathbf{L_c} + 3\mathrm{m}$, whichever is the greater.

(SOLAS II-1, 12.1)

B.3.2 Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g., a bulbous bow, the distances stipulated in B.3.1 is to be measured from a point $\mathrm{FP} + \mathrm{x}$ which is either:

- at the mid-length of such extension, i.e. $\mathrm{x} = 0.5\ \mathrm{a}$
- at a distance $0.015 \cdot \mathbf{L_c}$ forward of the forward perpendicular, i.e. $\mathrm{x} = 0.015 \cdot \mathbf{L_c}$, or
- at a distance 3 m forward of the forward perpendicular, i.e. $\mathrm{x} = 3.0$ m

whichever gives the smallest measurement

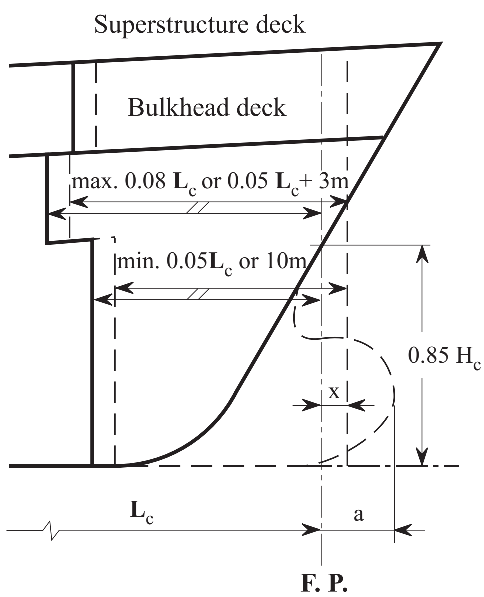


Fig. 27.1 Location of collision bulkhead

The length L_c and the distance a are to be specified in the approval documents.

(SOLAS II-1, 12.2)

B.3.3 If B.3.2 is applicable, the required distances specified in B.3.1 are to be measured from a reference point located at a distance x forward of the **F.P.**.

B.3.4 The collision bulkhead is to extend watertight up to the bulkhead deck. The bulkhead may have steps or recesses provided they are within the limits prescribed in B.3.1.

(SOLAS II-1, 12.3)

B.3.5 No doors, manholes, access openings, ventilation ducts or any other openings are permitted in the collision bulkhead below the bulkhead deck.

(SOLAS II-1, 12.4)

B.3.6 Except as provided in B.3.7 the collision bulkhead may be pierced below the bulkhead deck by not more than one pipe for dealing with fluid in the forepeak tank, provided that the pipe is fitted with a screw-down valve capable of being operated from above the bulkhead deck, the valve chest being secured inside the forepeak to the collision bulkhead. The Administration may, however, authorize the fitting of this valve on the after side of the collision bulkhead provided that the valve is readily accessible under all service conditions and the space in which it is located is not a cargo space. All valves are to be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

(SOLAS II-1, 12.5.1)

B.3.7 If the forepeak is divided to hold two different kinds of liquids the Administration may allow the collision bulkhead to be pierced below the bulkhead deck by two pipes, each of which is fitted as required by B.3.6, provided the Administration is satisfied that there is no practical alternative to the fitting of such a second pipe and that, having regard to the additional subdivision provided in the forepeak, the safety of the ship is maintained.

(SOLAS II-1, 12.5.2)

B.3.8 Where a long forward superstructure is fitted the collision bulkhead is to be extended weathertight to the deck next above the bulkhead deck. The extension need not be fitted directly above the bulkhead below provided it is located within the limits prescribed in B.3.1 or B.3.3 with the exception permitted by B.3.9 and that the part of the deck which forms the step is made effectively weathertight. The extension is to be so arranged as to preclude the possibility of the bow door causing damage to it in the case of damage to, or detachment of, a bow door.

(SOLAS II-1, 12.6)

B.3.9 Where bow doors are fitted and a sloping loading ramp forms part of the extension of the collision bulkhead above the bulkhead deck, the ramp is to be weathertight over its complete length. In cargo ships the part of the ramp which is more than 2.3 m above the bulkhead deck may extend forward of the limits specified in B.3.1 or B.3.3. Ramps not meeting the above requirements are to be disregarded as an extension of the collision bulkhead.

(SOLAS II-1, 12.7)

B.3.10 The number of openings in the extension of the collision bulkhead above the bulkhead deck are to be restricted to the minimum compatible with the design and normal operation of the ship. All such openings are to be capable of being closed weathertight.

(SOLAS II-1, 12.8)

B.4 Stern tube bulkhead and remaining watertight bulkheads

B.4.1 Bulkheads are to be fitted separating the machinery space from cargo and accommodation spaces forward and aft and made watertight up to the bulkhead deck. In passenger ships an afterpeak bulkhead is to also be fitted and made watertight up to the bulkhead deck. The afterpeak bulkhead may, however, be stepped below the bulkhead deck, provided the degree of safety of the ship as regards subdivision is not thereby diminished.

(SOLAS II-1, 12.9)

B.4.2 In all cases stern tubes are to be enclosed in watertight spaces of moderate volume. In passenger ships the stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the stern tube compartment and of such volume that, if flooded by leakage through the stern gland, the bulkhead deck will not be immersed. In cargo ships other measures to minimize the danger of water penetrating into the ship in case of damage to stern tube arrangements may be taken at the discretion of the Administration.

(SOLAS II-1, 12.10)

B.5 Partition bulkheads

B.5.1 Partition bulkheads between engine and boiler rooms

B.5.1.1 Boiler rooms generally are to be separated from adjacent engine rooms by bulkheads.

B.5.1.2 The bilges are to be separated from each other in such a way that no oil can pass from the boiler room bilge to the engine room bilge. Bulkhead openings are to have hinged doors.

B.5.1.3 Where a close connection between engine and boiler room is advantageous in respect of supervision and safety, complete bulkheads may be dispensed with, provided the conditions given in the GL Rules for Machinery Installations (I-1-2) are complied with.

B.6 Openings

B.6.1 Openings in watertight bulkheads and internal decks in cargo ships

B.6.1.1 The number of openings in watertight subdivisions is to be kept to a minimum compatible with the design and proper working of the ship.

Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity.

The Administration may permit relaxations in the water tightness of openings above the freeboard deck, provided that it is demonstrated that any progressive flooding can be easily controlled and that the safety of the ship is not impaired.

(SOLAS II-1, 13-1.1)

B.6.1.2 Doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors (see the Machinery Installations (I-1-2), Section 14) capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control position showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimize the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. It has to be possible to open and close the door by hand at the door itself from both sides.

(SOLAS II-1, 13-1.2)

B.6.1.3 Access doors and access hatch covers normally closed at sea, intended to ensure the watertight integrity of internal openings, are to be provided with means of indication locally and on the bridge showing whether these doors or hatch covers are open or closed. A notice is to be affixed to each such door or hatch cover to the effect that it is not to be left open.

(SOLAS II-1, 13-1.3)

B.6.1.4 Watertight doors or ramps of satisfactory construction may be fitted to internally subdivide large cargo spaces, provided that the Administration is satisfied that such doors or ramps are essential. These doors or ramps may be hinged, rolling or sliding doors or ramps, but are not to be remotely controlled, see interpretation of regulations of Part B-1 of SOLAS Chapter II-1 (MSC/Circ. 651). Should any of the doors or ramps be accessible during the voyage, they are to be fitted with a device which prevents unauthorized opening.

(SOLAS II-1, 13-1.4)

B.6.1.5 Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of internal openings are to be provided with a notice which is to be affixed to each such closing appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

(SOLAS II-1, 13-1.5)

B.6.2 Openings in watertight bulkheads below the bulkhead deck in passenger ships

B.6.2.1 The number of openings in watertight bulkheads is to be reduced to the minimum compatible with the design and proper working of the ship, satisfactory means is to be provided for closing these openings.

(SOLAS II-1, 13.1)

B.6.2.2 Where pipes, scupper, electric cables, etc are carried through watertight bulkheads, arrangements are to be made to ensure the watertight integrity of the bulkheads.

(SOLAS II-1, 13.2.1)

B.6.2.3 Valves not forming part of a piping system are not permitted in watertight bulkheads.

(SOLAS II-1, 13.2.2)

B.6.2.4 Lead or other heat sensitive materials are not to be used in systems which penetrate watertight bulkheads, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkheads.

(SOLAS II-1, 13.2.3)

B.6.2.5 No doors, manholes or access openings are permitted in watertight transverse bulkheads dividing a cargo space from an adjoining cargo space, except as provided in B.6.3.22 and in **SOLAS** II-1, 14.

(SOLAS II-1, 13.3)

B.6.2.6 Subject to B.3.24, not more than one door, apart from the doors to shaft tunnels, may be fitted in each watertight bulkhead within spaces containing the main and auxiliary propulsion machinery including boilers serving the needs of propulsion. Where two or more shafts are fitted, the tunnels are to be connected by an intercommunicating passage. There is to be only one door between the machinery space and the tunnel spaces where two shafts are fitted and only two doors where there are more than two shafts. All these doors are to be of the sliding type and are to be so located as to have their sills as high as practicable. The hand gear for operating these doors from above the bulkhead deck is to be situated outside the spaces containing the machinery.

(SOLAS II-1, 13.4)

B.6.2.7 Watertight doors, except as provided in B.6.3.22 or **SOLAS** II-1, 14, are to be power-operated sliding doors complying with the requirements of B.6.3.11 capable of being closed simultaneously from the central operating console at the navigation bridge in not more than $60 s$ with the ship in the upright position.

(SOLAS II-1, 13.5.1)

B.6.2.8 The means of operation whether by power or by hand of any power-operated sliding door is to be capable of closing the door with the ship listed to $15°$ either way. Consideration is also to be given to the forces which may act on either side of the door as may be experienced when water is flowing through the opening applying a static head equivalent to a water height of at least 1 m above the sill on the centreline of the door.

(SOLAS II-1, 13.5.2)

B.6.2.9 Watertight door controls, including hydraulic piping and electric cables, are to be kept as close as practicable to the bulkhead in which the doors are fitted, in order to minimize the likelihood of them being involved in any damage which the ship may sustain. The position of watertight doors and their controls is to be such that if the ship sustains damage within one fifth of the breadth of the ship, as defined in B.6.3.2 – B.6.3.4, such distance being measured at right angles to the centreline at the level of the deepest subdivision draught, the operation of the watertight doors clear of the damage portion of the ship is not impaired.

(SOLAS II-1, 13.5.3)

B.6.2.10 All power-operated sliding watertight doors are to be provided with means of indication which will show at all remote operating positions whether the doors are open or closed. Remote operating positions are only to be at the navigation bridge as required by 5. of B.6.3.11 and at the location where hand operation above the bulkhead is required by 4. of B.6.3.11.

(SOLAS II-1, 13.6)

B.6.2.11 Each power-operated sliding watertight door:

1. has to have a vertical or horizontal motion;
2. is, subjected to B.6.3.24, to be normally limited to a maximum clear opening width of 1.2 m. The Administration may permit larger doors only to the extent considered necessary for the effective operatin of the ship provided that other safety measures, including the following, are taken into consideration:
   - special consideration is to be given to the strength of the door and its closing appliances in order to prevent leakages; and
   - the door is to be located inboard the damage zone **B** / 5;
3. is to be fitted with the necessary equipment to open and close the door using electric power, hydraulic power, or any other form of power that is acceptable to the Administration;
4. is to be provided with an individual hand-operated mechanism. It has to be possible to open and close the door by hand at the door itself from either sides, and in addition, close the door from an accessible position above the bulkhead deck with an all round crank motion or some other movement providing the same degree of safety acceptable to the Administration. Direction of rotation or other movement is to be clearly indicated at all operating by hand gear and is not to exceed 90 s with the ship in the upright position;
5. is to be provided with controls for opening and closing the door by power from both sides of the door and also for closing the door by power from the central operating console at the navigation bridge;
6. is to be provided with an audible alarm, distinct from any other alarm in the area, which will sound whenever the door is closed remotely by power and which has to sound for at least 5 s but no more than 10s before the door begins to move and which has to continue sounding until the door is completely closed. In the case of remote hand operation it is sufficient for the audible alarm to sound only when the door is moving. Additionally, in passenger area and areas of high ambient noise the Administration may require the audible alarm to be supplemented by an intermittent visual signal at the door; and
7. has to have an approximately uniform rate of closure under power. The closure time, from the door begins to move to the time it reaches the completely closed position, is in no case to be less than 20s or more than 40 s with the ship in the upright position.

(SOLAS II-1, 13.7.1)

B.6.2.12 The electrical power required for power-operated sliding watertight doors is to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck. The associated control, indication and alarm circuits are to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck and be capable of being automatically supplied by the transitional source of emergency electrical power required by **SOLAS** II-1, 42.3.1.3 in the event of failure of either the main or emergency source of electrical power.

(SOLAS II-1, 13.7.2)

B.6.2.13 Power-operated sliding watertight doors have to have either:

1. a centralized hydraulic system with two independent power sources each consisting of a motor and pump capable of simultaneously closing all doors. In addition, there is to be for the whole installation hydraulic accumulators of sufficient capacity to operate all the doors at least three times, i.e. closed-open-closed, against an adverse list of $15\ °$. This operation cycle is to be capable of being carried out when the accumulator is at the pump cut-in pressure. The fluid used is to be chosen considering the temperatures liable to be encountered by the installation during its service. The power operating system is to be designed to minimize the possibility of having a single failure in the hydraulic piping adversely affect the operation of more than one door. The hydraulic system is to be provided with a low-level alarm for hydraulic fluid reservoirs serving the power-operated system and a low gas pressure alarm or other effective means of monitoring loss of stored energy in hydraulic accumulators. These alarms are to be audible and visual and are to be situated on the central operating console at the navigation bridge; or
2. an independent hydraulic system for each power of a motor and pump capable of opening and closing the door. In addition, there is to be a hydraulic accumulator of sufficient to operate the door at least three times, i.e. closed-open-closed, against an adverse list of $15\ °$. This operating cycle is to be capable of being carried out when the accumulator is at the pump cut-in pressure. The fluid used is to be chosen considering the temperatures liable to be encountered by the installation during its service. A low gas pressure group alarm or other effective means of monitoring loss of stored energy in hydraulic accumulators is to be provided at the central operating console on the navigation bridge. Loss of stored energy indication at each local operating position is also to be provided; or
3. an independent electrical system and motor for each door with each power source consisting of a motor capable of opening and closing the door. The power source is to be capable of being automatically supplied by the transitional source of emergency electrical power as required by **SOLAS** II-1, 42.3.1.3 in the event of failure of either the main or emergency source of electrical power and with sufficient capacity to operate the door at least three times, i.e. closed-open-closed, against an adverse list of $15\ °$.

For the systems specified in 1. to 3. of B.6.3.13, provisions should be made as follows:

- Power systems for power-operated watertight sliding doors are to be separated from any other power system.
- A single failure in the electric or hydraulic power-operated systems excluding the hydraulic actuator is not to prevent the hand operation of any door.

(SOLAS II-1, 13.7.3)

B.6.2.14 Control handles are to be provided at each side of the bulkhead at a minimum height of $1.6\ \mathrm{m}$ above the floor and are to be so arranged as to enable persons passing through the doorway to hold both handles in the open position without being able to set the power closing mechanism in operation accidentally. The direction of movement of the handles in opening and closing the door is to be in the direction of door movement and is to be clearly indicated.

(SOLAS II-1, 13.7.4)

B.6.2.15 As far as practicable, electrical equipment and components for watertight doors are to be situated above the bulkhead deck and outside hazardous areas and spaces.

(SOLAS II-1, 13.7.5)

B.6.2.16 The enclosures of electrical components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water.

(SOLAS II-1, 13.7.6)

B.6.2.17 Electric power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of that door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

(SOLAS II-1, 13.7.7)

B.6.2.18 A single electrical failure in the power door operating or control system of a power-operated sliding watertight door is not to result in a closed door opening. Availability of the power supply should be continuously monitored at a point in the electrical circuit as near as practicable to each of the motors required by B.3.13. Loss of any such power supply should activate an audible and visual alarm at the central operating console at the navigation bridge.

(SOLAS II-1, 13.7.8)

B.6.2.19 The central operating console at the navigation bridge has to have a "master mode" switch with two modes of control: a "local control" mode which is to allow any door to be locally opened and locally closed after use without automatic closure, and a "doors closed" mode which has automatically to close any door that is open. The "doors closed" mode is to permit doors to be opened locally and has automatically to re-close the doors upon release of the local control mechanism. The "master mode" switch is normally to be in the "local control" mode. The "doors closed" mode is only to be used in an emergency or testing purpose. Special consideration is to be given to the reliability of the "master mode" switch.

(SOLAS II-1, 13.8.1)

B.6.2.20 The central operating console at the navigation bridge is to be provided with a diagram showing the location of each door, with visual indicators to show weather each door is open or closed. A red light has to indicate a door is fully open and a green light has to indicate a door is fully closed. When the door is closed remotely the red light has to indicate the intermediate position by flashing. The indication circuit is to be independent of the control circuit for each door.

(SOLAS II-1, 13.8.2)

B.6.2.21 It is not to be possible to remotely open any door from the central operating console.

(SOLAS II-1, 13.8.3)

B.6.2.22 If the Administration is satisfied that such doors are essential, watertight doors of satisfactory construction may be fitted in watertight bulkheads dividing cargo between deck spaces. Such doors may be hinged, rolling or sliding doors but are not to be remotely controlled. They are to be fitted at the highest level and as far from the shell plating as practicable, but in no case the outboard vertical edges are to be situated at a distance from the shell plating which is less than one fifth of the breadth of the ship, such distance being measured at right angles to the centreline at the level of the deepest subdivision draught.

(SOLAS II-1, 13.9.1)

B.6.2.23 Should any such doors be accessible during the voyage, they are to be fitted a device which prevents unauthorized opening. When it is proposed to fit such doors, the number and arrangements are to receive the special consideration of the Administration.

(SOLAS II-1, 13.9.2)

B.6.2.24 Portable plates on bulkheads are not permitted except in machinery spaces. The Administration may permit not more than one power-operated sliding watertight door in each watertight bulkhead larger than those specified in 1. of B.6.3.11 to be substituted for these portable plates, provided these doors are intended to remain closed during navigation except in case of urgent necessity at the discretion of the master. These doors need not meet the requirements of 4. of B.6.3.11 regarding complete by hand-operated gear in 90 s.

(SOLAS II-1, 13.10)

B.6.2.25 Where trunkways or tunnels for access from crew accommodation to the stokehold, for piping, or for any other purpose are carried through watertight bulkheads, they are to be watertight and in accordance with the requirements of C.6. The access to at least one end of each such tunnel or trunkway, if used as a passage at sea, is to be through trunk extending watertight to a height sufficient to permit access above the bulkhead deck. The access to the other end of the trunkway or tunnel may be through a watertight door of the type required by its location in the ship. Such trunkway or tunnels are not to extend through the first subdivision bulkhead abaft the collision bulkhead.

(SOLAS II-1, 13.11.1)

B.6.2.26 Where it is proposed to fit tunnels piercing watertight bulkheads, these have to receive the special consideration of the Administration.

(SOLAS II-1, 13.11.2)

B.6.2.27 Where trunkways in connection with refrigerated cargo and ventilation or forced draught trunks are carried through more than one watertight bulkhead, the means of closure at such openings is to be operated by power and be capable of being closed from position situated above the bulkhead deck.

(SOLAS II-1, 13.11.3)

B.6.3 External openings in cargo ships

B.6.3.1 All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, are required to be watertight.

(SOLAS II-1, 15-1.1)

B.6.3.2 Such openings are, except for cargo hatch covers, to be fitted with indicators on the bridge.

(SOLAS II-1, 15-1.2)

B.6.3.3 Openings in the shell plating below the deck limiting the vertical extent of damage are to be fitted with a device that prevents unauthorized opening, if they are accessible during the voyage.

(SOLAS II-1, 15-1.3)

B.6.3.4 Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of external openings are to be provided with a notice affixed to each appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

(SOLAS II-1, 15-1.4)

B.6.4 Openings in the shell plating below the bulkhead deck of passenger ships and the freeboard deck of cargo ships

B.6.4.1 The number of openings in the shell plating is to be reduced to the minimum compatible with the design and proper working of the ship.

(SOLAS II-1, 15.1)

B.6.4.2 The arrangement and efficiency of the means for closing any opening in the shell plating are to be consistent with its intended purpose and the position in which it is fitted and generally to the satisfaction of the Administration.

(SOLAS II-1, 15.2)

B.6.4.3 Subject to the requirements of the **ICLL** in force, no sidescuttle is to be fitted in such a position that its sill is below a line drawn parallel to the bulkhead deck at side and having its lowest point 2.5% of the breadth of the ship above the deepest subdivision draught, or 500 mm, whichever is the greater.

(SOLAS II-1, 15.3.1)

B.6.4.4 All sidescuttles the sill of which are below the bulkhead deck of passenger ships and the freeboard deck of cargo ships, as permitted in B.6.5.3, are to be of such construction as will effectively prevent any person opening them without the consent of the master of the ship.

(SOLAS II-1, 15.3.2)

B.6.4.5 Efficient hinged inside deadlights so arranged that they can be easily and effective closed and secured watertight, are to be fitted to all sidescuttles except that abaft one eighth of the ship's length from the forward perpendicular and above a line drawn parallel to the bulkhead deck at side and having its lowest point at a height of 3.7 m plus 2.5 % of the breadth of the ship above the deepest subdivision draught, the deadlights may be portable in passenger accommodation other than that for steerage passengers, unless the deadlights are required by the **ICLL** in force to be permanently attached in their proper positions. Such portable deadlights are to be stowed adjacent to the sidescuttles they serve.

(SOLAS II-1, 15.4)

B.6.4.6 No sidescuttlers are to be fitted in any spaces which are appropriated exclusively to the carriage of cargo or coal.

(SOLAS II-1, 15.5.1)

B.6.4.7 Sidescuttles may, however, be fitted in spaces appropriated alternatively to the carriage of cargo or passengers, but they are to be of such construction as will effectively prevent any person opening them or their deadlights without the consent of the master.

(SOLAS II-1, 15.5.2)

B.6.4.8 Automatic ventilating sidescuttles are not to be fitted in the shell plating below the bulkhead deck of passenger ships and the freeboard deck of cargo ships without the special sanction of the Administration.

(SOLAS II-1, 15.6)

B.6.4.9 The number of scuppers, sanitary discharges and other similar openings in the shell plating is to be reduced to the minimum either by making each discharge serve for as many as possible of the sanitary and other pipes, or in any other satisfactory manner.

(SOLAS II-1, 15.7)

B.6.4.10 All inlets and discharges in the shell plating are to be fitted with efficient arrangements for preventing the accidental admission of water into the ship.

(SOLAS II-1, 15.8.1)

B.6.4.11 Subject to the requirements of the International Convention on Load Line in force, and except as provided in B.6.5.13, each separate discharge led through the shell plating from spaces below the bulkhead deck of passenger ships and the freeboard deck of cargo ships are to be provided with either one automatic non-return valve fitted with a positive means of closing it from above the bulkhead deck or with two automatic non-return valves without positive means of closing, provided that the inboard valve is situated above the deepest subdivision draught and is always accessible for examination under service conditions. Where a valve with positive means of closing is fitted, the operating position above the bulkhead deck is always to be readily accessible and means is to be provided for indication whether the valve is open or closed.

(SOLAS II-1, 15.8.2.1)

B.6.4.12 The requirements of **ICLL** in force are to be applied to discharges led through the shell plating from spaces above the bulkhead deck of passenger ships and the freeboard deck of cargo ships.

(SOLAS II-1, 15.8.2.2)

B.6.4.13 Machinery space, main and auxiliary sea inlets and discharges in connection with the operating of machinery are to be fitted with readily accessible valves between the pipes and the shell plating or between the pipes and fabricated boxes attached to the shell plating. In manned machinery spaces the valves may be controlled locally and are to be provided with indicators showing whether they are open or closed.

(SOLAS II-1, 15.8.3)

B.6.4.14 Moving parts penetrating the shell plating below the deepest subdivision draught are to be fitted with a watertight sealing arrangement acceptable to the Administration. The inboard gland is to be located within a watertight space of such volume that, if flooded, the bulkhead deck will not be submerged. The Administration may require that if such compartment is flooded, essential or emergency power and lightning, internal communication, signals or other emergency devices must remain available in other parts of the ship.

(SOLAS II-1, 15.8.4)

B.6.4.15 All shell fittings and valves required by this regulation are to be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable. All pipes to which this regulation refers are to be of steel or other equivalent material to the satisfaction of GL.

(SOLAS II-1, 15.8.5)

B.6.4.16 Gangway, cargo and fuelling ports fitted below the bulkhead deck of passenger ships and the freeboard deck of cargo ships are to be watertight and in case be so fitted as to have their lowest point below the deepest subdivision draught.

(SOLAS II-1, 15.9)

B.6.4.17 The inboard opening of each ash-chute, rubbish-chute, etc., is to be fitted with an efficient cover.

(SOLAS II-1, 15.10.1)

B.6.4.18 If the inboard opening is situated below the bulkhead deck of passenger ships and the freeboard deck of cargo ships, the cover is to be watertight and, in addition, an automatic non-return valve is to be fitted in the chute in an easily accessible position above the deepest subdivision draught.

(SOLAS II-1, 15.10.2)

B.7 Tanks

B.7.1 In tanks extending over the full breadth of the ship intended to be used for partial filling, (e.g. oil fuel and fresh water tanks), at least one longitudinal bulkhead is to be fitted, which may be a swash bulkhead.

B.7.2 Where the forepeak is intended to be used as tank, at least one complete or partial longitudinal swash bulkhead is to be fitted, if the tank breadth exceeds $0.5\ \mathbf{B}$ or $6\ \mathrm{m}$, whichever is the greater.

When the afterpeak is intended to be used as tank, at least one complete or partial longitudinal swash bulkhead is to be fitted. The largest breadth of the liquid surface should not exceed $0.3\ \mathbf{B}$ in the aft peak.

B.7.3 Peak tanks exceeding $0.06\ \mathbf{L}$ or $6\ \mathrm{m}$ in length, whichever is greater, are to be provided with a transverse swash bulkhead.

C Arrangement

C.1 Steering gear compartment

The steering gear compartment is to be, as far as practicable, separated from the machinery space.

(SOLAS II-1, 29.13)

C.2 Double bottom

C.2.1 For all passenger vessels and all cargo vessels of $500\ \mathrm{GT}$ and more excluding tankers the arrangement has to comply with Chapter II-1 of SOLAS as amended.

C.2.2 A double bottom is to be fitted extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

(SOLAS II-1, 9.1)

C.2.3 Where a double bottom is required to be fitted the inner bottom is to be continued out to the ship's sides in such a manner as to protect the bottom to the turn of the bilge. Such protection will be deemed satisfactory if the inner bottom is not lower at any part than a plane parallel with the keel line and which is located not less than a vertical distance h measured from the keel line, as calculated by the formula:

$$h = \mathbf{B} / 20$$

However, in no case is the value of h to be less than $760\ \mathrm{mm}$, and need not be taken as more than $2\ 000\ \mathrm{mm}$.

(SOLAS II-1, 9.2)

C.2.4 Small wells constructed in the double bottom in connection with drainage arrangements of holds, etc., are not to extend downward more than necessary. In no case the vertical distance from the bottom of such a well to a plane coinciding with the keel line is to be less than 500 mm. Other wells (e.g. for lubrication oil under main engines) may be permitted by the Administration if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with this regulation.

A well extending to the outer bottom, may, however, be permitted at the after end of the shaft tunnel.

(SOLAS II-1, 9.3)

C.2.5 A double bottom need not to be fitted in way of watertight tanks, including dry tanks of moderate size, provided the safety of the ship is not impaired in the event of bottom or side damage.

(SOLAS II-1, 9.4)

C.2.6 Any part of a passenger ship or a cargo ship that is not fitted with a double bottom in accordance with C.2.1, C.2.4 or C.2.5 is to be capable of withstanding bottom damages as specified in C.2.8 as amended, in that part of the ship.

(SOLAS II-1, 9.6)

C.2.7 In the case of unusual bottom arrangements in a passenger ship or a cargo ship, it is to be demonstrated that the ship is capable of withstanding bottom damages as specified in Chapter II-1 of **SOLAS** as amended.

(SOLAS II-1, 9.7)

C.2.8 Compliance with paragraphs C.2.6 or C.2.7 is to be achieved by demonstrating that s_i, when calculated in accordance with regulation 7-2, is not less than 1 for all service conditions when subject to a bottom damage assumed at any position along the ship's bottom and with an extent specified in 2. below for the affected part of the ship:

1. Flooding of such spaces is not to render emergency power and lighting, internal communication, signals or other emergency devices inoperable in other parts of the ship.
2. Assumed extent of damage is to be according to Table 27.1.
3. If any damage of a lesser extent than the maximum damage specified in 2. would result in a more severe condition, such damage should be considered.

Table 27.1 Assumed extend of damage

	For $0.3\,\mathbf{L}$ from the forward perpendicular of the ship	**Any other part of the ship**
Longitudinal extent	$1/3\,\mathbf{L}^{2/3}$ or 14.5 m, whichever is less	$1/3\,\mathbf{L}^{2/3}$ or 14.5 m, whichever is less
Transverse extent	$\mathbf{B}/6$ or 10 m, whichever is less	$\mathbf{B}/6$ or 5 m, whichever is less
Vertical extent, measured from the keel line	$\mathbf{B}/20$ or 2 m, whichever is less	$\mathbf{B}/20$ or 2 m, whichever is less

(SOLAS II-1, 9.8)

C.2.9 In case of large lower holds in passenger ships, the Administration may require an increased double bottom height of not more than $\mathbf{B}/10$ or 3 m, whichever is less, measured from the keel line. Alternatively, bottom damages may be calculated for these areas, in accordance with C.2.8, but assuming an increased vertical extent.

(SOLAS II-1, 9.9)

C.2.10 The centre girder should be watertight at least for $0.5\ \mathbf{L}$ amidships, unless the double bottom is subdivided by watertight side girders.

On ships to which timber load line are assigned, double bottom tanks, where fitted in within $0.5\ \mathbf{L}$ amidships, are to adequate watertight longitudinal subdivision.

(ICLL Annex 1, IV, 43 (3))

C.3 Tanks

C.3.1 Oil fuel tanks

C.3.1.1 General

C.3.1.1.1 In a ship in which oil fuel is used, the arrangements for the storage, distribution and utilization of the oil fuel are to be such as to ensure the safety of the ship and persons on board and have at least to comply with the following provisions.

(SOLAS II-2, 4.2.2)

C.3.1.1.2 As far as practicable, parts of the oil fuel system containing heated oil under pressure exceeding $0.18\ \mathrm{N/mm^2}$ are not to be placed in a concealed position such that defects and leakage cannot readily be observed. The machinery spaces in way of such parts of the oil fuel system are to be adequately illuminated.

(SOLAS II-2, 4.2.2.1)

C.3.1.1.3 Fuel oil, lubrication oil and other flammable oils are not to be carried in forepeak tanks.

(SOLAS II-2, 4.2.2.3.1)

C.3.1.1.4 As far as practicable, oil fuel tanks are to be part of the ships structure and are to be located outside machinery spaces of category A.

Where oil fuel tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries, and is preferably to have a common boundary with the double bottom tanks, and the area of the tank boundary common with the machinery spaces is to be kept to a minimum.

Where such tanks are situated within the boundaries of machinery spaces of category A they are not to contain oil fuel having a flashpoint of less than $60\ ^\circ\mathrm{C}$.

In general, the use of free-standing oil fuel tanks is to be avoided. When such tanks are employed their use is to be prohibited in category A machinery spaces on passenger ships. Where permitted, they are to be placed in an oil-tight spill tray of ample size having a suitable drain pipe leading to a suitably sized spill oil tank.

(SOLAS II-2, 4.2.2.3.2)

C.3.1.1.5 No oil fuel tank is to be situated where spillage or leakage there from can constitute a fire or explosion hazard by falling on heated surfaces.

(SOLAS II-2, 4.2.2.3.3)

C.3.1.1.6 Surfaces with temperatures above $220\ ^\circ\mathrm{C}$ which may be impinged as a result of a fuel system failure are to be properly insulated.

Precautions are to be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

(SOLAS II-2, 4.2.2.6)

C.3.1.2 Oil fuel tank protection

The arrangement and subdivision of fuel oil tanks of ships with an aggregate oil fuel capacity of $600\ \mathrm{m^3}$ and above which are delivered on or after 1 August 2010 has to be in compliance with **MARPOL**, Annex I, Reg. 12 A.

C.3.2 Separation of oil fuel tanks from tanks for other liquids

C.3.2.1 Oil fuel tanks are to be separated from tanks for lubricating oil, hydraulic oil, thermal oil, vegetable oil, feedwater, condensate water and potable water by cofferdams.

C.3.2.2 Upon special approval on small ships the arrangement of cofferdams between oil fuel and lubricating oil tanks may be dispensed with provided that:

- the common boundary is continuous, i.e. it does not abut at the adjacent tank boundaries, see Fig. 27.2
- Where the common boundary cannot be constructed continuously according to Fig. 27.2, the fillet welds on both sides of the common boundary are to be welded in two layers and the throat thickness is not to be less than $0.5 \cdot t$ (t = plate thickness).
- Stiffeners or pipes do not penetrate the common boundary.
- The corrosion allowance t_K for the common boundary is not less than 2.5mm.

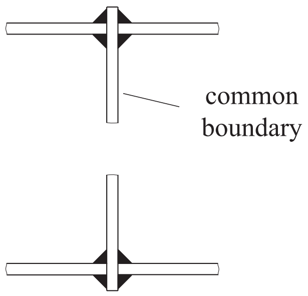


Fig. 27.2 Continuous common boundary replacing a cofferdam

C.3.2.3 Fuel oil tanks adjacent to lubricating oil circulation tanks are not permitted.

C.3.2.4 For fuel oil tanks which are heated up to a temperature which is higher than the flash point – 10°C of the relevant fuel, the GL Rules for Machinery Installations (I-1-2), Section 10, B.5. are to be observed specifically.

C.3.3 Seperation of fuel and lubricating oil tanks in double bottom

C.3.3.1 In double bottom tanks, fuel oil may be carried, the flash point (closed cup test) of which exceeds 60°C.

C.3.3.2 Where practicable, lubricating oil discharge tanks are to be separated from the shell.

C.3.3.3 The lubricating oil circulating tanks are to be separated from the shell by at least 500 mm.

C.4 Wells

C.4.1 Bilge wells are to have a capacity of more than $0.2\ m^3$. Small holds may have smaller bilge wells. For the use of manhole covers or hinged covers for the access to the bilge suctions, see the GL Rules for Machinery Installations (I-1-2), Section 11. Bilge wells are to be separated from the shell. Section 26, F.5. is to be applied analogously.

C.4.2 For small wells in the double bottom see C.2.4.

C.5 Minimum bow height, forecastle, poop and raised quarter deck

C.5.1 According to ICLL, Regulation 39, a minimum bow height is required at the forward perpendicular, which may be obtained by sheer extending for at least $0.15\ \mathbf{L_c}$, measured from the forward perpendicular, or by fitting a forecastle extending from the stem to a point at least $0.07\ \mathbf{L_c}$ abaft the forward perpendicular.

C.5.2 Ships carrying timber deck cargo and which are to be assigned the respective permissible freeboard, are to have a forecastle of the Rule height and a length of at least $0.07\ \mathbf{L_c}$. Furthermore, ships the length of which is less than 100 m, are to have a poop of Rule height or a raised quarter deck with a deckhouse.

C.6 Watertight ventilators and trunks

Watertight ventilators and trunks are to be carried at least up to the bulkhead deck in passenger ships and up to the freeboard deck in cargo ships.

(SOLAS II-1, 16-1.1)

D Accessibility

D.1 General

D.1.1 All parts of the hull are to be accessible for survey and maintenance.

D.1.2 Spaces, which are to be accessible for the service of the ship, hold spaces and accommodation spaces are to be gastight against each other.

D.1.3 The design appraisal and testing of accesses to ships (accommodation ladders, gangways) are not part of Classification.

However, approval of substructures in way of accommodation ladders and gangways is part of Classification.

Note

For ships subject to the requirements of BG *Verkehr Dienststelle Schiffssicherheit (BG Verkehr Ship Safety Division) the GL Guidelines for the Construction and Testing of Accesses to Ships (VI-2-4) apply. These Guidelines will be applied in all cases where GL is entrusted with the judgement of accesses to ships.*

D.1.4 Manholes for access to fuel oil double bottom tanks situated under cargo oil tanks are not permitted in cargo oil tanks or in the engine room (see also Section 24, A.12.4).

D.2 Provisions for safe access

D.2.1 The minimum clearance for transit areas should be at least 2 m high and 600 mm wide.

D.2.2 All relevant deck surfaces used for movement about the ship and all passageways and stairs should have non-slip surfaces.

D.2.3 Where necessary for safety, walkways on deck should be delineated by painted lines or otherwise marked by pictorial signs.

D.2.4 All protrusions in access ways, such as cleats, ribs and brackets that may give rise to a trip hazard should be highlighted in a contrasting colour.

D.3 Access to the steering gear compartment

The steering gear compartments is to be:

- easily accessible
- provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements are to include handrails and gratings or other nonslip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

(SOLAS II-1, 29.13)

D.4 Access to shaft tunnels

D.4.1 Shaft and stuffing box are to be accessible. Where one or more compartments are situated between stern tube bulkhead and engine room, a watertight shaft tunnel is to be arranged. The size of the shaft tunnel is to be adequate for service and maintenance purposes.

D.4.2 The access opening between engine room and shaft tunnel is to be closed by a watertight sliding door complying with the requirements according to B.6.1.2.2. For extremely short shaft tunnels watertight doors between tunnel and engine room may be dispensed with subject to special approval.

In this connection see also Chapter II-1, Regulation 11/8 of **SOLAS** as amended.

D.4.3 Tunnel ventilators and the emergency exit are to be constructed watertight up to the freeboard deck.

D.5 Access to the Cargo Area of Oil Tankers and Bulk Carriers

Special measures are to be taken for safe access to and working in spaces in and forward of the cargo area of tankers and bulk carriers for the purpose of maintenance and carrying out surveys.

D.5.1 Definitions

Rung

Rung means the step of a vertical ladder or step on the vertical surface.

Tread

Tread means the step of an inclined ladder or step for the vertical access opening.

Flight of an inclined ladder

Flight of an inclined ladder means the actual stringer length of an inclined ladder. For vertical ladders, it is the distance between the platforms.

Stringer

Stringer means:

- the frame of a ladder; or
- the stiffened horizontal plating structure fitted on the side shell, transverse bulkheads and/or longitudinal bulkheads in the space. For the purpose of ballast tanks of less than 5 m width forming double side spaces, the horizontal plating structure is credited as a stringer and a longitudinal permanent means of access, if it provides a continuous passage of 600 mm or more in width past frames or stiffeners on the side shell or longitudinal bulkhead. Openings in stringer plating utilized as permanent means of access are to be arranged with guard rails or grid covers to provide safe passage on the stringer or safe access to each transverse web.

Vertical ladder

Vertical ladder means a ladder of which the inclined angle is 70º and over up to 90º. A vertical ladder is not to be skewed by more than 2º.

Overhead obstructions

Overhead obstructions mean the deck or stringer structure including stiffeners above the means of access.

Distance below deck head

Distance below deck head means the distance below the plating.

Cross deck

Cross deck means the transverse area of the main deck which is located inboard and between hatch coamings.

D.5.2 Means of access to cargo and other spaces

Where a permanent means of access may be susceptible to damage during normal cargo loading and unloading operations or where it is impracticable to fit permanent means of access, the Administration may allow, in lieu thereof, the provision of movable or portable means of access, as specified in the Technical provisions, provided that the means of attaching, rigging, suspending or supporting the portable means of access forms a permanent part of the ship's structure. All portable equipment is to be capable of being readily erected or deployed by ship's personnel.

(SOLAS II-1, 3-6.2.2)

D.5.3 Safe access to cargo holds, cargo tanks, ballast tanks and other spaces

D.5.3.1 Safe access to cargo holds, cofferdams, ballast tanks, cargo tanks and other spaces in the cargo area is to be direct from the open deck and such as to ensure their complete inspection. Safe access to double bottom spaces may be from a pump-room, deep cofferdam, pipe tunnel, cargo hold, double hull space or similar compartment not intended for the carriage of oil or hazardous cargoes.

(SOLAS II-1, 3-6.3.1)

D.5.3.2 Tanks, and subdivisions of tanks, having a length of $35\ \mathrm{m}$ or more, are to be fitted with at least two access hatchways and ladders, as far apart as practicable. Tanks less than $35\ \mathrm{m}$ in length are to be served by at least one access hatchway and ladder. When a tank is subdivided by one or more swash bulkheads or similar obstructions which do not allow ready means of access to the other parts of the tank, at least two hatchways and ladders are to be fitted.

(SOLAS II-1, 3-6.3.2)

D.5.3.3 Each cargo hold is to be provided with at least two means of access as far apart as practicable. In general, these accesses should be arranged diagonally, for example one access near the forward bulkhead on the port side, the other one near the aft bulkhead on the starboard side.

(SOLAS II-1, 3-6.3.3)

D.5.4 Ship Structure Access Manual

D.5.4.1 A ship's means of access to carry out overall and close-up inspections and thickness measurements is to be described in a Ship Structure Access Manual approved by the Administration, an updated copy of which is to be kept on board. The Ship Structure Access Manual has to include the following for each space:

1. plans showing the means of access to the space, with appropriate technical specifications and dimensions;
2. plans showing the means of access within each space to enable an overall inspection to be carried out, with appropriate technical specifications and dimensions. The plans have to indicate from where each area in the space can be inspected;
3. plans showing the means of access within the space to enable close-up inspections to be carried out, with appropriate technical specifications and dimensions. The plans have to indicate the positions of critical structural areas, whether the means of access is permanent or portable and from where each area can be inspected;
4. instructions for inspecting and maintaining the structural strength of all means of access and means of attachment, taking into account any corrosive atmosphere that may be within the space;
5. instructions for safety guidance when rafting is used for close-up inspections and thickness measurements;
6. .instructions for the rigging and use of any portable means of access in a safe manner;
7. .an inventory of all portable means of access; and
8. records of periodical inspections and maintenance of the ship's means of access.

(SOLAS II-1, 3-6.4.1)

D.5.4.2 For the purpose of this regulation ''critical structural areas'' are locations which have been identified from calculations to require monitoring or from the service history of similar or sister ships to be sensitive to cracking, buckling, deformation or corrosion which would impair the structural integrity of the ship.

(SOLAS II-1, 3-6.4.2)

D.5.5 General technical specifications

D.5.5.1 Structural members subject to the close-up inspections and thickness measurements of the ship's structure, except those in double bottom spaces, are to be provided with a permanent means of access to the extent as specified in and Table 27.2, as applicable. For oil tankers and wing ballast tanks of ore carriers, approved alternative methods may be used in combination with the fitted permanent means of access, provided that the structure allows for its safe and effective use.

D.5.5.2 Permanent means of access should as far as possible be integral to the structure of the ships, thus ensuring that they are robust and at the same time contributing to the overall strength of the structure of the ship.

D.5.5.3 Elevated passageways forming sections of a permanent means of access, where fitted, are to have a minimum clear width of 600 mm, except for going around vertical webs where the minimum clear width may be reduced to 450 mm, and have guard rails over the open side of their entire length. Sloping structures providing part of the access are to be of a non-skid construction. Guard rails are to be 1000 mm in height and consist of a rail and an intermediate bar 500 mm in height and of substantial construction. Stanchions are not to be more than 3m apart.

D.5.5.4 Access to permanent means of access and vertical openings from the ship's bottom is to be provided by means of easily accessible passageways, ladders or treads. Treads are to be provided with lateral support for the foot. Where the rungs of ladders are fitted against a vertical surface, the distance from the centre of the rungs to the surface is to be at least 150 mm. Where vertical manholes are fitted higher than 600mm above the walking level, access is to be facilitated by means of treads and hand grips with platform landings on both sides.

D.5.5.5 Permanent inclined ladders are to be inclined at an angle of less than 70 º. There are to be no obstructions within 750 mm of the face of the inclined ladder, except that in way of an opening this clearance may be reduced to 600 mm. Resting platforms of adequate dimensions are to be provided, normally at a maximum of 6m vertical height. Ladders and handrails are to be constructed of steel or equivalent material of adequate strength and stiffness and securely attached to the structure by stays. The method of support and length of stay is to be such that vibration is reduced to a practical minimum. In cargo holds, ladders are to be designed and arranged so that cargo handling difficulties are not increased and the risk of damage from cargo handling gear is minimized.

D.5.5.6 The width of inclined ladders between stringers is not to be less than 400 mm. The treads are to be equally spaced at a distance apart, measured vertically, of between 200 mm and 300 mm. When steel is used, the treads are to be formed of two square bars of not less than 22 mm by 22 mm in section, fitted to form a horizontal step with the edges pointing upward. The treads are to be carried through the side stringers and attached thereto by double continuous welding. All inclined ladders are to be provided with handrails of substantial construction on both sides, fitted at a convenient distance above the treads.

D.5.5.7 For vertical ladders or spiral ladders, the width and construction should be in accordance with international or national standards accepted by the Administration.

D.5.5.8 No free-standing portable ladder are to be more than 5 m long.

D.5.5.9 Alternative means of access include, but are not limited to, such devices as:

- hydraulic arm fitted with a stable base
- wire lift platform
- staging
- rafting
- root arm or remotely operated vehicle (ROV)

- portable ladders more than 5 m long are only to be utilized if fitted with a mechanical device to secure the upper end of the ladder
- other means of access, approved by and acceptable to the Administration

Means for safe operation and rigging of such equipment to and from and within the spaces is to be clearly described in the Ship Structure Access Manual.

D.5.5.10 For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained airbreathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is not to be less than 600 mm x 600 mm. When access to a cargo hold is arranged through the cargo hatch, the top of the ladder is to be placed as close as possible to the hatch coaming. Access hatch coamings having a height greater than 900 mm are also to have steps on the outside in conjunction with the ladder.

(SOLAS II-1, 3-6.5.1)

D.5.5.11 For access through vertical openings, or manholes, in swash bulkheads, floors, girders and web frames providing passage through the length and breadth of the space, the minimum opening is not to be less than 600 mm x 800 mm at a height of not more than 600 mm from the bottom shell plating unless gratings or other foot holds are provided.

(SOLAS II-1, 3-6.5.2

D.5.5.12 For oil tankers of less than 5 000 tonnes deadweight, the Administration may approve, in special circumstances, smaller dimensions for the openings referred to in paragraphs 5.1 and 5.2, if the ability to traverse such openings or to remove an injured person can be proved to the satisfaction of the Administration.

(SOLAS II-1, 3-6.5.3

D.5.5.13 For bulk carriers, access ladders to cargo holds and other spaces are to be:

D.5.5.13.1 Where the vertical distance between the upper surface of adjacent decks or between deck and the bottom of the cargo space is not more than 6 m, either a vertical ladder or an inclined ladder.

D.5.5.13.2 Where the vertical distance between the upper surface of adjacent decks or between deck and the bottom of the cargo space is more than 6 m, an inclined ladder or series of inclined ladders at one end of the cargo hold, except the uppermost 2.5 m of a cargo space measured clear of overhead obstructions and the lowest 6m may have vertical ladders, provided that the vertical extent of the inclined ladder or ladders connecting the vertical ladders is not less than 2.5 m.

The second means of access at the other end of the cargo hold may be formed of a series of staggered vertical ladders, which should comprise of one or more ladder linking platforms spaced not more than 6 m apart vertically and displaced to one side of the ladder. Adjacent sections of ladder should be laterally offset from each other by at least the width of the ladder.

The uppermost entrance section of the ladder directly exposed to a cargo hold should be vertical for a distance of 2.5 m measured clear of overhead obstructions and connected to a ladder-linking platform.

D.5.5.13.3 A vertical ladder may be used as a means of access to topside tanks, where the vertical distance is 6m or less between the deck and the longitudinal means of access in the tank or the stringer or the bottom of the space immediately below the entrance. The uppermost entrance section from deck of the vertical ladder of the tank should be vertical for a distance of 2.5 m measured clear of overhead obstructions and comprise a ladder linking platform, unless landing on the longitudinal means of access, the stringer or the bottom within the vertical distance, displaced to one side of a vertical ladder.

D.5.5.13.4 Unless allowed in D.5.5.13.3 above, an inclined ladder or combination of ladders should be used for access to a tank or a space where the vertical distance is greater than 6 m between the deck and a stringer immediately below the entrance, between stringers, or between the deck or a stringer and the bottom of the space immediately below the entrance.

D.5.5.13.5 In case of D.5.5.13.5 above, the uppermost entrance section from deck of the ladder should be vertical for a distance of 2.5 m clear of overhead obstructions and connected to a landing platform and continued with an inclined ladder. The flights of inclined ladders should not be more than 9 m in actual length and the vertical height should not normally be more than 6 m. The lowermost section of the ladders may be vertical for a distance of not less than 2.5 m.

D.5.5.13.6 In double-side skin spaces of less than 2.5 m width, the access to the space may be by means of vertical ladders that comprise of one or more ladderlinking platforms spaced not more than 6 m apart vertically and displaced to one side of the ladder. Adjacent sections of ladder should be laterally offset from each other by at least the width of the ladder.

D.5.5.13.7 A spiral ladder is considered acceptable as an alternative for inclined ladders. In this regard, the uppermost 2.5 m can continue to be comprised of the spiral ladder and need not change over to vertical ladders.

D.5.5.14 The uppermost entrance section from deck of the vertical ladder providing access to a tank should be vertical for a distance of 2.5 m measured clear of overhead obstructions and comprise a ladder linking platform, displaced to one side of a vertical ladder. The vertical ladder can be between 1.6 m and 3 m below deck structure if it lands on a longitudinal or athwartship permanent means of access fitted within that range.

D.5.6 Other Regulations and Recommendations

Attention is drawn to Chapter 6 of the "Guidelines for the Inspection and Maintenance of Double Hull Tanker Structures", Tanker Structure Co-operative Forum 1995.

Table 27.2 Means of access for ballast and cargo tanks of oil tankers

Water ballast tanks except those specified in the right column, and cargo oil tanks	Water ballast wing tanks of less than 5m width forming double side spaces and their bilge hopper sections
Access to the underdeck and vertical structure	
For tanks of which the height is 6 m and over containing internal structures, permanent means of access is to be provided in accordance with 1. to 6.: 1. continuous athwartship permanent access arranged at each transverse bulkhead on the stiffened surface, at a minimum of 1.6 m to a maximum of 3 m below the deck head; 2. at least one continuous longitudinal permanent means of access at each side of the tank. One of these accesses is to be at a minimum of 1.6 m to a maximum of 6 m below the deck head and the other is to be at a minimum of 1.6 m to a maximum of 3 m below the deck head; 3. access between the arrangements specified in 1. and 2. and from the main deck to either 1. or 2.; 4. continuous longitudinal permanent means of access which are integrated in the structural member on the stiffened surface of a longitudinal bulkhead, in alignment, where possible, with horizontal girders of transverse bulkheads are to be provided for access to the transverse webs unless permanent fittings are installed at the uppermost platform for use of alternative means, as defined in D.5.5.9 for inspection at intermediate heights;	For double side spaces above the upper knuckle point of the bilge hopper sections, permanent means of access are to be provided in accordance with 1. to 3.: 1. where the vertical distance between horizontal uppermost stringer and deck head is 6 m or more, one continuous longitudinal permanent means of access is to be provided for the full length of the tank with a means to allow passing through transverse webs installed at a minimum of 1.6 m to a maximum of 3 m below the deck head with a vertical access ladder at each end of the tank; 2. continuous longitudinal permanent means of access, which are integrated in the structure, at a vertical distance not exceeding 6 m apart; and 3. plated stringers are, as far as possible, to be in alignment with horizontal girders of transverse bulkheads.

5. for ships having cross-ties which are 6m or more above tank bottom, a transverse permanent means of access on the cross-ties providing inspection of the tie flaring brackets at both sides of the tank, with access from one of the longitudinal permanent means of access in 4.; and 6. alternative means as defined in D.5.59 may be provided for small ships as an alternative to 4. for cargo oil tanks of which the height is less than 17 m.	
For tanks of which the height is less than 6m, alternative means as defined in D.5.5.9 or portable means may be utilized in lieu of the permanent means of access.	For bilge hopper sections of which the vertical distance from the tank bottom to the upper knuckle point is 6 m and over, one longitudinal permanent means of access is to be provided for the full length of the tank. It is to be accessible by vertical permanent means of access at each end of the tank. Where the vertical distance is less than 6m, alternative means as defined in D.5.5.9 or portable means of access may be utilised in lieu of the permanent means of access. To facilitate the operation of the alternative means of access, in-line openings in horizontal stringers are to be provided. The openings are to be of an adequate diameter and are to have suitable protective railings. The longitudinal continuous permanent means of access may be installed at a minimum 1.6 m to maximum 3 m from the top of the bilge hopper section. In this case, a platform extending the longitudinal continuous permanent means of access in way of the webframe may be used to access the identified structural critical areas. Alternatively, the continuous longitudinal permanent means of access may be installed at a minimum of 1.2 m below the top of the clear opening of the web ring allowing a use of portable means of access to reach identified structural critical areas.
Fore peak tanks For fore peak tanks with a depth of 6 m or more at the centre line of the collision bulkhead, a suitable means of access is to be provided for access to critical areas such as the underdeck structure, stringers, collision bulkhead and side shell structure. Stringers of less than 6 m in vertical distance from the deck head or a stringer immediately above are considered to provide suitable access in combination with portable means of access. In case the vertical distance between the deck head and stringers, stringers or the lowest stringer and the tank bottom is 6 m or more, alternative means of access according to D.5.5.9 is to be provided.	

Table 27.3 Means of access for bulk carriers

Cargo holds	Ballast tanks
Access to underdeck structure Permanent means of access is to be fitted to provide access to the overhead structure at both sides of the cross deck and in the vicinity of the centreline. Each means of access is to be accessible from the cargo hold access or directly from the main deck and installed at a minimum of 1.6 m to a maximum of 3 m below the deck. An athwartship permanent means of access fitted on the transverse bulkhead at a minimum 1.6 m to a maximum 3 m below the cross-deck head is accepted as equivalent. Access to the permanent means of access to overhead structure of the cross deck may also be via the upper stool. Ships having transverse bulkheads with full upper stools with access from the main deck which allows monitoring of all framing and plates from inside do not require permanent means of access of the cross deck. Alternatively, movable means of access may be utilized for access to the overhead structure of the cross deck if its vertical distance is 17 m or less above the tank top.	**Top side tanks** For each topside tank of which the height is 6 m and over, one longitudinal continuous permanent means of access is to be provided along the side shell webs and installed at a minimum of 1.6 m to a maximum of 3 m below deck with a vertical access ladder in the vicinity of each access to that tank. If no access holes are provided through the transverse webs within 600 mm of the tank base and the web frame rings have a web height greater than 1m in way of side shell and sloping plating, then step rungs / grab rails are to be provided to allow safe access over each transverse web frame ring. Three permanent means of access, fitted at the end bay and middle bay of each tank, are to be provided spanning from tank base up to the intersection of the sloping plate with the hatch side girder. The existing longitudinal structure, if fitted on the sloping plate in the space may be used as part of this means of access. For topside tanks of which the height is less than 6m, alternative means as defined in D.5.5.9 or portable means may be utilized in lieu of the permanent means of access.
Access to vertical structures Permanent means of vertical access is to be provided in all cargo holds and built into the structure to allow for an inspection of a minimum of 25 % of the total number of hold frames port and starboard equally distributed throughout the hold including at each end in way of transverse bulkheads. But in no circumstance this arrangement is to be less than 3 permanent means of vertical access fitted to each side (fore and aft ends of hold and mid-span). Permanent means of vertical access fitted between two adjacent hold frames is counted for an access for the inspection of both hold frames. A means of portable access may be used to gain access over the sloping plating of lower hopper ballast tanks. In addition, portable or movable means of access is to be utilized for access to the remaining hold frames up to their upper brackets and transverse bulkheads.	**Bilge hopper tanks** For each bilge hopper tank of which the height is 6m and over, one longitudinal continuous permanent means of access is to be provided along the side shell webs and installed at a minimum of 1.2 m below the top of the clear opening of the web ring with a vertical access ladder in the vicinity of each access to the tank. An access ladder between the longitudinal continuous permanent means of access and the bottom of the space is to be provided at each end of the tank. Alternatively, the longitudinal continuous permanent means of access can be located through the upper web plating above the clear opening of the web ring, at a minimum of 1.6 m below the deck head, when this arrangement facilitates more suitable inspection of identified structurally critical areas. An enlarged longitudinal frame can be used for the purpose of the walkway.
Portable or movable means of access may be utilized for access to hold frames up to their upper bracket in place of the permanent means as required above. These means of access is to be carried on board the ship and readily available for use. The width of vertical ladders for access to hold frames is to be at least 300 mm, measured between stringers. A single vertical ladder over 6 m in length is acceptable for the inspection of the hold side frames in a single skin construction.	For double-side skin bulk carriers, the longitudinal continuous permanent means of access may be installed within 6 m from the knuckle point of the bilge, if used in combination with alternative methods to gain access to the knuckle point. If no access holes are provided through the transverse ring webs within 600 mm of the tank base and the web frame rings have a web height greater than 1 m in way of side shell and sloping plating, then step rungs / grab rails are to be provided to allow safe access over each transverse web frame ring.

For double-side skin construction no vertical ladders for the inspection of the cargo hold surfaces are required. Inspection of this structure should be provided from within the double hull space.	For bilge hopper tanks of which the height is less than 6 m, alternative means as defined in D.5.5.9 or portable means may be utilized in lieu of the permanent means of access. Such means of access is to be demonstrated that they can be deployed and made readily available in the areas where needed. **Double-skin side tanks** Permanent means of access is to be provided in accordance with the applicable Sections of Table 27.2.
	Fore peak tanks For fore peak tanks with a depth of 6 m or more at the centreline of the collision bulkhead, a suitable means of access is to be provided for access to critical areas such as the underdeck structure, stringers, collision bulkhead and side shell structure. Stringers of less than 6 m in vertical distance from the deck head or a stringer immediately above are considered to provide suitable access in combination with portable means of access. In case the vertical distance between the deck head and stringers, stringers or the lowest stringer and the tank bottom is 6 m or more, alternative means of access according to D.5.5.9 is to be provided.

Section 28 Stability of Cargo Ships

A General

A.1 Application

A.1.1 All ships equal to or greater than $24\ \mathrm{m}$ in length may be assigned class only after it has been demonstrated that their intact stability is adequate for the service intended.

Adequate intact stability means compliance with standards laid down by the relevant Administration or with the requirements specified in this Section taking into account the ship's size and type. The level of intact stability for ships of all sizes in any case should not be less than that provided by the International Code on Intact Stability, 2008, chapter 2. In any case, the level of intact stability is not to be less than that provided by the GL-Rules.

Evidence of approval by the Administration concerned may be accepted for the purpose of classification.

(IACS UR L2)

A.1.2 The Rules also apply to ships less than $24\ \mathrm{m}$ in length. In this case, the requirements concerned may be partially omitted when deemed appropriate by GL.

A.1.3 For ships engaged in the carriage of grain in bulk the Grain Code apply In addition to this Section.

A.2 References

International conventions and codes

Paragraphs of this section are based on the following international convention(s) and / or code(s):

At the end of each relevant paragraph, the corresponding paragraphs of the international convention(s) and / or code(s) are given in brackets.

IACS UR L2 Rev.1

ICLL containing all amendments up to 1st July 2010

IS Code 2008 consolidated up to Res. MSC.319(89) adopted 2011

SOLAS including all amendments up to 1st July 2012

A.3 Definitions

Aft and forward terminal

Aft terminal is the aft limit of the subdivision length and forward terminal is the forward limit of the subdivision length.

Inclining test

The inclining test is a test to determine the light ship weight and the vertical position of the centre of gravity (VCG) of the ship.

The inclining test involves moving a series of known weights, normally in the transverse direction, and then measuring the resulting change in the equilibrium heel angle of the ship. By using this information and applying basic naval architecture principles, the ship’s vertical centre of gravity (VCG) is determined.

Lightship

Lightship condition is a ship complete in all respects, but without consumables, stores, cargo, crew and effects, and without any liquids on board except that machinery and piping fluids, such as lubricants and hydraulics, are at operating levels.

Lightweight survey

The light weight survey is a procedure to determine the light ship weight and the position of the centre of gravity (LGG) of the ship.

A lightweight survey involves taking an audit of all items which should be added, deducted or relocated on the ship at the time of the inclining test so that the observed condition of the ship can be adjusted to the lightship condition. The mass, longitudinal, transverse and vertical location of each item should be accurately determined and recorded. Using this information, the static waterline of the ship at the time of the inclining test as determined from measuring the freeboard or verified draught marks of the ship, the ship's hydrostatic data, and the sea water density, the lightship displacement and longitudinal centre of gravity (LCG) can be obtained. The transverse centre of gravity (TCG) may also be determined for mobile offshore drilling units (MODUs) and other ships which are asymmetrical about the centreline or whose internal arrangement or outfitting is such that an inherent list may develop from off-centre mass.

Machinery space

Machinery spaces are spaces between the watertight boundaries of a space containing the main and auxiliary propulsion machinery, including boilers, generators and electric motors primarily intended for propulsion. In the case of unusual arrangements, GL may define the limits of the machinery spaces.

Mid-length

Mid-length is the mid point of the subdivision length of the ship.

Timber

Timber means sawn wood or lumber, cants, logs, poles, pulpwood and all other types of timber in loose or packaged forms. The term does not include wood pulp or similar cargo.

Timber deck cargo

Timber deck cargo means a cargo of timber carried on an uncovered part of a freeboard or superstructure deck. The term does not include wood pulp or similar cargo.

Timber load line

Timber load line means a special load line assigned to ships complying with certain conditions related to their construction set out in the International Convention on Load Lines 1966, as amended, and used when the cargo complies with the stowage and securing conditions of the Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 1991 (Resolution A.715(17)).

Trim

Trim is the difference between the draught forward and the draught aft, where the draughts are measured at the forward and aft terminals respectively, disregarding any rake of keel.

Symbols

B : greatest moulded breadth $[m]$ of the ship at or below the deepest subdivision draught

d : vertical distance $[m]$ from the moulded baseline at mid-length to the waterline in question

d_S : deepest subdivision draught $[m]$ which corresponds to the summer load line draught of the ship

d_L : light service draught $[m]$ which corresponds to the lightest anticipated loading and associated tankage, including, however, such ballast as may be necessary for stability and / or immersion

d_P : partial subdivision draught $[m]$, defined as:

$$d_P = d_L + 0.6 \cdot \left(\left| d_S - d_L \right| \right)$$

L_S : subdivision length which is the greatest projected moulded length of that part of the ship at or below deck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision draught.

μ : permeability of a space which is the proportion of the immersed volume of that space which can be occupied by water

A.4 Examination procedure

A.4.1 Documents to be submitted

A.4.1.1 List of documents

For the purpose of the examination of the stability, following documentation is to be submitted:

- general arrangement
- capacity plan including volume and position of centre of gravity for each tank
- lines plan

The stability documentation to be submitted for approval is as follows:

- Inclining test report for the ship, as required in A.4.2, or where the stability data is based on a sister ship, the inclining test report of that sister ship along with the lightship measurement report for the ship in question;
- trim and stability booklet, as required in B.1.1
- and, as applicable:
  - grain loading manual according to the Grain Code
  - damage stability calculations according to C.2
  - damage control documentation according to C.3

A copy of the trim and stability booklet and, if applicable, the grain stability booklet, the damage control documentation is to be available on board for the attention of the Master.

A.4.1.2 Provisional documentation

GL reserves the right to accept or demand the submission of provisional stability documentation for examination. Provisional stability documentation includes loading conditions based on estimated lightship values.

Final stability documentation for the first vessel of a series of ships could serve as provisional documentation for all subsequent vessels as far as the documentation shows a clear link to each individual ship.

A.4.1.3 Final documentation

Final stability documentation based on the results of the inclining test or the lightweight check is to be submitted for examination.

A.4.1.4 Detailed procedure

A detailed procedure for conducting an inclining test is included in B.7.

A.4.2 Inclining test / lightweight survey

A.4.2.1 Inclining Test

A.4.2.1.1 Application

The inclining test is required in the following cases:

- Every cargo ship having a length of 24 m and upwards, should be inclined upon its completion and the elements of its stability determined, except for the cases specified in A.4.2.2.
- Where any variations are made to the ship which effect the lightship particulars in comparison with the approved stability information. The deviations should not exceed 2 % of the light ship displacement or 1 % of L_c of the longitudinal centre of gravity.
- The inclining test is adaptable to ships less than 24 m in length, provided that precautions are taken, on a case by case basis, to ensure the accuracy of the test procedure.

  (IS Code 2008 B, 8.1.1)

A.4.2.1.2 The inclining test or lightweight check is to be attended by a Surveyor of GL.

A.4.2.1.3 Detailed procedure

A detailed procedure of the test is to be submitted to GL prior to the test. This procedure is to include:

1. identification of the ship by name and shipyard hull number, if applicable
2. date, time and location of the test
3. inclining weight data:
   - type
   - amount (number of units and weight of each)
   - certification
   - method of handling (i.e. sliding rail or crane)
   - anticipated maximum angle of heel to each side
4. measuring devices:
   - pendulums - approximate location and length
   - U-tubes - approximate location and length
   - inclinometers - Location and details of approvals and calibrations
5. approximate trim
6. condition of tanks
7. estimate weights to deduct, to complete, and to relocate in order to place the ship in its true lightship condition.

A.4.2.2 Lightweight survey

A.4.2.2.1 Application

GL may allow a lightweight check to be carried out in lieu of an inclining test in the following cases:

- Stability data are available from the inclining test of a sister ship and it is shown to the satisfaction of GL that reliable stability information for the exempted ship can be obtained from such basic data. A weight survey is to be carried out upon completion and the ship is to be inclined whenever in comparison with the data derived from the sister ship, a deviation from the lightship displacement exceeding $1\ \%$ for ships of $160\ \mathrm{m}$ or more in length and $2\ \%$ for ships of $50\ \mathrm{m}$ or less in length and as determined by linear interpolation for intermediate lengths or a deviation from the lightship longitudinal centre of gravity exceeding $0.5\ \%$ of $\mathbf{L_S}$ is found.
- Special types of ship, such as pontoons, provided that the vertical centre of gravity is considered at the level of the deck.

  (SOLAS II-1, 5 and IS Code 2008 B, 8)

A.4.2.3 Detailed procedure

For the lightweight check, the same procedure as for the inclining test applies except as provided for in A.4.2.1.3.

B Intact Stability

B.1 General

B.1.1 Information for the master

B.1.1.1 Stability booklet

B.1.1.1.1 Each ship is to be provided with a stability booklet, approved by GL, which contains sufficient information to enable the Master to operate the ship in compliance with the applicable requirements contained in this Section. If a stability instrument is used as a supplement to the stability booklet for the purpose of determining compliance with the relevant stability criteria such instrument is to be subject to the approval by GL (see part IS Code , B, chapter 4 − Stability calculations performed by stability instruments).

(IS Code 2008 A, 2.1.6)

B.1.1.1.2 Where any alterations are made to a ship so as to materially affect the stability, the ship should be reinclined.

(IS Code 2008 B, 8.1.4)

B.1.1.1.3 Stability data and associated plans should be drawn up in the working language of the ship and any other language GL may require. Reference is also made to the International Safety Management (ISM) Code, adopted by IMO by resolution A.741(18). All translations of the stability booklet are to be approved.

The format of the trim and stability booklet and the information included are specified in B.8.

(IS Code 2008 B, 3.6.1)

B.1.1.2 Operating booklets for certain ships

Special purpose ships and novel craft, should be provided with additional information in the stability booklet such as design limitations, maximum speed, worst intended weather conditions or other information regarding the handling of the craft that the Master needs to operate the ship.

(IS Code 2008 B, 3.8.1)

B.1.2 Permanent ballast

B.1.2.1 If used, permanent ballast should be located in accordance with a plan approved by GL and in a manner that prevents shifting of position. Permanent ballast should not to be removed from the ship or relocated within the ship without the approval of GL. Permanent ballast particulars are to be noted in the ship's stability booklet.

(IS Code 2008 B, 3.2)

B.1.2.2 Permanent solid ballast is to be installed under the supervision of GL.

B.2 Design criteria

B.2.1 General intact stability criteria

B.2.1.1 General

The intact stability criteria specified in B.2.1.2 – B.2.1.5, and are to be complied with for the loading conditions mentioned in B.8.2.

However, the lightship condition not being an operational loading case, GL may accept that parts of the above-mentioned criteria are not fulfilled.
These criteria set minimum values, but no maximum values are recommended. It is advisable to avoid excessive values of metacentric height, since these might lead to acceleration forces which could be prejudicial to the ship, its equipment and to safe carriage of the cargo. Slack tanks may, in exceptional cases, be used as a means of reducing excessive values of metacentric height. In such cases, due consideration should be given to sloshing effects.

(IS Code 2008 B, 5.1.6)

B.2.1.2 GZ curve area

The area under the righting lever curve (GZ curve) is not to be less than $0.055\ \mathrm{m\ rad}$ up to $\theta = 30\ °$ angle of heel and not less than $0.09\ \mathrm{m\ rad}$ up to $\theta = 40\ °$ or the angle of down flooding θ_f if this angle is less than $40\ °$. Additionally, the area under the righting lever curve (GZ curve) between the angles of heel of $30\ °$ and $40\ °$ or between $30\ °$ and θ_f, if this angle is less than $40\ °$, is to be not less than $0.03\ \mathrm{m\ rad}$.

θ_f : angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight submerge. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open.

(IS Code 2008 A, 2.2.1)

B.2.1.3 Minimum righting lever

The righting lever GZ is to be at least 0.20 m at an angle of heel equal to or greater than $30°$.

(IS Code 2008 A, 2.2.2)

B.2.1.4 Angle of maximum righting lever

The maximum righting arm is to occur at an angle of heel not less than $25°$.

If this is not practicable, alternative criteria, based on an equivalent level of safety*, may be applied subject to the approval of GL.

(IS Code 2008 A, 2.2.3)

B.2.1.5 Initial metacentric height

The initial metacentric height $\overline{GM_0}$ is not to be less than 0.15 m.

(IS Code 2008 A, 2.2.3)

B.2.1.6 Elements affecting stability

A number of influences such as the dead ship condition, wind on ships with large windage area, rolling characteristics, severe seas, etc., were taken into account based on the state-of-the-art technology and knowledge at the time of the development of the Code.

(IS Code 2008 Preamble 3)

B.2.1.7 Elements reducing stability

Provisions are to be made for a safe margin of stability at all stages of the voyage, regard being given to additions of weight, such as those due to absorption of water and icing (details regarding ice accretion are given in IS Code, Part B, Chapter 6) and to losses of weight such as those due to consumption of fuel and stores.

(IS Code 2008 A, 2.1.5)

B.3 Serve wind and rolling criterion (weather criterion)

B.3.1 The ability of a ship to withstand the combined effects of beam wind and rolling is to be demonstrated for each standard condition of loading, with reference to Fig. 28.1 as follows:

- the ship is subjected to a steady wind pressure acting perpendicular to the ship's centreline which results in a steady wind heeling lever ℓ_{W1}
- from the resultant angle of equilibrium φ_0, the ship is assumed to roll owing to wave action to an angle of roll φ_1 to windward. The angle of heel under action of steady wind φ_0 is to be limited to $16°$or $80\ \%$ of the angle of deck edge immersion, whichever is less.
- the ship is then subjected to a gust wind pressure which results in a gust wind heeling lever ℓ_{W2}
- under these circumstances, area b is to be equal to or greater than area a, as indicated in Fig. 28.1

a : area above the GZ curve and below ℓ_{W2}, between φ_R and the intersection of ℓ_{W2} with the GZ curve

b : area above the heeling lever ℓ_{W2} and below the GZ curve, between the intersection of ℓ_{W2} with the GZ curve and φ_2

ℓ_{W1}, ℓ_{W2} : wind heeling levers according to B.3.2

φ_0 : angle of heel [°] under action of steady wind

φ_2 : angle [°], defined as:

$$\varphi_2 = \min\left[\varphi_f \ ; \varphi_c \ ; 50\right]$$

φ_f : angle of heel [°] at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight immerse. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open

φ_c : angle [°] of second intercept between wind heeling lever ℓ_{W2} and GZ curves

φ_R : angle [°], defined as:

$$\varphi_R = \varphi_0 - \varphi_1$$

(IS Code 2008 A, 2.3.1)

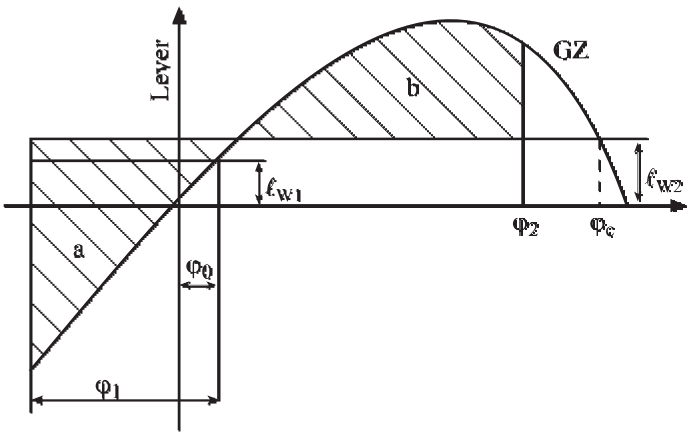


Fig. 28.1 Severe wind and rolling

B.3.2 The wind heeling levers ℓ_{W1} and ℓ_{W2} [m] are constant values at all angles of inclination and are to be calculated as follows:

$$\ell_{W1} = \frac{P \cdot A \cdot Z}{g \cdot \Delta} \cdot 10^{-3} \quad [m]$$

$$\ell_{W2} = 1.5 \cdot \ell_{W1} \quad [m]$$

P : load [N / m²], defined as:

$P = 504$ for unrestricted navigation notation

The value of P used for ships with restricted navigation notation may be reduced subject to the approval of GL

A : projected lateral area [m²], of the portion of the ship and deck cargo above the waterline

Z : vertical distance [m], from the centre of A to the centre of the underwater lateral area or approximately to a point at one half the draught

Δ : displacement [t]

g : gravity [m / s²], defined as:

$g = 9.81$

(IS Code 2008 A, 2.3.2)

B.3.3 Alternative means for determining the wind heeling lever ℓ_{W1} may be accepted, to the satisfaction of GL as an equivalent to the calculation in B.3.2. When such alternative tests are carried out, reference is to be made based on the Interim Guidelines for alternative assessment of the weather criterion (IMO MSC.1/Circ.1200). the wind velocity used in the tests is to be 26 m / s in full scale with uniform velocity profile. the value of wind velocity used for ships in restricted services may be reduced to the satisfaction of GL.

(IS Code 2008 A, 2.3.3)

B.3.4 The angle of roll is to be calculated as follows:

$$\varphi_1 = 109 \cdot k \cdot X_1 \cdot X_2 \cdot \sqrt{r \cdot s} \quad [°]$$

k : coefficient, defined as:

$k = 1.0$	for a round-bilged ship having no bilge or bar keels
$k = 0.7$	for a ship having sharp bilge
$k =$ according to Table 28.1	for a ship having bilge keels, a bar keel or both

X_1, X_2 : coefficients according to Table 28.1

r : factor, defined as:

$$r = 0.73 \cdot \pm 0.6 \cdot \frac{OG}{T_1}$$

OG : distance $[m]$ between the centre of gravity and the waterline (positive if centre of gravity is above the waterline, negative if it is below)

T_1 : mean moulded draught $[°]$ of the ship

s : factor according to Table 28.1

A_K : total overall area $[m^2]$ of bilge keels, or area of the lateral projection of the bar keel, or sum of these areas, or area of the lateral projection of any hull appendages generating added mass during ship roll

T_R : rolling period $[°]$, defined as:

$$T_R = \frac{2 \cdot C \cdot B}{\sqrt{\overline{GM}}} \quad [s]$$

C : coefficient, defined as:

$$C = 0.373 + 0.023 \cdot \frac{B}{T_1} - 0.043 \cdot \frac{L_W}{100}$$

L_W : length $[m]$ of the ship at the waterline

$\overline{GM}$: metacentric height $[m]$ corrected for free surface effect

(IS Code 2008 A, 2.3.4)

Table 28.1 Coefficient X_1 and X_2 and factors k and s

B / T_1	X_1	C_B	X_2	$\frac{A_K \cdot 100}{L_c \cdot B}$	k	T_R	s
≤ 2.4	1.00	≤ 0.45	0.75	0.0	1.00	≤ 6	0.100
2.5	0.98	0.50	0.82	1.0	0.98	7	0.098
2.6	0.96	0.55	0.89	1.5	0.95	8	0.093
2.7	0.95	0.60	0.95	2.0	0.88	12	0.065
2.8	0.93	0.65	0.97	2.5	0.79	14	0.053
2.9	0.91	≥ 0.70	1.00	3.0	0.74	16	0.044

3.0	0.90			3.5	0.72	18	0.038
3.1	0.88			≥ 4.0	0.70	≥ 20	0.035
3.2	0.86						
3.4	0.82						
≥ 3.5	0.80						

B.3.5 The formula for the angle of roll is based on data from ships having:

- B / T_1 smaller than 3.5
- $KG / T_1 - 1$ between – 0.3 and 0.5
- T_R smaller than 20 s.

For ships with parameters outside of the above limits the angle of roll φ_1 may be determined with model experiments of a subject ship with the procedure described in IMO MSC.1/Circ. 1200 as the alternative. In addition, GL may accept such alternative determinations for any ship, if deemed appropriate.

(IS Code 2008 A, 2.3.5)

B.4 Effects of free surfaces of liquids in tanks

B.4.1 General

For all loading conditions, the initial metacentric height and the righting lever curve should be corrected for the effect of free surfaces of liquids in tanks.

(IS Code 2008 B, 3.1.1)

B.4.2 Consideration of free surface effects

B.4.2.1 Free surface effects should be considered whenever the filling level in a tank is less than 98 % of full condition. Free surface effects need not be considered where a tank is nominally full, i.e. filling level is 98 % or above. Free surface effects for small tanks may be ignored under the condition in B.4.8.

Nominally full cargo tanks should be corrected for free surface effects at 98 % filling level. In doing so, the correction to initial metacentric height should be based on the inertia moment of liquid surface at 5 ° of the heeling angle divided by displacement, and the correction to righting lever is suggested to be on the basis of real shifting moment of cargo liquids.

(IS Code 2008 B, 3.1.2)

B.4.3 Categories of tanks

Tanks which are taken into consideration when determining the free surface correction may be one of two categories:

- tanks with fixed filling level (e.g. liquid cargo, water ballast). The free surface correction should be defined for the actual filling level to be used in each tank; or
- tanks with variable filling level (e.g. consumable liquids such as fuel oil, diesel oil, and fresh water, and also liquid cargo and water ballast during liquid transfer operations). Except as permitted in B.4.5 and B.4.6, the free surface correction should be the maximum value attainable among the filling limits envisaged for each tank, consistent with any operating instructions.

(IS Code 2008 B, 3.1.3)

B.4.4 Consumable liquids

In calculating the free surfaces effect in tanks containing consumable liquids, it should be assumed that for each type of liquid at least one transverse pair or a single centreline tank has a free surface and the tank or combination of tanks taken into account should be those where the effect of free surface is the greatest.

(IS Code 2008 B, 3.1.4)

B.4.5 Water ballast tanks

Where water ballast tanks, including anti-rolling tanks and anti-heeling tanks, are to be filled or discharged during the course of a voyage, the free surfaces effect should be calculated to take account of the most onerous transitory stage relating to such operations.

(IS Code 2008 B, 3.1.5)

B.4.6 Liquid transfer operation

For ships engaged in liquid transfer operations, the free surface corrections at any stage of the liquid transfer operations may be determined in accordance with the filling level in each tank at the stage of the transfer operation.

(IS Code 2008 B, 3.1.6)

B.4.7 $\overline{GM_0}$ and GZ curve correction

B.4.7.1 The corrections to the initial metacentric height and to the righting lever curve are to be addressed separately as follows:

(IS Code 2008 B, 3.1.7)

B.4.7.2 In determining the correction to the initial metacentric height, the transverse moments of inertia of the tanks should be calculated at 0 angle of heel according to the categories indicated in B.4.3.

(IS Code 2008 B, 3.1.8)

B.4.7.3 The righting lever curve may be corrected by any of the following methods subject to the agreement of GL:

- correction based on the actual moment of fluid transfer for each angle of heel calculated;
- correction based on the moment of inertia, calculated at $0\,°$ angle of heel, modified at each angle of heel calculated

The corrections may be calculated according to the categories indicated in B.4.2.1

(IS Code 2008 B, 3.1.9 and 3.1.10)

B.4.7.4 Whichever method is selected for correcting the righting lever curve, only that method should be presented in the ship's trim and stability booklet. However, where an alternative method is described for use in manually calculated loading conditions, an explanation of the differences which may be found in the results, as well as an example correction for each alternative, are to be included.

(IS Code 2008 B, 3.1.11)

B.4.8 Small amount of free surface moments

Tanks which satisfy the following condition corresponding to an angle of inclination of 30 need not be included in the correction:

$$\frac{M_{fs}}{\Delta_{min}} < 0.01 \text{ m}$$

Δ_{min} : minimum ship displacement $[t]$ calculated at d_{min}

d_{min} : minimum mean service draught, in m, of ship without cargo, with $10\ \%$ stores and minimum water ballast, if required

B.4.9 Remainder of liquids

The usual remainder of liquids in the empty tanks need not be taken into account in calculating the corrections, providing the total of such residual liquids does not constitute a significant free surface effect.

(IS Code 2008 A, 3.1.13)

B.5 Cargo ships carrying timber deck cargoes

B.5.1 Application

The provisions given hereunder apply to ships of 24 m in length and over engaged in the carriage of timber deck cargoes. Ships that are provided with and make use of their timber load line are also to comply with the requirements of regulations 41 to 45 of the International Load Line Convention 1966, as amended

(IS Code 2008 A, 3.3.1)

B.5.2 Alternative stability criteria

For ships loaded with timber deck cargoes and provided that the cargo extends longitudinally between superstructures (where there is no limiting superstructure at the after end, the timber deck cargo is to extend at least to the after end of the aftermost hatchway) and transversely for the full beam of ship, after due allowance for a rounded gunwale, not exceeding $4\,\%$ of the breadth of the ship and / or securing the supporting uprights and which remains securely fixed at large angles of heel, may be:

- the area under the GZ curve is not to less than 0.08 m rad up to $\varphi = 40°$ or the angle of flooding if this angle is less than $40°$
- the maximum value of the righting lever GZ is to be at least 0.25 m
- at all times during a voyage, the metacentric height $\overline{GM_0}$ is not to less than 0.10 m after correction for the free surface effects of liquid in tanks and, where appropriate, the absorption of water by the deck cargo and / or ice accretion on the exposed surfaces (details regarding ice accretion are given in B.6).
- when determining the ability of the ship to withstand the combined effects of beam wind and rolling according to B.3, the $16°$ limiting angle of heel under action of steady wind is to be complied with, but the additional criterion of $80\,\%$ of the angle of deck edge immersion may be ignored

(IS Code 2008 A, 3.3.2)

B.5.3 Stability booklet

For ships carrying timber deck cargoes:

- comprehensive stability information should be supplied which takes into account timber deck cargo. Such information should enable the master, rapidly and simply, to obtain accurate guidance as to the stability of the ship under varying conditions of service. Comprehensive rolling period tables or diagrams have proved to be very useful aids in verifying the actual stability conditions;
- GL may deem it necessary that the master be given information setting out the changes in deck cargo from that shown in the loading conditions, when the permeability of the deck cargo is significantly different from $25\,\%$ (see B.5.4); and
- conditions should be shown indicating the maximum permissible amount of deck cargo having regard to the lightest stowage rate likely to be met in service.

(IS Code 2008 B, 3.6.3)

B.5.4 Calculation of the stability curve

In addition to the provisions given in B.8, GL may allow account to be taken of the buoyancy of the deck cargo assuming that such cargo has a permeability of $25\,\%$ of the volume occupied by the cargo. Additional curves of stability may be required if GL considers it necessary to investigate the influence of different permeabilities and / or assumed effective height of the deck cargo.

(IS Code 2008 B, 3.5.3)

B.5.5 Loading conditions to be considered

The loading conditions which are to be considered for ships carrying timber deck cargoes are specified in B.8.2.2.

(IS Code 2008 B, 3.4.1.3)

B.5.6 Assumptions for calculating loading conditions

B.5.6.1 Considering timber deck cargo the following assumptions are to be made for calculating the loading conditions referred to in B.8.2.2:

- the amount of cargo and ballast is to correspond to the worst service condition in which all the relevant stability criteria reported in B.2.1.2 – B.2.1.5, or the optional criteria given in B.5.2, are met
- in the arrival condition, it should be assumed that the weight of the deck cargo has increased by $10\ \%$ owing to water absorption

(IS Code 2008 B, 3.4.2.6)

B.5.6.2 The stability of the ship at all times, including during the process of loading and unloading timber deck cargo, should be positive and in compliance with the stability criteria of B.5.2. It should be calculated having regard to:

- the increased weight of the timber deck cargo due to:
  - absorption of water in dried or seasoned timber, and
  - ice accretion, if applicable (as reported in B.6)
- variations in consumable
- the free surface effect of liquid in tanks, and
- weight of water trapped in broken spaces within the timber deck cargo and especially logs.

(IS Code 2008 B, 3.7.1)

B.5.6.3 However, excessive initial stability is to be avoided as it will result in rapid and violent motion in heavy seas which will impose large sliding and racking forces on the cargo causing high stresses on the lashings. Operational experience indicates the metacentric height is generally not to exceed $3\ \%$ of the breadth in order to prevent excessive acceleration in rolling provided that the relevant stability criteria given in B.5.2 are satisfied. This recommendation may not apply to all ships and the master should take into consideration the stability information obtained from the ship's stability booklet.

(IS Code 2008 B, 3.7.5)

B.5.7 Stowage of timber deck cargoes

The stowage of timber deck cargoes should comply with the provisions of chapter 3 of the Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 1991 (resolution A.715(17)).

(IS Code 2008 B, 3.4.1.3)

B.6 Icing

B.6.1 Application

For any ship having an ice class notation or operating in areas where ice accretion is likely to occur, adversely affecting a ship's stability, icing allowances are to be included in the analysis of conditions of loading.

(IS Code 2008 B, 6.1.1)

B.6.2 Cargo ships carrying timber deck cargoes

B.6.2.1 The master should establish or verify the stability of his ship for the worst service condition, having regard to the increased weight of deck cargo due to water absorption and / or ice accretion and to variations in consumable.

(IS Code 2008 B, 6.2.1)

B.6.2.2 When timber deck cargoes are carried and it is anticipated that some formation of ice will take place, an allowance is to be made in the arrival condition for the additional weight.

(IS Code 2008 B, 6.2.2)

B.6.3 Allowance for ice accretion

B.6.3.1 For ships operating in areas where ice accretion is likely to occur, the following icing allowance should be made in the stability calculations:

- 30 kg per square metre on exposed weather decks and gangways;
- 7.5 kg per square metre for the projected lateral area of each side of the ship above the water plane;
- the projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging of ships having no sails and the projected lateral area of other small objects are to be computed by increasing the total projected area of continuous surfaces by 5 % and the static moments of this area by 10 %.

(IS Code 2008 B, 6.3.1)

B.6.3.2 Ships intended for operation in areas where ice is known to occur are to be:

- designed to minimise the accretion of ice, and
- equipped with such means for removing ice as, for example, electrical and pneumatic devices, and / or special tools such as axes or wooden clubs for removing ice from bulwarks, rails and erections.

(IS Code 2008 B, 6.3.1)

B.6.4 Guidance relating ice accretion

B.6.4.1 The following icing areas are to be considered:

1. the area north of latitude 65 °30 "N, between longitude 28°W and the west coast of Iceland; north of the north coast of Iceland; north of the rhumb line running from latitude 66 °N, longitude 15 °W to latitude 73 °30 "N, longitude 15 °E, north of latitude 73 °30 "N between longitude 15 °E and 35 °E, and east of longitude 35 °E, as well as north of latitude 56 °N in the Baltic Sea;
2. the area north of latitude 43 °N bounded in the west by the North American coast and the east by the rhumb line running from latitude 43 °N, longitude 48 °W to latitude 63 °N, longitude 28 °W and thence along longitude 28 °W;
3. all sea areas north of the North American Continent, west of the areas defined in 1. and 2.
4. the Bering and Okhotsk Seas and the Tartary Strait during the icing season, and
5. south of latitude 60 °S.,

(IS Code 2008 B, 6.3.2)

B.6.4.2 For ships operating where ice accretion may be expected:

- within the areas defined in 1., 2., 3. and 4. of B.6.4.1 known to having icing conditions significantly different from those described i n B.6.3, ice accretion requirements of one half to twice the required allowance may be applied; and
- within the area defined in 2., where ice accretion in excess of twice the allowance required by B.6.3 may be expected, more severe requirements than those given in B.6.3 may be applied.

(IS Code 2008 B, 6.3.2)

B.7 Inclining Test and Lightweight Check

B.7.1 General

B.7.1.1 General conditions of the ship

The following conditions are to be met, as far as practicable:

- the weather conditions are to be favourable
- the ship should be moored in a quiet, sheltered area free from extraneous forces such as propeller wash from passing vessels, or sudden discharges from shore side pumps. The tide conditions and the trim of the ship during the test should be considered. Prior to the test, the depth of water should be measured and recorded in as many locations as are necessary to ensure that the ship will not contact the bottom. The specific gravity of water should be accurately recorded. The ship should be

moored in a manner to allow unrestricted heeling. The access ramps should be removed. Power lines, hoses, etc., connected to shore should be at a minimum, and kept slack at all times

(IS Code 2008 B, 8.2.2.6)

- the ship should be as upright as possible; with inclining weights in the initial position, up to one-half degree of list is acceptable. The actual trim and deflection of keel, if practical, should be considered in the hydrostatic data. In order to avoid excessive errors caused by significant changes in the water plane area during heeling, hydrostatic data for the actual trim and the maximum anticipated heeling angles should be checked beforehand

(IS Code 2008 B, 8.2.2.7)

- the anticipated liquid loading for the test should be included in the planning for the test. Preferably, all tanks should be empty and clean, or completely full. The number of slack tanks should be kept to an absolute minimum. The viscosity of the fluid, the depth of the fluid and the shape of the tank should be such that the free surface effect can be accurately determined

(IS Code 2008 B, 8.2.2.5)

- all work on board is to be suspended and crew or personnel not directly involved in the incline test are to leave the ship
- decks should be free of water. Water trapped on deck may shift and pocket in a fashion similar to liquids in a tank. Any rain, snow or ice accumulated on the ship should be removed prior to the test.

(IS Code 2008 B, 8.2.2.4)

B.7.1.2 Inclining weights

B.7.1.2.1 The total weight used should be sufficient to provide a minimum inclination of one degree and a maximum of four degrees of heel to each side. GL may, however, accept a smaller inclination angle for large ships provided that the requirement on pendulum deflection or U-tube difference in height specified in B.7.1.4 is complied with. Test weights are to be compact and of such a configuration that the VCG (vertical centre of gravity) of the weights can be accurately determined. Each weight is to be marked with an identification number and its weight. Re-certification of the test weights is to be carried out prior to the incline. A crane of sufficient capacity and reach, or some other means, is to be available during the inclining test to shift weights on the deck in an expeditious and safe manner. Water ballast transfer may be carried out, when it is impractical to incline using solid weights and subject to requirement of B.7.1.3.

(IS Code 2008 B, 8.2.2.8)

B.7.1.2.2 Weights, such as porous concrete, that can absorb significant amounts of moisture should only be used if they are weighed just prior to the inclining test or if recent weight certificates are presented. Each weight should be marked with an identification number and its weight. For small ships, drums completely filled with water may be used. Drums should normally be full and capped to allow accurate weight control. In such cases, the weight of the drums should be verified in the presence of a surveyor of GL using a recently calibrated scale.

(IS Code 2008 Annex 1, 2.3.1)

B.7.1.2.3 Precautions should be taken to ensure that the decks are not overloaded during weight movements. If deck strength is questionable then a structural analysis should be performed to determine if existing framing can support the weight.

(IS Code 2008 Annex 1, 2.3.2)

B.7.1.2.4 Generally, the test weights should be positioned as far outboard as possible on the upper deck. The test weights should be on board and in place prior to the scheduled time of the inclining test.

(IS Code 2008 Annex 1, 2.3.3)

B.7.1.3 Water ballast as inclining weight

Where the use of solid weights to produce the inclining moment is demonstrated to be impracticable, the movement of ballast water may be permitted as an alternative method. This acceptance would be granted for a specific test only, and approval of the test procedure by GL is required. As a minimal prerequisite for acceptability, the following conditions are to be required:

- inclining tanks are to be wall-sided and free of large stringers or other internal members that create air pockets. Other tank geometries may be accepted at the discretion of GL;

- tanks are to be directly opposite to maintain ship's trim;
- specific gravity of ballast water is to be measured and recorded;
- pipelines to inclining tanks are to be full. If the ship's piping layout is unsuitable for internal transfer, portable pumps and pipes / hoses may be used;
- blanks must be inserted in transverse manifolds to prevent the possibility of liquids being "leaked" during transfer. Continuous valve control must be maintained during the test;
- all inclining tanks must be manually sounded before and after each shift;
- vertical, longitudinal and transverse centres are to be calculated for each movement;
- accurate sounding / ullage tables are to be provided. The ship's initial heel angle is to be established prior to the incline in order to produce accurate values for volumes and transverse and vertical centres of gravity for the inclining tanks at every angle of heel. The draught marks amidships (port and starboard) are to be used when establishing the initial heel angle
- verification of the quantity shifted may be achieved by a flowmeter or similar device; and
- the time to conduct the inclining is to be evaluated. If time requirements for transfer of liquids are considered too long, water may be unacceptable because of the possibility of wind shifts over long periods of time.

(IS Code 2008 Annex 1, 2.3.4)

B.7.1.4 Pendulums

The use of three pendulums is recommended but a minimum of two are to be used to allow identification of bad readings at any one pendulum station. However, for ships of a length equal to or less than 30 m, only one pendulum can be accepted. They are each to be located in an area protected from the wind. The pendulums are to be long enough to give a measured deflection, to each side of upright, of at least 15 cm. To ensure recordings from individual instruments are kept separate, it is suggested that the pendulums be physically located as far apart as practical.The use of an inclinometer or U-tube is to be considered in each separate case. It is recommended that inclinometers or other measuring devices only be used in conjunction with at least one pendulum.

(IS Code 2008 B, 8.2.2.9)

B.7.1.5 Free surface and slack tanks

The number of slack tanks should normally be limited to one port / starboard pair or one centreline tank of the following:

- fresh water reserve feed tanks;
- fuel / diesel oil storage tanks;
- fuel / diesel oil day tanks;
- lube oil tanks;
- sanitary tanks; and
- potable water tanks.

To avoid pocketing, slack tanks are normally to be of regular (i.e. rectangular, trapezoidal, etc.) cross section and be 20 % to 80 % full if they are deep tanks and 40 % to 60 % full if they are double-bottom tanks. These levels ensure that the rate of shifting of liquid remains constant throughout the heel angles of the inclining test. If the trim changes as the ship is inclined, then consideration are also to be given to longitudinal pocketing. Slack tanks containing liquids of sufficient viscosity to prevent free movement of the liquids, as the ship is inclined (such as bunker at low temperature), are to be avoided since the free surface cannot be calculated accurately. A free surface correction for such tanks is not to be used unless the tanks are heated to reduce viscosity. Communication between tanks are never to be allowed. Cross-connections, including those via manifolds, are to be closed. Equal liquid levels in slack tank pairs can be a warning sign of open cross connections. A bilge, ballast, and fuel oil piping plan can be referred to, when checking for cross connection closures.

(IS Code 2008 Annex 1, 2.1.2)

B.7.1.6 Means of communications

Efficient two-way communications are to be provided between central control and the weight handlers and between central control and each pendulum station. One person at a central control station is to have complete control over all personnel involved in the test.

(IS Code B, 8.2.2.10)

B.7.1.7 Available Plans

The person in charge of the inclining test is to have available a copy of the following plans at the time of the test:

- lines plan;
- hydrostatic curves or hydrostatic data;
- general arrangement plan of decks, holds, inner bottoms, etc.;
- capacity plan showing capacities and vertical and longitudinal centres of gravity of cargo spaces, tanks, etc. When water ballast is used as inclining weights, the transverse and vertical centres of gravity for the applicable tanks, for each angle of inclination, must be available;
- tank sounding tables;
- draught mark locations, and
- docking drawing with keel profile and draught mark corrections (if available).

(IS Code B, 8.3)

B.7.1.8 Determination of the displacement

The measures necessary for the accurate evaluation of the displacement of the ship at the time of the inclining test, as listed below, are to be carried out:

- draught mark readings are to be taken at aft, midship and forward, at starboard and port sides
- the mean draught (average of port and starboard reading) should be calculated for each of the locations where draught readings are taken and plotted on the ship's lines drawing or outboard profile to ensure that all readings are consistent and together define the correct waterline. The resulting plot should to yield either a straight line or a waterline which is either hogged or sagged. If inconsistent readings are obtained, the freeboards / draughts are to be retaken

  (IS Code Annex 1, 4.2.8)

- the specific gravity of the sea water should to be determined. Samples should be taken from a sufficient depth of the water to ensure a true representation of the sea water and not merely surface water, which could contain fresh water from run off of rain. A hydrometer should to be placed in a water sample and the specific gravity read and recorded. For large ships, it is recommended that samples of the sea water be taken forward, midship and aft, and the readings averaged. For small ships, one sample taken from midship should be sufficient. The temperature of the water should be taken and the measured specific gravity corrected for deviation from the standard, if necessary a correction to water specific gravity is not necessary if the specific gravity is determined at the inclining experiment site. Correction is necessary if specific gravity is measured when the sample temperature differs from the temperature at the time of the inclining (e.g., if the check of specific gravity is performed at the office). Where the value of the average calculated specific gravity is different from that reported in the hydrostatic curves, adequate corrections are to be made to the displacement curve
- all double bottoms, as well as all tanks and compartments which can contain liquids, are to be checked, paying particular attention to air pockets which may accumulate due to the ship's trim and the position of air pipes, and also taking into account the provisions of B.7.1.1
- it is to be checked that the bilge is dry, and an evaluation of the liquids which cannot be pumped, remaining in the pipes, boilers, condenser, etc., is to be carried out
- the entire ship is to be surveyed in order to identify all items which need to be added, removed or relocated to bring the ship to the lightship condition. Each item is to be clearly identified by weight and location of the centre of gravity
- the possible solid permanent ballast is to be clearly identified and listed in the report.

- normally, the total value of missing weights is not to exceed 2 % and surplus weights, excluding liquid ballast, not exceed 4 % of the lightship displacement. For smaller vessels, higher percentages may be allowed.

B.7.1.9 The incline

The standard test generally employs eight distinct weight movements.

The weights are to be transversely shifted, so as not to modify the ship's trim and vertical position of the centre of gravity.

After each weight shifting, the new position of the transverse centre of gravity of the weights is to be accurately determined.

The pendulum deflection is to be read when the ship has reached a final position after each weight shifting.

After each weight movement, the distance the weight was moved (centre to centre) is to be measured and the heeling moment calculated by multiplying the distance by the amount of weight moved. The tangent is calculated for each pendulum by dividing the deflection by the length of the pendulum. The resultant tangents are plotted on the graph as shown in Fig. 28.2.

If there is a deviation of points, either between the points for a particular weight movement, or from the straight line, the deflections and moments should be checked and corrected prior to the next weight movement.

Personnel should be instructed to remain on their assigned positions while inclination readings are being taken and a check should be made that all mooring lines, etc., remain slack following each weight shift until all deflections have been taken and recorded.

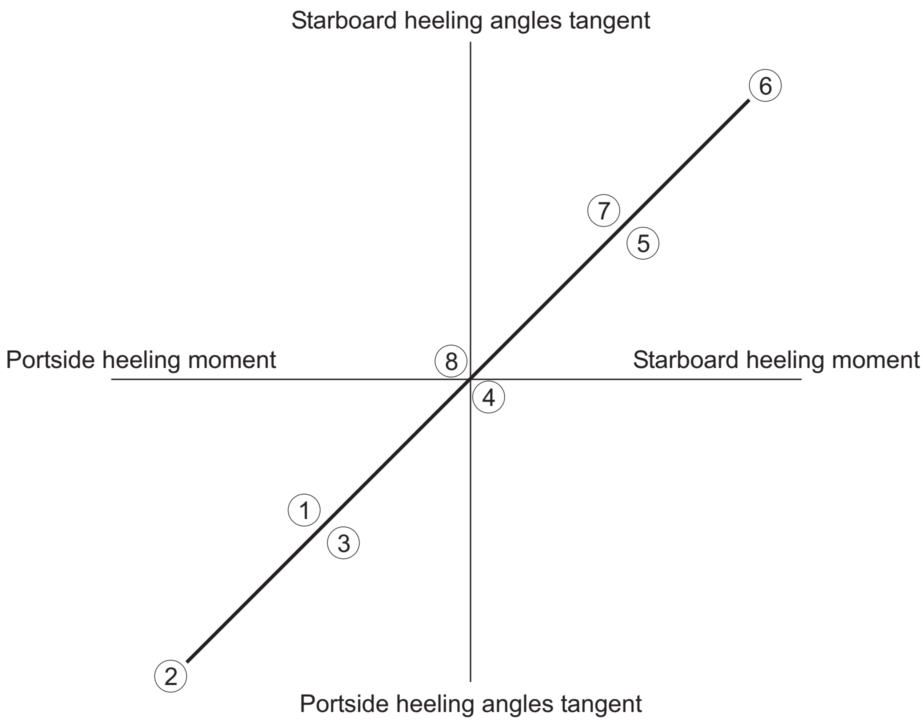


Fig. 28.2 Graph of resultant tangents

B.8 Trim and stability booklet

B.8.1 Information to be included in the trim and stability booklet

B.8.1.1 General

Each ship should be provided with an approved stability booklet, which is to contain information to enable the Master to operate the ship in compliance with the applicable requirements.

The format of the stability booklet and the information included vary depending on the ship type and operation.

B.8.1.2 List of information

The following information is to be included in the trim and stability booklet:

- a general description of the ship, including:
  - the ship's name
  - the ship type and service notation
  - the yard, the hull number and the year of delivery
  - the Flag, the port of registry, the international call sign and the IMO number
  - the moulded dimensions
  - the draught corresponding to the assigned summer load line, the draught corresponding to the assigned summer timber load line and the draught corresponding to the tropical load line, if applicable
  - the displacement corresponding to the above-mentioned draughts
- instructions on the use of the booklet
- general arrangement and capacity plans indicating the assigned use of compartments and spaces (cargo, stores, accommodation, etc.)
- a sketch indicating the position of the draught marks referred to the ship's perpendiculars
- hydrostatic curves or tables corresponding to the design trim, and, if significant trim angles are foreseen during the normal operation of the ship, curves or tables corresponding to such range of trim are to be introduced. A reference relevant to the sea density, in t / m^3, is to be included as well as the draught measure (from keel or underkeel)
- cross curves (or tables) of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves
- tank sounding tables or curves showing capacities, centres of gravity, and free surface data for each tank
- lightship data from the inclining test, as indicated in A.4.2, including lightship displacement, centre of gravity co-ordinates, place and date of the inclining test, as well as GL approval details specified in the inclining test report. It is suggested that a copy of the approved test report be included Where the above-mentioned information is derived from a sister ship, the reference to this sister ship is to be indicated, and a copy of the approved inclining test report relevant to this sister ship is to be included
- standard loading conditions as indicated in B.8.2 and examples for developing other acceptable loading conditions using the information contained in the booklet
- intact stability results (total displacement and its centre of gravity co-ordinates, draughts at perpendiculars, $\overline{GM}$, $\overline{GM}$ corrected for free surfaces effect, GZ values and curve, criteria as indicated in B.2 and B.3 as well as possible additional criteria for special shiptypes when applicable, reporting a comparison between the actual and the required values) are to be available for each of the above-mentioned operating conditions. The method and assumptions to be followed in the stability curve calculation are specified in B.8.3
- information on loading restrictions (maximum allowable load on double bottom, maximum specific gravity allowed in liquid cargo tanks, maximum filling level or percentage in liquid cargo tanks, maximum KG or minimum $\overline{GM}$ curve or table which can be used to determine compliance with the applicable intact and damage stability criteria) when applicable
- information about openings (location, tightness, means of closure), pipes or other progressive flooding sources
- information concerning the use of any special crossflooding fittings with descriptions of damage conditions which may require cross-flooding, when applicable
- any other guidance deemed appropriate for the operation of the ship
- a table of contents and index for each booklet.

- Inclining test report for the ship, or
  - where the stability data are based on a sister ship, the inclining test report of that sister ship along with the lightship measurement report for the ship in question ,
  - where lightship particulars are determined by other methods than from inclining of the ship or its sister, a summary of the method used to determine those particulars.

B.8.2 Loading conditions

B.8.2.1 General

The standard loading conditions to be included in the trim and stability booklet are:

- lightship condition
- ship in the fully loaded departure condition, with cargo homogeneously distributed throughout all cargo spaces and with full stores and fuel.
- ship in the fully loaded arrival condition, with cargo homogeneously distributed throughout all cargo spaces and with 10 % stores and fuel remaining
- ship in ballast in the departure condition, without cargo but with full stores and fuel
- ship in ballast in the arrival condition, without cargo and with 10 % stores and fuel remaining.
- Loading case in docking condition, if applicable (for stability booklets acting as loading manuals)

Further loading cases may be included when deemed necessary or useful.

When a tropical freeboard is to be assigned to the ship, the corresponding loading conditions are also to be included.

B.8.2.2 Ships carrying cargo on deck

In addition to the loading conditions indicated in B.8.2.1 and B.8.2.2, in the case of cargo carried on deck the following cases are to be considered:

- ship in the fully loaded departure condition having cargo homogeneously distributed in the holds and a cargo specified in extension and weight on deck, with full stores and fuel
- ship in the fully loaded arrival condition having cargo homogeneously distributed in holds and a cargo specified in extension and weight on deck, with 10 % stores and fuel.
- Lightship condition
- Loading case in docking condition, if applicable (for stability booklets acting as loading manuals)

B.8.3 Calculation of stability curves

B.8.3.1 3.5.1 General

Hydrostatic and stability curves should be prepared for the trim range of operating loading conditions taking into account the change in trim due to heel (free trim hydrostatic calculation). The calculations should take into account the volume to the upper surface of the deck sheathing. Furthermore, appendages and sea chests need to be considered when calculating hydrostatics and cross curves of stability. In the presence of port-starboard asymmetry, the most unfavourable righting lever curve should be used.

(IS Code 2008 B, 3.5.1)

B.8.3.2 3.5.2 Superstructures, deckhouses, etc., which may be taken into account

B.8.3.2.1 Enclosed superstructures complying with regulation 3(10)(b) of the 1966 Load Line Convention and the Protocol of 1988 relating thereto, as amended, may be taken into account.

(IS Code 2008 B, 3.5.2.1)

B.8.3.2.2 Additional tiers of similarly enclosed superstructures may also be taken into account. As guidance windows (pane and frame) that are considered without deadlights in additional tiers above the second tier if considered buoyant should be designed with strength to sustain a safety margin* with regard to the required strength of the surrounding structure.

(IS Code 2008 B, 3.5.2.1)

B.8.3.2.3 Deckhouses on the freeboard deck may be taken into account, provided that they comply with the conditions for enclosed superstructures laid down in regulation 3(10)(b) of the 1966 Load Line Convention and the Protocol of 1988 relating thereto, as amended.

(IS Code 2008 B, 3.5.2.3)

B.8.3.2.4 Where deckhouses comply with the above conditions, except that no additional exit is provided to a deck above, such deckhouses should not be taken into account; however, any deck openings inside such deckhouses should be considered as closed even where no means of closure are provided.

(IS Code 2008 B, 3.5.2.4)

B.8.3.2.5 Deckhouses, the doors of which do not comply with the requirements of regulation 12 of the 1966 Load Line Convention and the Protocol of 1988 relating thereto, as amended, should not be taken into account; however, any deck openings inside the deckhouse are regarded as closed where their means of closure comply with the requirements of regulations 15, 17 or 18 of the 1966 Load Line Convention and the Protocol of 1988 relating thereto, as amended.

(IS Code 2008 B, 3.5.2.5)

B.8.3.2.6 Deckhouses on decks above the freeboard deck should not be taken into account, but openings within them may be regarded as closed.

(IS Code 2008 B, 3.5.2.6)

B.8.3.2.7 Superstructures and deckhouses not regarded as enclosed can, however, be taken into account in stability calculations up to the angle at which their openings are flooded (at this angle, the static stability curve should show one or more steps, and in subsequent computations the flooded space should be considered non-existent).

(IS Code 2008 B, 3.5.2.7)

B.8.3.2.8 In cases where the ship would sink due to flooding through any openings, the stability curve should be cut short at the corresponding angle of flooding and the ship should be considered to have entirely lost its stability.

(IS Code 2008 B, 3.5.2.8)

B.8.3.2.9 Small openings such as those for passing wires or chains, tackle and anchors, and also holes of scuppers, discharge and sanitary pipes should not be considered as open if they submerge at an angle of open if GL considers this to be a source of significant flooding.

(IS Code 2008 B, 3.5.2.9)

B.8.3.2.10 Trunks may be taken into account. Hatchways may also be taken into account having regard to the effectiveness of their closures.

(IS Code 2008 B, 3.5.2.10)

C Damage Stability

C.1 General

C.1.1 Application

Damage stability calculation is required for ships which will be assigned with the symbol ☐.

C.1.2 Scope

Damage stability calculations are required in order to assess the behaviour and stability of the ship after flooding.

In order to assess the stability of the ship after damage, two approaches have been developed: the deterministic and the probabilistic, which are to be applied depending on the ship type.

The metacentric heights $\overline{GM}$, stability levers GZ and centre of gravity positions for judging the final conditions are to be calculated by method of lost buoyancy.

C.1.2.1 Deterministic approach

The deterministic approach is based on standard dimensions of damage extending anywhere along the ship's length or between transverse bulkheads depending on the relevant requirements.

The required compartment status defines a group of damage cases which have to be calculated for each loading condition where the applicable criteria are to be complied with.

The deterministic concept is to be applied for oil tankers, chemical tankers, gas tankers, offshore service vessels (up to 100 m in length) and all high speed craft vessels.

The deterministic concept is to be applied with in case of freeboard reduction (ref…).

C.1.2.2 Probabilistic Approach

The probabilistic concept uses the probability of survival after collision as a measure of ship's safety in a damage condition referred to as the attained subdivision index A.

All damage cases complying with the applicable criteria contribute to the attained index A which is to be equal or greater than minimum required level of safety the required index R.

Producing the index A requires calculation of various damage scenarios defined by the extend of damage and the initial loading conditions of the ship before damage.

The probabilistic damage stability concept is to apply to cargo ships of 80 m in length and more and to all cargo ships for which no deterministic method is applicable.

C.2 Documents to be submitted

C.2.1 Damage stability calculations

C.2.1.1 Damage stability documentation

For all ships to which damage stability requirements apply, documents including damage stability calculations are to be submitted.

The damage stability calculations are to include:

- list of the characteristics (volume, centre of gravity, permeability) of each compartment which can be damaged
- a table of openings in bulkheads, decks and side shell reporting all the information about:
  - identification of the opening
  - vertical, transverse and horizontal location
  - type of closure: sliding, hinged or rolling for doors
  - type of tightness: watertight, weathertight, semi-watertight or unprotected
  - operating system: remote control, local operation, indicators on the bridge, television surveillance, water leakage detection, audible alarm, as applicable
  - foreseen utilization: open at sea, normally closed at sea, kept closed at sea
- list of all damage cases corresponding to the applicable requirements
- detailed results of damage stability calculations for all the loading conditions required by the applicable requirements
- the limiting $\overline{GM} / KG$ curve, if applicable
- capacity plan
- cross and down flooding devices and the calculations thereof with informations about diameter, valves, pipe lengths and coordinates of inlet / outlet
- watertight and weathertight door plan
- side contour and wind profile
- pipes and damaged area when the destruction of these pipes results in progressive flooding.

C.2.1.2 Additional information for the probabilistic approach

In addition to the information listed in C.2.1.1, the following is to be provided:

- subdivision length L_S
- initial draughts and the corresponding $\overline{GM}$-values
- required subdivision index R
- attained subdivision index A with a summary table for all contributions for all damaged zones.
- draught, trim, $\overline{GM}$ in damaged condition
- damage extension and definition of damage cases with probabilistic values p, v and r
- righting lever curve (including $\overline{GM}_{max}$ and range) with factor of survivability s
- critical weathertight and unprotected openings with their angle of immersion
- details of sub-compartments with amount of in-flooded water / lost buoyancy with their centres of gravity.

C.2.2 Permeabilities

C.2.2.1 Definition

Permeability
Permeability of a space is the proportion of the immersed volume of that space which can be occupied by water.

The permeabilities relevant to the type of spaces which can be flooded depend on the applicable requirements. Such permeabilities are indicated in C.4.6 for each type of ship.

(SOLAS II-1, 2.14)

C.2.2.2 Progressive flooding

C.2.2.3 Definition

Progressive flooding is the additional flooding of spaces which were not previously assumed to be damaged. Such additional flooding may occur through openings as indicated in C.2.2.4.

C.2.2.4 Openings

The openings may be listed in the following categories, depending on their means of closure:

- Unprotected

  Unprotected openings may lead to progressive flooding if they are situated within the range of the positive righting lever curve or if they are located below the waterline after damage (at any stage of flooding). Unprotected openings are openings which are not fitted with at least weathertight means of closure.

- Weathertight

  Openings fitted with weathertight means of closure are not able to sustain a constant head of water, but they can be intermittently immersed within the positive range of stability.

  Weathertight openings may lead to progressive flooding if they are located below the waterline after damage (at any stage of flooding).

- Watertight

  Watertight means having scantlings and arrangements capable of preventing the passage of water in any direction under the head of water likely occur in intact and damage conditions. In the damage conditions, the head of water is to be considered in the worst situation at equilibrium, including intermediate stages of flooding.

C.2.3 Bottom damages

C.2.3.1 General

Ships which are not fitted with a double bottom as required by Section 27, C.2.3 or which are fitted with unusual bottom arrangements as defined in Section 27, C.2.7, are to comply with C.2.3.2 and C.2.3.3.

C.2.3.2 Bottom damage description

The assumed extent of damage is described in Table 28.2.

If any damage of a lesser extent than the maximum damage specified in Table 28.2 would result in a more severe condition, such damage should be considered.

C.2.3.3 Stability criteria

Compliance with the requirements of Section 27, C.2.6 or Section 27, C.2.7 is to be achieved by demonstrating that s_i, when calculated in accordance with C.4.5, is not less than 1 for all service conditions when subject to a bottom damage assumed at any position along the ship's bottom and with an extent specified in C.2.3.2 for the affected part of the ship.

Flooding of such spaces is not to render emergency power and lighting, internal communication, signals or other emergency devices inoperable in other parts of the ship.

Table 28.2 Assumed extent of damage

	For 0.3 L from the forward perpendicular of the ship	**Any other part of the ship**
Longitudinal extend	$1 / 3\ \mathbf{L}^{2/3}$ or 14.5 m, whichever is less	$1 / 3\ \mathbf{L}^{2/3}$ or 14.5 m, whichever is less
Transverse extend	**B** / 6 or 10 m, whichever is less	**B** / 6 or 5 m, whichever is less
Vertical extend, measured from the keel line	**B** / 20 or 2 m, whichever is less	**B** / 20 or 2 m, whichever is less

C.3 Damage control documentation

The damage control documentation is to include a damage control plan which is intended to provide ship's officers with clear information on the ship's watertight compartmentation and equipment related to maintaining the boundaries and effectiveness of the compartmentation so that, in the event of damage causing flooding, proper precautions can be taken to prevent progressive flooding through openings therein and effective action can be taken quickly to mitigate and, where possible, recover the ship's loss of stability.

The damage control documentation is to be clear and easy to understand. It is not to include information which is not directly relevant to damage control, and is to be provided in the language or languages of the ship's officers.

The damage control plan is required for cargo ships of 500 GT and over.

C.4 Probabilistic damage stability method for cargo ships

C.4.1 Application

C.4.1.1 The requirements are to be applied to cargo ships over 80 m in length L_S, but are not to be applied to those ships which are shown to comply with subdivision and damage stability regulations already required by following instances:

1. Annex I to MARPOL 73/78, except OBO ships with type B freeboards are not excluded;
2. International Bulk Chemical Code;
3. International Gas Carrier Code;
4. Guidelines for the design and construction of offshore supply vessels, 2006 (resolution MSC 235 (82));
5. Code of Safety for Special Purpose Ships, 2008 (resolution MSC 266 (84));
6. Damage stability requirements of regulation 27 of the 1966 Load Lines Convention as applied in compliance with resolutions A.320(IX) and A.514(13), provided that in the case of cargo ships to which regulation 27(9) applies, main transverse watertight bulkheads, to be considered effective, are spaced according to paragraph (12)(f) of resolution A.320(IX), except ships intended for the carriage of deck cargo; and
7. Damage stability requirements of regulation 27 of the 1988 Load Lines Protocol, except ships intended for the carriage of deck cargo.

C.4.1.2 The requirements of this Appendix are to be applied in conjunction with the explanatory notes as set out by the IMO resolution MSC 281 (85).

C.4.2 Required subdivision index R

For all ships to which the damage stability requirements of this chapter apply, the degree of subdivision to be provided is to be determined by the required subdivision index R, as follows:

$$R = 1 - \frac{128}{L_S + 152} \qquad \text{for } L_S > 100 \text{ m}$$

$$R = 1 - \frac{1}{1 + \frac{L_S}{100} \cdot \frac{R_0}{1 - R_0}} \qquad \text{for } 80 \le L_S \le 100 \text{ m}$$

R_0 : value of R as calculated in accordance with the formula given for ships with $L_S > 100$ m

(SOLAS II-1, B-1, 6.2)

C.4.3 Attained subdivision index A

C.4.3.1 The attained subdivision index A is obtained by the summation of the partial indices A_S, A_P and A_L (weighed as shown), calculated for the draughts d_S, d_P and d_L. in accordance with the following formula:

$$A = 0.4 \cdot A_S + 0.4 \cdot A_P + 0.2 \cdot A_L$$

The attained subdivision index A is not to be less than the required subdivision index R. In addition, the partial indices A_S, A_P and A_L are not to be less than $0.5\ R$.

(SOLAS II-1, B-1, 6.1 and 7.1)

C.4.3.2 Each partial index is a summation of contributions from all damage cases taken in consideration, using the following formula:

$$A = \sum p_i \cdot s_i$$

i : represents each compartment or group of compartments under consideration

p_i : accounts for the probability that only the compartment or group of compartments under consideration may be flooded, disregarding any horizontal subdivision, as defined in C.4.4

s_i : accounts for the probability of survival after flooding the compartment or group of compartments under consideration, and includes the effects of any horizontal subdivision, as defined in C.4.5

(SOLAS II-1, B-1, 7.1)

C.4.3.3 In the calculation of A, the level trim is to be used for the deepest subdivision draught d_S and the partial subdivision draught d_P. The actual service trim is to be used for the light service draught d_L. If, in any service condition, the trim variation in comparison with the calculated trim is greater than $0.5\ \%$ of L_S, one or more additional calculations of A are to be submitted for the same draughts but different trims so that, for all service conditions, the difference in trim in comparison with the reference trim used for one calculation is less than $0.5\ \%$ of L_S.

(SOLAS II-1, B-1, 7.2)

C.4.3.4 When determining the positive righting lever GZ of the residual stability curve, the displacement used is to be that of the intact condition. That is, the constant-displacement method of calculation is to be used.

(SOLAS II-1, B-1, 7.3)

C.4.3.5 The summation indicated by the formula in C.4.3.2 is to be taken over the ship's subdivision length L_S for all cases of flooding in which a single compartment or two or more adjacent compartments are involved. In the case of unsymmetrical arrangements, the calculated A value should be the mean value obtained from calculations involving both sides. Alternatively, it is to be taken as that corresponding to the side which evidently gives the least favourable result.

(SOLAS II-1, B-1, 7.4)

C.4.3.6 Wherever wing compartments are fitted, contribution to the summation indicated by the formula is to be taken for all cases of flooding in which wing compartments are involved. Additionally, cases of simultaneous flooding of a wing compartment or group of compartments and the adjacent inboard compartment or group of compartments, but excluding damage of transverse extent greater than one half of the ship breadth $\mathbf{B}$, may be added. For the purpose of this regulation, transverse extent is measured inboard from ship's side, at right angle to the centreline at the level of the deepest subdivision draught.

(SOLAS II-1, B-1, 7.5)

C.4.3.7 In the flooding calculations carried out according to the regulations, only one breach of the hull and only one free surface need to be assumed. The assumed vertical extent of damage is to extend from the baseline upwards to any watertight horizontal subdivision above the waterline or higher. However, if a lesser extent of damage gives a more severe result, such extent is to be assumed.

(SOLAS II-1, B-1, 7.6)

C.4.3.8 If pipes, ducts or tunnels are situated within the assumed extent of damage, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed flooded. However, GL may permit minor progressive flooding if it is demonstrated that its effects can be easily controlled and the safety of the ship is not impaired.

(SOLAS II-1, B-1, 7.7)

C.4.4 Calculation of factor p_i

C.4.4.1 The factor p_i for a compartment or group of compartments is to be determined by the following formulae:

- If the damage involves a single zone only:

$$p_i = p\left(x_{1(j)}\,,\, x_{2(j)}\right)\cdot\left[r\left(x_{1(j)}\,,\, x_{2(j)}\,,\, b_k\right) - r\left(x_{1(j)}\,,\, x_{2(j)}\,,\, b_{k-1}\right)\right]$$

- If the damage involves two adjacent zones:

$$\begin{aligned}p_i = {} & p\left(x_{1(j)}\,,\, x_{2(j+1)}\right)\cdot\left[r\left(x_{1(j)}\,,\, x_{2(j+1)}\,,\, b_k\right) - r\left(x_{1(j)}\,,\, x_{2(j+1)}\,,\, b_{k-1}\right)\right] \\ & - p\left(x_{1(j)}\,,\, x_{2(j)}\right)\cdot\left[r\left(x_{1(j)}\,,\, x_{2(j)}\,,\, b_k\right) - r\left(x_{1(j)}\,,\, x_{2(j)}\,,\, b_{k-1}\right)\right] \\ & - p\left(x_{1(j+1)}\,,\, x_{2(j+1)}\right)\cdot\left[r\left(x_{1(j+1)}\,,\, x_{2(j+1)}\,,\, b_k\right) - r\left(x_{1(j+1)}\,,\, x_{2(j+1)}\,,\, b_{k-1}\right)\right]\end{aligned}$$

- If the damage involves three or more adjacent zones:

$$\begin{aligned}p_i = {} & p\left(x_{1(j)}\,,\, x_{2(j+n-1)}\right)\cdot\left[r\left(x_{1(j)}\,,\, x_{2(j+n-1)}\,,\, b_k\right) - r\left(x_{1(j)}\,,\, x_{2(j+n-1)}\,,\, b_{k-1}\right)\right] \\ & - p\left(x_{1(j)}\,,\, x_{2(j+n-2)}\right)\cdot\left[r\left(x_{1(j)}\,,\, x_{2(j+n-2)}\,,\, b_k\right) - r\left(x_{1(j)}\,,\, x_{2(j+n-2)}\,,\, b_{k-1}\right)\right] \\ & - p\left(x_{1(j+1)}\,,\, x_{2(j+n-1)}\right)\cdot\left[r\left(x_{1(j+1)}\,,\, x_{2(j+n-1)}\,,\, b_k\right) - r\left(x_{1(j+1)}\,,\, x_{2(j+n-1)}\,,\, b_{k-1}\right)\right] \\ & + p\left(x_{1(j+1)}\,,\, x_{2(j+n-2)}\right)\cdot\left[r\left(x_{1(j+1)}\,,\, x_{2(j+n-2)}\,,\, b_k\right) - r\left(x_{1(j+1)}\,,\, x_{2(j+n-2)}\,,\, b_{k-1}\right)\right]\end{aligned}$$

with:

$$r\left(x_1\,,\, x_2\,,\, b_0\right) = 0$$

j : aftmost damage zone number involved in the damage starting with no.1 at the stern

n : number of adjacent damage zones involved in the damage

k : number of a particular longitudinal bulkhead as barrier for transverse penetration in a damage zone, counted from shell towards the centreline. The shell has $k = 0$.

x_1 : distance from the aft terminal of L_s to the aft end of the zone in question

x_2 : distance from the aft terminal of L_s to the forward end of the zone in question

b : mean transverse distance, in metres, measured at right angles to the centreline at the deepest subdivision draught between the shell and an assumed vertical plane extended between the longitudinal limits used in calculating the factor p_i and which is a tangent to, or common with, all or part of the outermost portion of the longitudinal bulkhead under consideration. This vertical plane is to be so orientated that the mean transverse distance to the shell is a maximum, but not more than twice the least distance between the plane and the shell. If the upper part of a longitudinal bulkhead is below the deepest subdivision draught the vertical plane used for determination of b is assumed to extend upwards to the deepest subdivision waterline. In any case, b is not to be taken greater than $B / 2$.

(SOLAS II-1, B-1, 7-1)

C.4.4.2 The factor $p(x_1, x_2)$ is to be calculated according to the following formulae:

Where neither limit of the compartment or group of compartments under consideration coincides with the aft or forward terminals:

$$p(x_1\,;\,x_2) = p_1 = \frac{1}{6} \cdot J^2 \cdot (b_{11} \cdot J + 3 \cdot b_{12}) \qquad \text{for } J \le J_k$$

$$\begin{aligned} p(x_1\,;\,x_2) = p_2 = &-\frac{1}{3} \cdot b_{11} \cdot J_k^3 + \frac{1}{2} \cdot (b_{11} \cdot J + 3 \cdot b_{12}) \cdot J_k^2 + b_{12} \cdot J \cdot J_k \\ &-\frac{1}{3} \cdot b_{21} \cdot \left(J_n^3 - J_k^3\right) + \frac{1}{2} \cdot (b_{21} \cdot J - b_{22}) \cdot \left(J_n^2 - J_k^2\right) + b_{22} \cdot J \cdot (J_n - J_k) \end{aligned} \qquad \text{for } J > J_k$$

Where the aft limit of the compartment or group of compartments under consideration coincides with the aft terminal or the forward limit of the compartment or group of compartments under consideration coincides with the forward terminal:

$$p(x_1\,;\,x_2) = \frac{1}{2}(p_1 + J) \qquad \text{for } J \le J_k$$

$$p(x_1\,;\,x_2) = \frac{1}{2}(p_2 + J) \qquad \text{for } J > J_k$$

Where the compartment or group of compartments considered extends over the entire subdivision length L_S:

$$p(x_1\,;\,x_2) = 1$$

x_1 : distance from the aft terminal of L_s to the aft end of the zone in question

x_2 : distance from the aft terminal of L_s to the forward end of the zone in question

J : non-dimensional damage length, defined as:

$$J = \frac{x_2 - x_1}{L_S}$$

b_{11} : coefficient, defined as:

$$b_{11} = 4 \cdot \frac{1 - p_k}{(J_m - J_k) J_k} - 2 \cdot \frac{p_k}{J_k^2}$$

p_k : cumulative probability at J_{kn}, defined as:

$$p_k = 11/12$$

J_m : normalized length, defined as:

$$J_m = \min\left[J_{max}\ ;\ \frac{\ell_{max}}{L_S}\right] \quad \text{for } L_S \le L^*$$

$$J_m = \frac{J_m^* \cdot L^*}{L_S} \quad \text{for } L_S > L^*$$

J_{max} : overall normalized max damage length, defined as:

$$J_{max} = 10/33$$

ℓ_{max} : maximum absolute damage length $[m]$, defined as:

$$\ell_{max} = 60$$

$J_m{}^*$: normalized length, defined as:

$$J_m^* = \min\left[J_{max}\ ;\ \frac{\ell_{max}}{L^*}\right]$$

L^* : length $[m]$ where normalized distribution ends, defined as:

$$L^* = 260$$

J_k : normalized length, defined as:

$$J_k = \frac{J_m}{2} + \frac{1 + \sqrt{1 + (1 - 2 \cdot p_k) \cdot b_0 \cdot J_m + \frac{1}{4} \cdot b_0^2 \cdot J_m^2}}{b_0} \quad \text{for } L_S \le L^*$$

$$J_k = \frac{J_k^* \cdot L^*}{L_S} \quad \text{for } L_S > L^*$$

b_0 : probability density at $J = 0$, defined as:

$$b_0 = 2 \cdot \left(\frac{p_k}{J_{kn}} - \frac{1 - p_k}{J_{max} - J_{kn}}\right)$$

J_{kn} : knuckle point in the distribution, defined as:

$$J_{kn} = 5/33$$

$J_k{}^*$: normalized length, defined as:

$$J_k^* = \frac{J_m^*}{2} + \frac{1 + \sqrt{1 + (1 - 2 \cdot p_k) \cdot b_0 \cdot J_m^* + \frac{1}{4} \cdot b_0^2 \cdot J_m^{*2}}}{b_0}$$

b_{12} : coefficient, defined as:

$$b_{12} = b_0 \quad \text{for } L_S \le L^*$$

$$b_{12} = 2 \cdot \left(\frac{p_k}{J_k} - \frac{1 - p_k}{J_m - J_k}\right) \quad \text{for } L_S > L^*$$

b_{21} : coefficient, defined as:

$$b_{21} = -2 \cdot \frac{1 - p_k}{\left(J_m - J_k\right)^2}$$

b_{22} : coefficient, defined as:

$$b_{22} = -b_{21} \cdot J_m$$

J_n : normalized length of a compartment or group of compartments, defined as:

$$J_n = \min\left[J \; ; \; J_m\right]$$

(SOLAS II-1, B-1, 7-1.1)

C.4.4.3 The factor $r(x_1, x_2, b)$ is to be determined by the following formula:

$$r\left(x_1 \, , \, x_2 \, , \, b\right) = 1 - \left(1 - C\right) \cdot \left[1 - \frac{G}{p\left(x_1 \, , \, x_2\right)}\right]$$

C : coefficient, defined as:

$$C = 12 \cdot J_b \cdot \left(4 - 45 \cdot J_b\right)$$

J_b : normalized length, defined as:

$$J_b = \frac{b}{15 \cdot \mathbf{B}}$$

G : coefficient, defined as:

$$G = G_1 = \frac{1}{2} \cdot b_{11} \cdot J_b^2 + b_{12} \cdot J_b$$

where the compartment or group of compartments considered extends over the entire sub-division length L_S

$$G = G_2 = -\frac{1}{3} \cdot b_{11} \cdot J_0^3 + \frac{1}{2}\left(b_{11} \cdot J - b_{12}\right) \cdot J_0^2 + b_{12} \cdot J \cdot J_0$$

where neither limit of the compartment or group of compartments under consideration coincides with the aft or forward terminals

$$G = \frac{1}{2}\left(G_2 + G_1 \cdot J\right)$$

where the aft limit of the compartment or group of compartments under consideration coincides with the aft terminal or the forward limit of the compartment or group of compartments under consideration coincides with the forward terminal

b_{11}, b_{12} : coefficient according to C.4.4.2

J_0 : normalized length, defined as:

$$J_0 = \min\left[J \; ; \; J_b\right]$$

J : non-dimensional damage length according to C.4.4.2

(SOLAS II-1, B-1, 7-1.2)

C.4.5 Calculation of factor s_i

C.4.5.1 The factor s_i is to be determined for each case of assumed flooding, involving a compartment or group of compartments, in according to the requirements of C.4.5.2 to C.4.5.5.

(SOLAS II-1, B-1, 7-2.1)

C.4.5.2 The factor s_i, for any damage case at any initial loading conditions d_i, is to be obtained from the following formula:

$$s_i = K \cdot \left[\frac{GZ_{max}}{0.12} \cdot \frac{Range}{16}\right]^{\frac{1}{4}}$$

K : coefficient, defined as:

$K = 1$ if $\theta_e \le 25°$

$K = \sqrt{\frac{30° - \theta_e}{5°}}$ if $25° < \theta_e < 30°$

$K = 0$ if $\theta_e \ge 30°$

θ_e : final equilibrium heel angle [°] in any stage of flooding

GZ_{max} : maximum positive righting lever [m] up to the angle θ_{ϖ}, with:

$GZ_{max} \le 0:12$

θ_{ϖ} : angle [°] where the righting lever becomes negative, or angle at which an opening incapable of being closed weathertight becomes submerged

Range . range [°] of positive righting levers measured from the angle θ_e. The positive range is to be taken up to the angle θ_{ϖ}. Range is not to be taken as more than $16°$

(SOLAS II-1, B-1, 7-2.1.1 and 7-2.3)

C.4.5.3 Unsymmetrical flooding is to be kept to a minimum consistent with the efficient arrangements. Where it is necessary to correct large angles of heel, the means adopted are, where practicable, to be self-acting, but in any case where controls to equalization devices are provided they are to be operable from above the bulkhead deck. These fittings, together with their controls, are to be acceptable to GL. Suitable information concerning the use of equalization devices are to be supplied to the master of the ship.

(SOLAS II-1, B-1, 7-2.5)

C.4.5.4 Tanks and compartments taking part in such equalization are to be fitted with air pipes or equivalent means of sufficient cross-section to ensure that the flow of water into the equalization compartments is not delayed.

(SOLAS II-1, B-1, 7-2.5.1)

C.4.5.5 In all cases, s_i is to be taken as zero in those cases where the final waterline, taking into account sinkage, heel and trim, immerses:

- the lower edge of openings through which progressive flooding may take place and such flooding is not accounted for in the calculation of factor s_i. Such openings are to include air-pipes, ventilators and openings which are closed by means of weathertight doors or hatch covers; but openings closed by means of watertight manhole covers and flush scuttles, small watertight hatch covers, remotely operated sliding watertight doors, sidescuttles of the non-opening type as well as watertight access doors and hatch covers required to be kept closed at sea need not be considered.
- immersion of any vertical escape hatch in the bulkhead deck intended for compliance with the applicable requirements of Section 22, E.11
- any controls intended for the operation of watertight doors, equalization devices, valves on piping or on ventilation ducts intended to maintain the integrity of watertight bulkheads from above the bulkhead deck become inaccessible or inoperable

- immersion of any part of piping or ventilation ducts carried through a watertight boundary that is located within any compartment included in damage cases contributing to the attained index A, if not fitted with watertight means of closure at each boundary.

(SOLAS II-1, B-1, 7-2.5.2, 7-2.5.3 and 7-2.5.5)

C.4.5.6 Where horizontal watertight boundaries are fitted above the waterline under consideration, the s-value calculated for the lower compartment or group of compartments is to be obtained by multiplying the value as determined in C.4.5.2 by the reduction factor v_m according to C.4.5.7, which represents the probability that the spaces above the horizontal subdivision will not be flooded.

(SOLAS II-1, B-1, 7-2.6)

C.4.5.7 The factor v_m is to be obtained from the following formula:

$$v_m = v\left(H_{j,n,m}\ , d\right) - v\left(H_{j,n,m-1}\ , d\right)$$ with $0 \le v_m \le 1$

$v(H , d)$: factor, defined as:

$$v\left(H\ , d\right) = 0.8 \cdot \frac{H-d}{7.8}$$ for $\left(H_m\ , d\right) \le 7.8$ m

$$v\left(H\ , d\right) = 0.8 + 0.2 \cdot \frac{\left(H-d\right)-7.8}{4.7}$$ for $\left(H_m\ , d\right) > 7.8$ m

$$v\left(H_{j,n,m}\ , d\right) = 1.0$$ if H_m coincides with the uppermost watertight boundary of the ship within the range $(x1(j)... x2(j+n-1))$

$$v\left(H_{j,n,0}\ , d\right) = 0$$

$H_{j,\,n,\,m}$: least height [m] above the baseline within the longitudinal range of $x_1(j)...x_2(j+n-1)$ of the m^{th} horizontal boundary which is assumed to limit the vertical extent of flooding for the damaged compartments under consideration

$H_{j,\,n,\,m-1}$: least height [m] above the baseline within the longitudinal range of $x_1(j)...x_2(j+n-1)$ of the $(m-1)^{th}$ horizontal boundary which is assumed to limit the vertical extent of flooding for the damaged compartments under consideration

j : the aft terminal of the damaged compartments under consideration

m : represents each horizontal boundary counted upwards from the waterline under consideration

d : draught in question according to A.3

x_1, x_2 : : represent terminals of the compartment or group of compartments considered in C.4.4.1.

(SOLAS II-1, B-1, 7-2.6.1 and 7-2.6.1.1)

C.4.5.8 In general, each contribution dA to the index A in the case of horizontal subdivisions is obtained from the following formula:

$$dA = p_i \cdot \left[v_1 \cdot s_{min\,1} + \left(v_2 - v_1\right) \cdot s_{min\,2} + ... + \left(1 - v_{m-1}\right) \cdot s_{min\,m} \right]$$

p_i : factor according to C.4.4.1

v_m : v-value calculated in accordance with C.4.5.7

s_{min} : least s-factor for all combinations of damages obtained when the assumed damage extends from the assumed damage height H_m downwards.

(SOLAS II-1, B-1, 7-2.6.2)

C.4.6 Permeability

C.4.6.1 For the purpose of the subdivision and damage stability calculations the permeability of each space or part of a space is to be according to Table 28.3.

Table 28.3 Permeability

Spaces	Permeability
Appropriate to stores	0.60
Occupied by accommodations	0.95
Occupied by machinery	0.85
Void spaces	0.95
Intended for liquids	0 or 0.95[1]

[1] whichever results in the more severe requirements

(SOLAS II-1, B-1, 7-3.1)

C.4.6.2 For the purpose of the subdivision and damage stability calculations the permeability of each cargo compartment is to be according to Table 28.4.

Table 28.4 Permeability of cargo compartments

Spaces	Permeability at draught		
	d_s	d_p	d_L
Dry cargo spaces	0.70	0.80	0.95
Container spaces	0.70	0.80	0.95
Ro-ro spaces	0.90	0.90	0.95
Cargo liquids	0.70	0.80	0.95

(SOLAS II-1, B-1, 7-3.2)

C.4.6.3 Other figures for permeability as according to Table 28.3 and Table 28.4 may be used if substantiated by calculations.

(SOLAS II-1, B-1, 7-3.3)

C.4.7 Stability information

C.4.7.1 The master is to be supplied with such information satisfactory to GL as is necessary to enable him by rapid and simple processes to obtain accurate guidance as to the stability of the ship under varying conditions of service. A copy of the stability information is to be furnished to GL.

(SOLAS II-1, B-1, 5-1.1)

C.4.7.2 The information is to include:

- curves or tables of minimum operational metacentric height $\overline{GM}$ versus draught which assures compliance with the relevant intact and damage stability requirements, alternatively corresponding curves or tables of the maximum allowable vertical centre of gravity KG versus draught, or with the equivalents of either of these curves
- instructions concerning the operation of cross-flooding arrangements
- all other data and aids which might be necessary to maintain the required intact stability and stability after damage

(SOLAS II-1, B-1, 5-1.2)

C.4.7.3 The stability information is to show the influence of various trims in cases where the operational trim range exceeds $\pm 0.5\ \%$ of L_S.

(SOLAS II-1, B-1, 5-1.3)

C.4.7.4 For ships which have to fulfil the stability requirements of C.4, information referred to in C.4.7.2 is determined from considerations related to the subdivision index, in the following manner: Minimum required $\overline{GM}$ (or maximum permissible vertical position of centre of gravity KG) for the three draughts d_S, d_P and d_L are equal to the $\overline{GM}$ (or KG values) of corresponding loading cases used for the calculation of survival factor s_i. For intermediate draughts, values to be used are to be obtained by linear interpolation applied to the $\overline{GM}$ value only between the deepest subdivision draught and the partial subdivision draught and between the partial load line and the light service draught respectively. Intact stability criteria will also to be taken into account by retaining for each draught the maximum among minimum required $\overline{GM}$ values or the minimum of maximum permissible KG values for both criteria. If the subdivision index is calculated for different trims, several required $\overline{GM}$ curves will be established in the same way.

(SOLAS II-1, B-1, 5-1.4)

C.4.7.5 When curves or tables of minimum operational metacentric height $\overline{GM}$ versus draught are not appropriate, the master is to ensure that the operating condition does not deviate from a studied loading condition, or verify by calculation that the stability criteria are satisfied for this loading condition.

(SOLAS II-1, B-1, 5-1.5)

C.5 Damage stability calculation for ships assigned with a reduced freeboard

C.5.1 General

The requirements of this Appendix apply to:

- Type A ships having a length greater than 150 m, and
- Type B-60 ships and Type B-100 ships having a length greater than 100 m

C.5.2 Initial loading condition

C.5.3 The initial condition of loading before flooding is to be determined according to C.5.4 and C.5.5.

(ICLL Annex B, Annex I, III, 27(11))

C.5.4 The ship is loaded to its summer load waterline on an imaginary even keel.

(ICLL Annex B, Annex I, III, (11a))

C.5.5 When calculating the vertical centre of gravity, the following principles apply:

1. Homogeneous cargo is carried.
2. All cargo compartments, except those referred to under 3., but including compartments intended to be partially filled, are to be considered fully loaded except that in the case of fluid cargoes each compartment is to be treated as $98\ \%$ full.
3. If the ship is intended to operate at its summer load waterline with empty compartments, such compartments are to be considered empty provided the height of the centre of gravity so calculated is not less than as calculated under 2.
4. Fifty per cent of the individual total capacity of all tanks and spaces fitted to contain consumable liquids and stores is allowed for. It is to be assumed that for each type of liquid, at least one transverse pair or a single centre line tank has maximum free surface, and the tank or combination of tanks to be taken into account are to be those where the effect of free surfaces is the greatest; in each tank the centre of gravity of the contents is to be taken at the centre of volume of the tank. The remaining tanks are to be assumed either completely empty or completely filled, and the distribution of consumable liquids between these tanks is to be effected so as to obtain the greatest possible height above the keel for the centre of gravity.

5. At an angle of heel of not more than 5 ° in each compartment containing liquids, as prescribed in 2. except that in the case of compartments containing consumable fluids, as prescribed in 4., the maximum free surface effect is to be taken into account. Alternatively, the actual free surface effects may be used, provided the methods of calculation are acceptable to GL.

6. Weights are to be calculated on the basis of Table 28.5

(ICLL Annex B, Annex I, III, 27(11b))

Table 28.5 Specific gravities

Weight item	Specific gravity [t / m^3]
Salt water	1.025
Fresh water	1.000
Fuel oil	0.950
Diesel oil	0.900
Lubrication oil	0.900

C.5.6 Damage assumption

C.5.6.1 Damage dimension

C.5.6.1.1 The principles indicated in C.5.6.1.2 – C.5.6.1.5 regarding the character of the assumed damage apply.

C.5.6.1.2 The vertical extent of damage in all cases is assumed to be from the base line upwards without limit.

(ICLL Annex B, Annex I, III, 27(12a))

C.5.6.1.3 The transverse extent of damage is equal to B / 5 or 11.5 m, whichever is the lesser, measured inboard from the side of the ship perpendicularly to the centre line at the level of the summer load waterline.

(ICLL Annex B, Annex I, III, 27(12b))

C.5.6.1.4 If damage of a lesser extent than specified in C.5.6.1.2 and C.5.6.1.3 results in a more severe condition, such lesser extent is to be assumed.

(ICLL Annex B, Annex I, III, 27(12c))

C.5.6.1.5 Except where otherwise required in C.5.6.4.4, the flooding is to be confined to a single compartment between adjacent transverse bulkheads provided the inner longitudinal boundary of the compartment is not in a position within the transverse extent of assumed damage. Transverse boundary bulkheads of wing tanks, which do not extend over the full breadth of the ship are to be assumed not to be damaged, provided they extend beyond the transverse extent of assumed damage prescribed in C.5.6.1.3.

(ICLL Annex B, Annex I, III, 27(12d))

C.5.6.2 Steps and recesses

C.5.6.2.1 If in a transverse bulkhead there are steps or recesses of not more than 3.0 m in length located within the transverse extent of assumed damage as defined in C.5.6.1.3, such transverse bulkhead may be considered intact and the adjacent compartment may be floodable singly. If, however, within the transverse extent of assumed damage there is a step or recess of more than 3.0 m in length in a transverse bulkhead, the two compartments adjacent to this bulkhead are to be considered as flooded. The step formed by the after peak bulkhead and the after peak tank top is not to be regarded as a step for the purpose of this regulation.

(ICLL Annex B, Annex I, III, 27(12d))

C.5.6.2.2 Where a main transverse bulkhead is located within the transverse extent of assumed damage and is stepped in way of a double bottom or side tank by more than 3.0 m, the double bottom or side tanks adjacent to the stepped portion of the main transverse bulkhead are to be considered as flooded simultaneously. If this side tank has openings into one or several holds, such as grain feeding holes, such hold or holds are to be considered as flooded simultaneously. Similarly, in a ship designed for the carriage of fluid cargoes, if a side tank has openings into adjacent compartments, such adjacent compartments are to be considered as empty and flooded simultaneously. This provision is applicable even where such openings are fitted with closing appliances, except in the case of sluice valves fitted in bulkheads between tanks and where the valves are controlled from the deck. Manhole covers with closely spaced bolts are considered equivalent to the unpierced bulkhead except in the case of openings in topside tanks making the topside tanks common to the holds.

(ICLL Annex B, Annex I, III, 27(12e))

C.5.6.3 Transverse bulkhead spacing

Where the flooding of any two adjacent fore and aft compartments is envisaged, main transverse watertight bulkheads are to be spaced at least $1/3 \cdot L^{2/3}$ or 14.5 m, whichever is the lesser, in order to be considered effective. Where transverse bulkheads are spaced at a lesser distance, one or more of these bulkheads are to be assumed as non-existent in order to achieve the minimum spacing between bulkheads.

(ICLL Annex B, Annex I, III, 27(12f))

C.5.6.4 Damage assumption

C.5.6.4.1 A Type A ship, if over 150 m in length to which a freeboard less than Type B has been assigned, when loaded as considered in C.5.2, is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0.95, consequent upon the damage assumptions specified in C.5.6.1, and is to remain afloat in a satisfactory condition of equilibrium as specified in C.5.6.5 and C.5.6.6. In such a ship, the machinery space is to be treated as a floodable compartment, but with a permeability of 0.85. See Table 28.6

(ICLL Annex B, Annex I, III, 27(3))

C.5.6.4.2 A Type B-60 ship, when loaded as considered in C.5.2, is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0.95, consequent upon the damage assumptions specified in C.5.6.1, and is to remain afloat in a satisfactory condition of equilibrium as specified in C.5.6.5 and C.5.6.6. In such a ship, if over 150 m in length, the machinery space is to be treated as a floodable compartment, but with a permeability of 0.85. See Table 28.6.

(ICLL Annex B, Annex I, III, 27(8d))

C.5.6.4.3 A Type B-100 ship, when loaded as considered in C.5.2, is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0.95, consequent upon the damage assumptions specified in C.5.6.1, and is to remain afloat in a satisfactory condition of equilibrium as specified in C.5.6.5 and C.5.6.6. Any one transverse bulkhead throughout the length of the ship will be assumed to be damaged, such that two adjacent fore and aft compartments are to be flooded simultaneously, except that such damage will not apply to the boundary bulkheads of a machinery space. In such a ship, if over 150 m in length, the machinery space is to be treated as a floodable compartment, but with a permeability of 0.85. See Table 28.6.

(ICLL Annex B, Annex I, III, 27(8d))

Table 28.6 FR-Freeboard reduction

Type	L [m]	Compartment status	Engine room
Type A	> 150 m	1	to be flodded
Type B FR ≤ B-60	≤ 150 m	1	not applicable

Type B FR ≤ B-60	> 150 m	1	to be flodded
Type B B-60 < FR ≤ B-100	≤ 150 m	2	not applicable
Type B B-60 < FR ≤ B-100	> 150 m	2	engine room to be flooded seperately

C.5.6.5 Condition of equilibrium

C.5.6.5.1 The condition of equilibrium after flooding is to be regarded as satisfactory according to C.5.6.5.2 and C.5.6.5.3.

(ICLL Annex B, Annex I, III, 27(13))

C.5.6.5.2 The final waterline after flooding, taking into account sinkage, heel and trim, is below the lower edge of any opening through which progressive downflooding may take place. Such openings are to include air pipes, ventilators and openings which are closed by means of weathertight doors or hatch covers, unless closed by watertight gasketed covers of steel or equivalent material, and may exclude those openings closed by means of manhole covers and flush scuttles, cargo hatch covers, remotely operated sliding watertight doors, and side scuttles of the non-opening type. However, in the case of doors separating a main machinery space from a steering gear compartment, watertight doors may be of a hinged, quick acting type kept closed at sea, whilst not in use, provided also that the lower sill of such doors is above the summer load waterline.

(ICLL Annex B, Annex I, III, 27(13a))

C.5.6.5.3 If pipes, ducts or tunnels are situated within the assumed extent of damage penetration as defined in C.5.6.1.3, arrangements are to be made so that progressive flooding cannot thereby extend to compartments other than those assumed to be floodable in the calculation for each case of damage.

(ICLL Annex B, Annex I, III, 27(13b))

C.5.6.6 Damage stability criteria

C.5.6.6.1 The angle of heel due to unsymmetrical flooding does not exceed $15\,°$. If no part of the deck is immersed, an angle of heel of up to $17\,°$ may be accepted.

(ICLL Annex B, Annex I, III, 27(13c))

C.5.6.6.2 The metacentric height in the flooded condition is positive.

(ICLL Annex B, Annex I, III, 27(13d))

C.5.6.6.3 When any part of the deck outside the compartment assumed flooded in a particular case of damage is immersed, or in any case where the margin of stability in the flooded condition may be considered doubtful, the residual stability is to be investigated. It may be regarded as sufficient if the righting lever curve has a minimum range of $20\,°$ beyond the position of equilibrium with a maximum righting lever of at least 0.1 m within this range. The area under the righting lever curve within this range is to be not less than 0.0175 metre-radians. GL is to give consideration to the potential hazard presented by protected or unprotected openings which may become temporarily immersed within the range of residual stability.

(ICLL Annex B, Annex I, III, 27(13e))

C.5.6.6.4 During intermediate stages of flooding GL will apply the same criteria relevant to the final stage.

Section 29 Work Ships

A General

A.1 Application

Ships intended to get the Notations **SUPPLY VESSEL** or **WORK SHIP** are to be in compliance with this section. Unless specially mentioned in this Section, the requirements of Sections 1 – 22, 27 and 28 apply.

A.2 References

A.2.1 For vessels which are intended to supply and support offshore installations, and vessels intended for offshore towing operations, well stimulation and other offshore services the requirements of the GL Rules for Hull Structures (I-6-1) have to be applied.

A.2.2 For supply vessels which shall transport limited amounts of hazardous and/or noxious liquid substances in bulk, the IMO-Resolution A.673 (16), is to be observed (see also the GL Rules for Chemical Tankers (I-1-7), Section 20.).

B Shell Plating and Frames

B.1 Shell plating

B.1.1 The thickness t of the side shell plating including bilge strake is not to be less than determined by the following formula:

$$t = 7 + 0.04 \cdot \mathbf{L} \quad [\text{mm}]$$

B.1.2 Flat parts of the ship's bottom in the stern area are to be efficiently stiffened.

B.1.3 Where the stern area is subjected to loads due to heavy cargo, sufficient strengthenings are to be provided.

B.2 Frames

The section modulus of main and 'tweendeck frames is to be increased by $25\ \%$ above the values required by Section 9.

C Weather Deck

C.1 The scantlings of the weather deck are to be based on the design load p determined by the following formula:

$$p = p_L + c \cdot p_D \quad [kN/m^2]$$

p_L : load on cargo decks according to Section 4, C.1, with:

$$p_L \geq 15 \text{ kN/m}^2$$

p_D : load on exposed decks according to Section 4, B.1

c : coefficient, defined as:

$c = 1.28 - 0.032 \cdot p_L$ for $p_L < 40 \text{ kN/m}^2$

$c = 0$ for $p_L \geq 40 \text{ kN/m}^2$

C.2 The thickness of deck plating is not to be taken less than 8.0 mm. In areas for the stowage of heavy cargoes the thickness of deck plating is to be suitably increased.

C.3 On deck stowracks for deck cargo are to be fitted which are effectively attached to the deck.

The stowracks are to be designed for a load at an angle of heel of 30 °. Under such loads the following stress values are not to be exceeded:

$\sigma_b \leq \frac{120}{k} \quad [N/mm^2]$ for bending stresses

$\tau \leq \frac{80}{k} \quad [N/mm^2]$ for shear stresses

k : material factor according to Section 2, A.3

C.4 The thickness of the bulwark plating is not to be less than 7.5 mm.

C.5 Air pipes and ventilators are to be fitted in protected positions in order to avoid damage by cargo and to minimize the possibility of flooding of other spaces.

C.6 Due regard is to be given to the arrangement of freeing ports to ensure the most effective drainage of water trapped in pipe deck cargoes. In vessels operating in areas where icing is likely to occur, no shutters are to be fitted in the freeing ports.

D Superstructures and Deckhouses

D.1 The plate thickness of the external boundaries of superstructures and deckhouses is to be increased by 1 mm above the thickness as required in Section 16, E.2.1.

D.2 The section modulus of stiffeners is to be increased by 50 % above the values as required in Section 16, E.2.2.

E Access to Spaces

E.1 Access to the machinery space

E.1.1 Access to the machinery space should, if possible, be arranged within the forecastle.

Any access to the machinery space from the exposed cargo deck is to be provided with two weathertight closures.

E.1.2 Due regard is to be given to the position of the machinery space ventilators. Preferably they should be fitted in a position above the superstructure deck or above an equivalent level.

E.2 Access to spaces below the exposed cargo deck

Access to spaces below the exposed cargo deck is preferably to be from a position within or above the superstructure deck.

F Equipment

Depending on service area and service conditions it may be necessary to choose the anchor chain cable thicker and longer as required in Section 18.

Section 30 Ships for Sheltered Water Service

A General

A.1 Application

Ships intended to get the Notation **RSA (SW)** affixed to their Character of Classification are to be in compliance with this section. Unless specially mentioned in this Section, the requirements of Sections 1 – 22 apply.

B Deck Load

The deck load on weather decks is to be taken as $p_D = 6\ \text{kN} / \text{m}^2$ unless a greater load is required by the Owner.

C Shell Plating

C.1 Minimum thickness

The minimum thickness t_{min} of the shell plating is defined as:

$$t_{min} = 3.5\ \text{mm}$$

C.2 Bottom plating

C.2.1 The thickness t_B of bottom plating is not to be less than determined by the following formula:

$$t_B = 1.3 \cdot \frac{\mathbf{a}}{a_0} \cdot \sqrt{\frac{\mathbf{L} \cdot \mathbf{T}}{\mathbf{H}}} \quad [\text{mm}] \qquad \text{with } t_B \ge t_{min}$$

a_0 : standard frame spacing $[\text{m}]$, defined as:

$$a_0 = \frac{\mathbf{L}}{500} + 0.48$$

t_{min} : minimum thickness according to C.1

C.2.2 For ships having flat bottoms the thickness is to be increased by $0.5\ \text{mm}$.

C.2.3 The thickness within $0.05\ \mathbf{L}$ from the forward and aft end of the length $\mathbf{L}$ may be $1.0\ \text{mm}$ less than the value determined by accoding to C.2.1.

C.2.4 Strengthening of the bottom forward according to Section 6, D is not required.

C.3 Side shell plating and sides of superstructures

C.3.1 The thickness t_S of the side shell plating and sides of superstructures are to be determined by the following formula:

$$t_S = t_B \quad [mm]$$ with $t_S \geq t_{min}$

t_B : thickness of bottom plating according to C.2.1

t_R : reduction of thickness $[mm]$, defined as:

$t_R = 0.5$ within $0.4\,\mathbf{L}$ amidships

$t_R = 0$ within $0.05\,\mathbf{L}$ from the forward and aft end of the length $\mathbf{L}$

t_{min} : minimum thickness according to C.1

C.3.2 The thickness t_S of the side shell plating within $0.4\,\mathbf{L}$ may be 0.5 mm less than the bottom plating according to C.3.1.

D Watertight Bulkheads and Tank Bulkheads

D.1 The scantlings of watertight bulkheads are to be determined according to Section 11.

The plate thickness need not be greater than the midship thickness of the side shell plating at the corresponding frame spacing.

However, the plate thickness is not to be less than:

$t_{min} = 3.5 \quad mm$ for the lowest plate strake

$t_{min} = 3.0 \quad mm$ for the remaining plate strakes

D.2 The scantlings of tank bulkheads and tank walls are to be determined according to Section 12. However, the thickness of plating and stiffener webs is not to be less than:

$$t_{min} = 5 \quad mm$$

E Deck Openings

E.1 Hatchways

E.1.1 The height h_{hc} above deck of hatchway coamings is not to be less than:

$h_{hc} = 600$ mm on decks in Position 1

$h_{hc} = 380$ mm on decks in Position 2

E.1.2 The thickness t_c of coamings is to be determined by the following formulae:

$t_c = 4.5 + \frac{\ell}{6} \quad [mm]$ for longitudinal coamings

$t_c = 2.75 + \frac{b}{2} \quad [mm]$ for transverse coamings

ℓ : length [m] of hatchway

b : breadth [m] of hatchway

E.1.3 For hatch covers the requirements of Section 17, Section 21, O and Section 21, P apply.

E.2 Casings, companionways

E.2.1 The height of machinery and boiler room casings is not to be less than 600 mm, their thickness is not to be less than 3 mm. Coamings are not to be less in height than 350 mm and they are not to be less in thickness than 4 mm.

E.2.2 The height h_{cc} above deck of companionway coamings h_{cc} is not to be less than:

$h_{cc} = 600$ mm on decks in Position 1

$h_{cc} = 380$ mm on decks in Position 2

F Equipment

F.1 The equipment of anchors, chain cables and recommended ropes is to be determined according to Section 18.

F.2 The anchor mass may be 60 % of the value required by Section 18, Table 18.2. The chain diameter may be determined according to the reduced anchor mass.

F.3 For anchor masses of less than 120 kg, the chain cable diameter d of grade K1 steel is to be determined by the following formula:

$$d = 1.15 \cdot \sqrt{P} \quad [\text{mm}]$$

P : anchor mass [kg]

Short link chain cables are to have the same breaking load as stud link chain cables.

F.4 If an anchor mass of less than 80 kg has been determined, only one anchor is required and the chain cable length need not exceed 50 % of the length required by Section 18, Table 18.2.

F.5 The length of the ropes is recommended to be 50 % of the length given in Section 18, Table 18.2 (see also Section 18, F).

Section 31 Barges and Pontoons

A General

A.1 Application

Ships intended to get the Notations **BARGE** or **PONTOON** are to be in compliance with this section. Unless specially mentioned in this Section, the requirements of Sections 1 – 24, and 27 and the stability requirements of the IS Code apply.

A.2 References

For barges having the Notation **HOPPER BARGE** including split hopper barges see Section 32.

A.3 Definitions

Barges

Barges as defined in this Section are unmanned or manned vessels, normally without self-propulsion, sailing in pushed or towed units with following characteristics:

- the ratios of the main dimensions of barges are in a range usual for seagoing ships
- their construction complies with the usual construction of seagoing ships
- their cargo holds are suitable for the carriage of dry or liquid cargo

Pontoons

Pontoons as defined in this Section are unmanned or manned floating units, normally without self-propulsion with following characteristics:

- the ratios of the main dimensions of pontoons deviate from those usual for seagoing ships
- they are designed to usually carry deck load or working equipment (e.g. lifting equipment, rams etc.) and have no holds for the carriage of cargo

Symbols

k : material factor as defined in Section 2, A.2

B Longitudinal Strength

B.1 For barges of 65 m in length and more and for pontoons of 90 m in length and more, the scantlings of the longitudinal hull structure are to be determined on the basis of longitudinal bending moments and shear forces calculations according to Section 5.

B.2 For barges of less than 65 m in length and pontoons of less than 90 m in length, the minimum midship section modulus according to Section 5, E.1.2.2 is to be fulfilled.

B.3 The midship section modulus may be 5 % less than required according to Section 5.

B.4 The scantlings of the primary longitudinal members (strength deck, shell plating, deck longitudinals, bottom and side longitudinals, etc.) may be 5 % less than required according to the respective preceding Sections of this Chapter. The minimum thickness specified in these Sections are, however, to be adhered to.

B.5 Longitudinal strength calculations for the condition "Barge, fully loaded at crane" are required, where barges are intended to be lifted on board ship by means of cranes. The following permissible stresses are to be observed:

$$\sigma_b = \frac{150}{k} \quad [\mathrm{N/mm^2}]$$ for bending stresses

$$\tau = \frac{100}{k} \quad [\mathrm{N/mm^2}]$$ for shear stresses

Special attention is to be paid to the transmission of lifting forces into the barge structure.

B.6 For pontoons carrying lifting equipment, rams etc. or concentrated heavy deck loads, calculation of the stresses in the longitudinal structures under such loads may be required. In such cases the stresses according to B.5 are not to be exceeded.

C Watertight Bulkheads and Tank Bulkheads

C.1 For barges and pontoons, the position of the collision bulkhead is to be determined according to Section 27, B.3.

Where in barges and pontoons, the form and construction of their ends is identical so that there is no determined "fore or aft ship", a collision bulkhead is to be fitted at each end.

C.2 A watertight bulkhead is to be fitted at the aft end of the hold area. In the remaining part of the hull, watertight bulkheads are to be fitted as required for the purpose of watertight subdivision and for transverse strength.

C.3 The scantlings of watertight bulkheads and of tank bulkheads are to be determined according to Section 11 and Section 12 respectively.

Where tanks are intended to be emptied by compressed air, the maximum blowing-out pressure p_v according to Section 4, A.3 is to be inserted in the formulae for determining the pressures p_{T1}.

D Structural Details at the Ends

D.1 Where barges have typical ship-shape fore and aft ends, the scantlings of structural elements are to be determined according to Section 8, B.1.2 and Section 9, B.5 respectively.

The scantlings of fore and aft ends deviating from the normal ship shape are to be determined by applying the formulae analogously such as to obtain equal strength.

D.2 Where barges are always operating with horizontal trim, in consideration of the forebody form, relaxations from the requirements concerning strengthening of the bottom forward may be admitted.

D.3 Where barges have raked ends with flat bottoms, at least one centre girder and one side girder on each side are to be fitted. The girders are to be spaced not more than 4.5 m apart. The girders are to be scarphed into the midship structure. A raked fore-end with a flat bottom is to be strengthened according to Section 6, D.

D.4 In pontoons which are not assigned a Notation for restricted service area or which are assigned the Notation **RSA (200)**, the construction of the fore peak is to be reinforced against wash of the sea by additional longitudinal girders, stringers and web frames. In case of raked bottoms forward, the reinforcements are, if necessary, to be arranged beyond the collision bulkhead. If necessary, both ends are to be reinforced, see also C.1.

E Pushing and Towing Devices, Connecting Elements

Devices for pushing and towing of linked barges as well as the connecting elements required for linking the barges are to be dimensioned for the acting external forces.

The forces are to be specially determined for the respective service range. When determining the scantlings of these devices and elements as well as of the substructures of the barge hull, the following permissible stresses are to be observed:

$$\sigma_b = \frac{100}{k} \quad [\mathrm{N/mm^2}]$$ for bending stresses

$$\tau = \frac{60}{k} \quad [\mathrm{N/mm^2}]$$ for shear stresses

$$\sigma_v = \sqrt{\sigma^2 + 3 \cdot \tau^2} = \frac{120}{k} \quad [\mathrm{N/mm^2}]$$ for equivalent stresses

F Equipment

F.1 Barges and pontoons are to be provided with anchor equipment, designed for quick and safe operation in all foreseeable service conditions. The anchor equipment is to consist of anchors, chain cables and a windlass or other equipment (e.g. cable lifter with a friction band brake, by means of which the anchor can be lifted using an auxiliary drum or a crank handle) for dropping and lifting the anchor and holding the ship at anchor. The requirements of the GL Rules for Machinery Installations (I-1-2), Section 14, D. are to be observed.

F.2 Unless otherwise specified in this Section, the required equipment of anchors and chain cables and the recommended ropes for manned barges and pontoons are to be determined according to Section 18. A stream anchor is not required.

F.3 The equipment numeral Z for determining the equipment according to Section 18, Table 18.2 is to be determined for pontoons carrying lifting equipment, rams etc. by the following formula:

$$\mathrm{Z} = \mathrm{D}^{2/3} + \mathbf{B} \cdot \mathrm{f_b} + \mathrm{f_w}$$

D : displacement of the pontoon $[\mathrm{t}]$ at maximum anticipated draught

$\mathrm{f_b}$: distance $[\mathrm{m}]$ between pontoon deck and waterline

$\mathrm{f_w}$: wind area of the erections on the pontoon deck $[\mathrm{m^2}]$ which are exposed to the wind from forward, including houses and cranes in upright position

F.4 In special cases, upon Owner's request, for unmanned barges and pontoons the number of anchors may be reduced to one and the length of the chain cable to $50\,\%$ of the length required by Section 18, Table 18.2. The notation "special equipment" will be entered into the Certificate and Register in such cases.

F.5 If necessary for a special purpose, for barges and pontoons mentioned under F.4., the anchor mass may be further reduced by up to $20\,\%$. Upon Owner's request the anchor equipment may be dispensed with. The notation "Without anchor equipment" will be entered into the Certificate and Register in such cases.

Additionally the notation "For sea voyages anchor equipment is to be available" will be entered into the Certificate.

F.6 If a wire rope is to be provided instead of a chain cable, the following is to be observed:

F.6.1 The length of the wire rope is to be 1.5 times the required chain cable length. The wire rope is to have the same breaking load as the required chain cable of grade K1.

F.6.2 Between anchor and wire rope, a chain cable is to be fitted the length of which is $12.5\ \mathrm{m}$ or equal to the distance between the anchor in stowed position and the windlass. The smaller value is to be taken.

F.6.3 A winch has to be provided which is to be designed in accordance with the requirements for windlasses (see also the GL Rules for Machinery Installations (I-1-2), Section 14, D.).

F.7 Push barges not operating at the forward or aft end of pushed or towed units need not have any equipment.

F.8 Anchor equipment fitted in addition to that required herein (e.g. for positioning purposes) is not part of Classification.

Section 32 Dredgers and Hopper Barges

A General

A.1 Application

Ships intended to get the Notations **DREDGER**, **SUCTION DREDGER** or **HOPPER BARGE** are to be in compliance with this section. Unless specially mentioned in this Section, the requirements of Sections 1 – 22 and 27 apply.

The requirements of the Guidelines for the Assignment of Reduced Freeboards for Dredgers (DR-68) developed by the Joint Working Group on Dredgers operating at Reduced Freeboards apply.

A.1.1 Dredgers intended for unusual dredging methods and of unusual form will be specially considered.

A.1.2 Dredgers engaged in international service are to comply with the requirements of the **ICLL**.

A.1.3 Dredgers with a restricted service area operating exclusively in national waters are to comply, as far as possible, with the requirements of the **ICLL**. The height of companionway coamings above deck is not to be less than 300 mm.

Note

For dredgers with a restricted service area according to the GL Rules for Classification and Surveys (I-0), Section 2, C.3.1 operating exclusively in national waters, a special "Dredger Freeboard" is assigned by some Administrations.

A.2 Definitions

Dredger

For the purposes of this Section, "dredgers" means all hopper dredgers, hopper barges and similar vessels which may be self-propelled or non-self-propelled and which are designed for all common dredging methods (e.g. bucket dredging, suction dredging, grab dredging etc.)

Split hopper barge

For the purposes of this Section “split hopper barges” means self-unloading hopper barges where the port and starboard portions are hinged at the hopper end bulkheads to facilitate rotation around the longitudinal axis when the bottom opens.

Symbols

a : spacing [m] of stiffeners

h : distance $[m]$ of lower edge of plating or of the load centre of the respective member to the upper edge of overflow

k : material factor as defined in Section 2, A.2

t_K : corrosion addition as defined in Section 3, G

ρ : density $[t / m^3]$ of the spoil, with:

$\rho \geq 1.2$

B Principal Dimensions

B.1 Local structures and deviations from the principal design dimensions associated with the attachment of the dredging gear, are to be ignored when determining the principal dimensions in accordance with Section 1, A.3.

B.2 Where a "Dredger Freeboard" is assigned in accordance with A.1.4, the length $\mathbf{L}$, draught $\mathbf{T}$ and block coefficient C_B according to Section 1, A.3.1 are to be determined for this freeboard.

B.3 The thickness of main structural members which are particularly exposed to abrasion by a mixture of spoil and water, e.g. where special loading and discharge methods are employed, are to be adequately strengthened. Upon approval by GL such members may alternatively be constructed of special abrasion resistant materials.

B.4 On dredgers with closed hopper spaces suitable structural measures are to be taken in order to prevent accumulation of inflammable gas-air mixture in the hopper vapour space. The requirements of the GL Rules for Electrical Installations (I-1-3), are to be observed.

C Longitudinal Strength

C.1 For dredgers of $100\ m$ in length and more, the scantlings of the longitudinal hull structure are to be determined on the basis of longitudinal bending moments and shear forces calculations according to Section 5.

For dredgers classed for particular service areas, dispensations of Section 5 may be approved.

C.2 For dredgers of less than $100\ m$ in length, the minimum midship section modulus according to Section 5, E.1.2.2 is to be fulfilled.

For dredgers of less than $100\ m$ in length longitudinal strength calculations may be required in special instances.

C.3 Irrespective of their length, for split hopper barges longitudinal strength calculations are to be carried out for the unloading condition according to J.

D Shell Plating

D.1 The thickness of the bottom shell plating of dredgers intended or expected to operate while aground, is to be increased by $20\ \%$ above the value required in Section 6.

D.2 Where hopper doors are fitted on the vessel's centreline or where there is a centreline well for dredging gear (bucket ladder, suction tube etc.), a plate strake is to be fitted on each side of the well or door opening the width of which is not less than 50 % of the rule width of the flat keel and the thickness not less than that of the rule flat keel.

The same applies where the centreline box keel is located above the base line at such a distance that it cannot serve as a docking keel.

In this case, the bottom plating of the box keel need not be thicker than the rule bottom shell plating.

D.3 The flat bottom plating of raked ends which deviate from common ship forms, is to have a thickness not less than that of the rule bottom shell plating within 0.4 **L** amidships, up to 500 mm above the maximum load waterline. The shell plating above that is to have a thickness not less than the rule side shell plating.

The reinforcements required in D.1 are also to be observed.

D.4 The corners of hopper door openings and of dredging gear wells generally are to comply with Section 7, B.3.1. The design of structural details and welded connections in this area is to be carried out with particular care.

E Bottom Structure

E.1 Single bottom transversely framed

E.1.1 Abreast of hoppers and centreline dredging wells, the floors are to be dimensioned in accordance with Section 8, B.1.2.1 where ℓ_{min} may be taken as 0.4 **B**. The depth h of floor is not to be less than determined by the following formula:

$$h = 45 \cdot \mathbf{B} - 45 \quad [\mathrm{mm}] \qquad \text{with } h \geq h_{min} = 180 \text{ mm}$$

E.1.2 Floors, longitudinal girders etc. below dredging machinery and pump seats are to be adequately designed for the additional loads.

E.1.3 Where floors are additionally stressed by the reactions of the pressure required for closing the hopper doors, their section modulus and their depth are to be increased accordingly.

E.1.4 Where the unsupported span of floors exceeds 3 m, one side girder in accordance with Section 8, B.2.2.2 is to be fitted.

E.1.5 Floors in line with the hopper lower cross members fitted between hopper doors are to be connected with the hopper side wall by brackets of approx. equal legs. The brackets are to be flanged or fitted with face bars and are to extend to the upper edge of the cross members.

E.1.6 Floors of dredgers intended or expected to operate while aground are to be stiffened by vertical buckling stiffeners the spacing of which is such as to guarantee that the reference degree of slenderness λ for the plate field is less than 1.0. For λ see Section 3, D.2.

E.2 Single bottom longitudinally framed

E.2.1 The spacing of bottom transverses generally is not to exceed 3.6 m. Section modulus W and web cross sectional area A are not to be less than determined by the following formulae:

$$W = c \cdot e \cdot \ell^2 \cdot p \cdot k \quad [\mathrm{cm}^3]$$

$$A_W = k \cdot 0.061 \cdot e \cdot \ell \cdot p \quad [\mathrm{cm}^2]$$

c : coefficient, defined as:

$$c = 0.9 - 0.002 \cdot \mathbf{L} \qquad \text{for } \mathbf{L} \leq 100 \text{ m}$$

$c = 0.7$ for $\mathbf{L} > 100$ m

e : spacing [m] of bottom transverses between each other or from bulkheads

ℓ : unsupported span [m], any longitudinal girders not considered

p : load [kN/m^2] on single bottom, defined as:

$p = \max[p_B\ ;\ p_{T1}]$ as applicable

p_B : load on the ship's bottom according to Section 4, B.5

p_{T1} : load for filled tanks according to Section 4, D.1.1

The web depth is not to be less than the depth of floors according to E.1.1.

E.2.2 The bottom longitudinals are to be determined in accordance with Section 9, C.

E.2.3 Where the centreline box keel cannot serve as a docking keel, brackets are to be fitted on either side of the centre girder or at the longitudinal bulkheads of dredging wells and of hopper spaces. The brackets are to extend to the adjacent longitudinals and longitudinal stiffeners. Where the spacing of bottom transverses is less than 2.5 m, one bracket is to be fitted, for greater spacings, two brackets are to be fitted.

The thickness of the brackets is at least to be equal to the web thickness of the adjacent bottom transverses. The brackets are to be flanged or fitted with face bars.

E.2.4 Where longitudinal bulkheads and the side shell are framed transversely, the brackets according to E.2.3 are to be fitted at every frame and are to extend to the bilge.

E.2.5 The bottom transverses are to be stiffened by means of flat bar stiffeners at every longitudinal.

E.2.6 The bottom structure of dredgers intended or expected to operate while aground is to be dimensioned as follows:

E.2.6.1 The spacing of the bottom transverses according to E.2.1 is not to exceed 1.8 m. The webs are to be stiffened according to E.1.6.

E.2.6.2 The section modulus of the bottom longitudinals according to E.2.2 is to be increased by 50 %.

E.2.7 The requirements of E.1.2 to E.1.5 are to be applied analogously.

E.3 Double bottom

E.3.1 Double bottoms need not be fitted adjacent to the hopper spaces.

E.3.2 In addition to the requirements of Section 8, C.5, plate floors are to be fitted in way of hopper spaces intended to be unloaded by means of grabs.

E.3.3 Where brackets are fitted in accordance with Section 8, C.6.3, the requirements according to E.2.3 and E.2.4 are to be observed where applicable.

E.3.4 The bottom structure of dredgers intended or expected to operate while aground is to be strengthened in accordance with Section 8, C.1. Where applicable, E.2.6 is to be applied analogously.

F Hopper and Well Construction

F.1 The scantlings of the boundaries of hopper spaces and wells are to be determined as follows.

F.1.1 Plating

The plate thickness t is not to be less than determined by the following formula:

$$t = 1.21 \cdot a \cdot \sqrt{p_{HW} \cdot k} + t_K \quad [mm] \qquad \text{with } t \geq t_{min}$$

t_{min} : minimum plate thickness as defined in Section 24, G

p_{HW} : load $[kN/m^2]$ on hopper and well constructions, defined as:

$$p_{HW} = 10 \cdot \rho \cdot h \cdot (1 + a_v)$$

a_v : acceleration addition according to Section 4, A.3

F.1.2 Stiffeners

The section muduli W_x and W_y of stiffeners are not to be less than determined by the following formulae:

$$W_y = 0.6 \cdot a \cdot \ell^2 \cdot p_{HW} \cdot k \quad [cm^3]$$ for transverse stiffeners of longitudinal bulkheads and stiffeners of transverse bulkheads

$$W_x = \max\left[W_y \; ; \; W_\ell\right]$$ for longitudinal stiffeners

W_ℓ : section modulus according to Section 9, C.3

ℓ : unsupported span $[m]$ of stiffener

p_{HW} : load on hopper and well constructions according to F.1.1

F.1.3 The strength is not to be less than that of the ship's sides. Particular attention is to be paid to adequate scarphing at the ends of longitudinal bulkheads of hopper spaces and wells.

The top and bottom strakes of the longitudinal bulkheads are to be extended through the end bulkheads, or else scarphing brackets are to be fitted in line with the walls in conjunction with strengthenings at deck and bottom.

Where the length of wells does not exceed 0.1 **L** and where the wells and/or ends of hopper spaces are located beyond 0.6 **L** amidships, special scarphing is, in general, not required.

F.2 In hoppers fitted with hopper doors, transverse girders are to be fitted between the doors the spacing of which is normally not to exceed 3.6 m.

F.3 The depth of the transverse girders spaced in accordance with F.2 is not to be less than 2.5 times the depth of floors according to Section 8, B.1.2.1. The web plate thickness is not to be less than the thickness of the side shell plating. The top and bottom edges of the transverse girders are to be fitted with face plates. The thickness of the face plates is to be at least 50 % greater than the rules web thickness.

Where the transverse girders are constructed as watertight box girders, the scantlings are not to be less than required according to F.1. At the upper edge, a plate strengthened by at least 50 % is to be fitted.

F.4 Vertical stiffeners spaced not more than 900 mm apart are to be fitted at the transverse girders.

F.5 The transverse bulkheads at the ends of the hoppers are to extend from board to board.

F.6 Regardless of whether the longitudinal or the transverse framing system is adopted, web frames in accordance with Section 12, B.2 are to be fitted in line with the transverse girders according to F.2.

The density of the spoil is to be considered when determining the scantlings.

F.7 Strong beams are to be fitted transversely at deck level in line with the web frames according to F.6. The scantlings are to be determined, for the actual loads complying with an equivalent stress of

$\sigma_v = 150 / k$ [N / mm²]. The maximum reactions of hydraulically operated rams for hopper door operation are, for instance, to be taken as actual load.

The strong beams are to be supported by means of pillars according to Section 10, C at the box keel, if fitted.

F.8 On bucket dredgers, the ladder wells are to be isolated by transverse and longitudinal cofferdams at the bottom, of such size as to prevent the adjacent compartments from being flooded in case of any damage to the shell by dredging equipment and dredged objects. The cofferdams are to be accessible.

G Box Keel

G.1 The scantlings are to be determined as follows:

G.1.1 Plating

G.1.1.1 Bottom plating

- Where the box keel can serve as a docking keel, the requirements for flat plate keels according to Section 6, B.4 apply.
- Where the box keel cannot serve as a docking keel (see also D.2), the requirements for bottom plating according to Section 6, B.1 and Section 6, B.2 apply.

G.1.1.2 Remaining plating

- Outside the hopper space, the requirements for bottom plating according to Section 6, B.1 and Section 6, B.2 apply.
- Within the hopper space the requirements for hopper space plating according to F.1.1 apply. The thickness of the upper portion particularly subjected to damage is to be increased by not less than 50 %.

G.1.2 Floors

The requirements according to E.1 and E.2 respectively apply.

G.1.3 Stiffeners

The requirements for hopper stiffeners according to F.1.2 apply.

G.2 Strong webs of plate floors are to be fitted within the box keel in line with the web frames according to F.6 to ensure continuity of strength across the vessel.

G.3 With regard to adequate scarphing at the ends of a box keel, F.1.3 is to be observed.

H Stern Frame and Rudder

H.1 Where dredgers with stern wells for bucket ladders and suction tubes are fitted with two rudders, the stern frame scantlings are to be determined in accordance with Section 13, C.1.

H.2 Where dredgers are fitted with auxiliary propulsion and their speed does not exceed 5 kn at maximum draught, the value $v_0 = 7$ kn is to be taken for determining the rudder stock diameter.

I Bulwark, Overflow Arrangements

I.1 Bulwarks are not to be fitted in way of hoppers where the hopper weirs discharge onto the deck instead of into enclosed overflow trunks. Even where overflow trunks are provided, it is recommended not to fit bulwarks.

Where, however, bulwarks are fitted, freeing ports are to be provided throughout their length which should be of sufficient width to permit undisturbed overboard discharge of any spoil spilling out of the hopper in the event of rolling.

I.2 Dredgers without restricted service range notation are to be fitted with overflow trunks on either side suitably arranged and of sufficient size to permit safe overboard discharge of excess water during dredging operations.

The construction is to be such as not to require cut-outs at the upper edge of the sheer strake. Where overflow trunks are carried through the wing compartments, they are to be arranged such as to pierce the sheer strake at an adequate distance from the deck.

I.3 Dredgers with restricted service area notation may have overflow arrangements which permit discharge of excess water during dredging operations onto the deck.

J Split Hopper Barges

J.1 For the unloading condition of split hopper barges, the bending moments and the stresses related to the inertia axis y'-y' and z'-z' are to be determined by the following formula:

$$\sigma = \frac{M_y' \cdot e_z'}{I_y'} + \frac{M_z' \cdot e_y'}{I_z'} \quad [\mathrm{N/mm^2}]$$

M_y', M_z' : bending moments related to the inertia axis y'-y' and z'-z' respectively

I_y', I_z' : moments of inertia of the cross section shown in Fig. 32.1 related to the respective inertia axis

e_y', e_z' : the greater distance from the neutral axis y'-y' and z'-z' respectively

The still water bending moments are to be determined for the most unfavourable distribution of cargo and consumables. The vertical still water and wave bending moments are to be determined in accordance with Section 5, D.1.

The horizontal still water bending moment within the hold length is to be calculated on the basis of the horizontal pressure difference between external hydrostatic pressure and cargo pressure in still water.

The following portion of the dynamic moment is to be added to the horizontal still water moment:

$$M_z = \frac{\ell^2}{24} \cdot \left[10 \cdot \mathbf{T}^2 - \frac{(10 \cdot \mathbf{T} - p_0)^2}{10 \cdot \mathbf{T} + p_0} \cdot \mathbf{T} \right]$$

p_0 : basic external dynamic load according to Section 4, A.3, with $f = 1$

ℓ : spacing [m] between hinges

The stresses are not to exceed the following values:

$$\sigma_{sw} = 15 \cdot \frac{\sqrt{\mathbf{L}}}{k} \le \frac{150}{k} \quad [\mathrm{N/mm^2}]$$ for still water condition

$$\sigma_p = \frac{175}{k} \quad [\mathrm{N/mm^2}]$$ for seaway condition

GL may approve reduced vertical wave bending moments if the vessel is intended for dumping within specified service ranges or in sheltered waters only.

J.2 The bearing seating and all other members of the hinge are to be so designed as not to exceed the following permissible stress values:

$$\sigma_p = \frac{90}{k} \quad [N/mm^2]$$ for bending stresses

$$\tau = \frac{55}{k} \quad [N/mm^2]$$ for shear stresses

The loads indicated in Fig. 32.1 are to be applied correspondingly.

p'_S, p'_B : water pressure $[kN/m^2]$ at draught $\mathbf{T}$

p'_L : cargo pressure $[kN/m^2]$, defined as:

$$p'_L = 10 \cdot \rho \cdot h$$

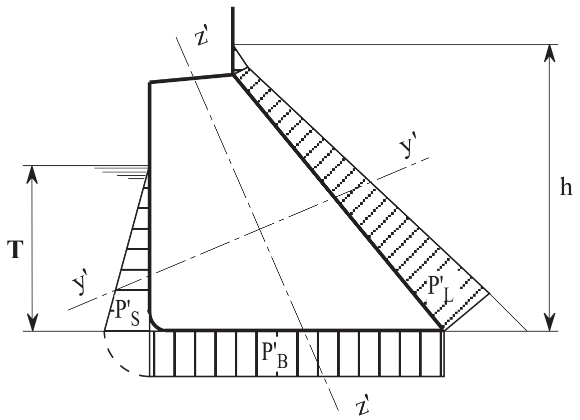


Fig. 32.1 Static loads on a self-unloading barge, loaded

K Equipment

K.1 The equipment of anchors, chain cables, wires and recommended ropes for dredgers for unrestricted service area having normal ship shape of the underwater part of the hull is to be determined in accordance with Section 18.

When calculating the Equipment Number according to Section 18, B bucket ladders and gallows need not to be included. For dredgers of unusual design of the underwater part of the hull, the determination of the equipment requires special consideration.

The equipment for dredgers for restricted service area is to be determined as for vessels with the Notations **RSA (20)** and/or **RSA (50)**.

For dredgers with the Notation **RSA (SW)**, see Section 30, F.

(IACS UR A1.3.2)

K.2 The equipment of non-self-propelled dredgers is to be determined as for barges, in accordance with Section 31, F.

K.3 Considering rapid wear and tear, it is recommended to strengthen the anchor chain cables which are also employed for positioning of the vessel during dredging operations.

K.4 Dredgers intended to work in conjunction with other vessels are to be fitted with strong fenders.

Section 33 Strengthening against Collisions

A General

A.1 Application

A.1.1 Ships, the side structures of which are specially strengthened in order to resist collision impacts, may be assigned the Notations **COLL**, with index numbers 1 – 6, e.g. **COLL2**, affixed to the Character of Classification.

The index numbers 1 to 6 result from the ratio of the critical deformation energies calculated for both the strengthened side structure and the single hulled ship without any strengthening and without any ice strengthening. The critical deformation energy is defined as that amount of energy when exceeded in case of a collision, a critical situation is expected to occur.

The index numbers will be assigned according to Table 33.1 on the basis of the characteristic ratio C* of the critical deformation energies as defined in B.8.

In special cases **COLL**-notations higher than **COLL6** may be assigned if justified by the design and construction of the ship.

Table 33.1 COLL-Notation

C*	COLL-Notation
2	**COLL1**
3	**COLL2**
4	**COLL3**
6	**COLL4**
10	**COLL5**
20	**COLL6**

A.1.2 A **COLL**-notation will be assigned under the provision that the ship has a sufficient residual longitudinal strength in the damaged condition.

A.1.3 For general cargo ships and tankers, the notation **COLL** with a corresponding restrictive note in the Certificate may also be granted for individual compartments only.

A.1.4 If wing tanks are arranged in the area to be investigated which are to be assumed as being flooded whereas the longitudinal bulkheads remain intact, sufficient floatability and stability in such damaged conditions is to be proved. Longitudinal bulkheads fitted outside the envelope curve of the penetration depths determined for the collision cases as defined in B.5 are to be considered intact.

A.1.5 The definition of the critical situation is entered into the Certificate.

A.2 Definitions

Critical situation

Critical situations are, for instance:

- tearing up of cargo tanks with subsequent leakage of, e.g., oil, chemicals, etc.
- water ingress into dry cargo holds during carriage of particularly valuable or dangerous cargo
- tearing up of fuel oil tanks with subsequent leakage of fuel oil

Symbols

$T_{1,max}$: design draught of the striking ship

$T_{1,min}$: ballast draught of the striking ship

$T_{2,max}$: design draught of the struck ship

$T_{2,min}$: ballast draught of the struck ship

v_{cr} : critical speed [kn] is the speed of the striking ship. If this speed is exceeded, a critical situation may be expected.

B Calculation of the Deformation Energy

B.1 The deformation energy is to be calculated by procedures recognized by GL.

In case of high-energy-collisions the Minorsky method may be accepted, if the bow and side structures are found suitable.

Note

On request, the required calculation of deformation energy are carried out by GL.

B.2 For low-energy-collisions, the Minorsky method does not give sufficiently precise results. Analyses of these collisions are to be based on assumptions which take into account the ultimate loads of the bow and side structures hitting each other in the area calculated, and their interactions.

The computations of ultimate loads are to be based on the assumption of an ideal elastic plastic material behaviour. The calculated limit stress R_{UC} to be assumed is the mean value of the yield strength and the tensile strength, as follows:

$$R_{UC} = \frac{1}{2} \cdot \left(R_{eH} + R_m\right)$$

The elongation at fracture of the shell is to be taken as 5 %.

B.3 Ships of approximately equal displacement and with design draughts approximately identical to that of the struck ship to be examined are to be assumed as striking ships. 2 bow shapes are to be investigated:

- bow shape 1: raked bow contour without bow bulb
- bow shape 2: raked bow contour with bow bulb

Extremely fully shaped bow configurations are not to be used for the computations.

B.4 The computations are to be carried out for a rectangular, central impact, making the following assumptions:

- the bow of the striking ship encounters the side of the struck ship vertically
- the struck ship is floating freely and has no speed

B.5 Various collision cases are to be investigated for bow shapes 1 and 2, for the strengthened and non-strengthened side structure, covering the design and ballast draughts of the ships involved in the collision.

The essential factor for determining the deformation energy are the draught differentials ΔT of the ships involved in the collision, see Fig. 33.1.

The following draught differentials are to be considered:

$$\Delta T_1 = T_{2,max} - \frac{3 \cdot T_{1,min} + T_{1,max}}{4}$$ for collision case 1

$$\Delta T_2 = T_{2,max} - \frac{T_{1,min} + 3 \cdot T_{1,max}}{4}$$ for collision case 2

$$\Delta T_3 = \frac{T_{2,min} + 3 \cdot T_{2,max}}{4} - T_{1,max}$$ for collision case 3

$$\Delta T_4 = \frac{3 \cdot T_{2,min} + T_{2,max}}{4} - T_{1,max}$$ for collision case 4

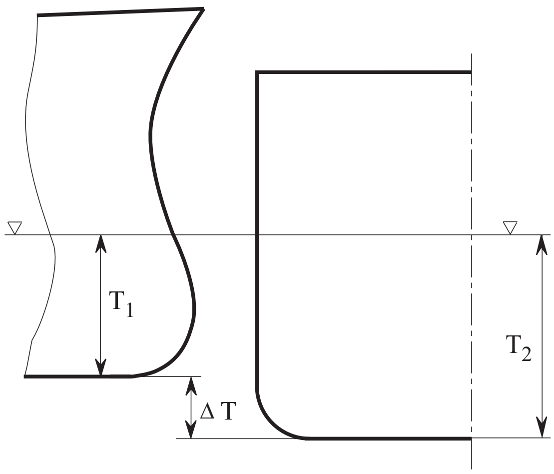


Fig. 33.1 Draught differential ΔT of ships involved in a collision

B.6 Based on the deformation energies calculated for the strengthened and non-strengthened side structure for the different collision cases defined in B.5 above, the mean values of the critical deformation energies are to be evaluated by means of weighting factors.

B.7 The mean critical deformation energies are to be determined for the collision cases 1 to 4 and for both bow shapes by the following formulae:

For bow shape 1:

$$\overline{E_{01}} = \frac{1}{8} \cdot \left[E_{01,1} + 3 \cdot E_{01,2} + 3 \cdot E_{01,3} + E_{01,4} \right]$$

$$\overline{E_{11}} = \frac{1}{8} \cdot \left[E_{11,1} + 3 \cdot E_{11,2} + 3 \cdot E_{11,3} + E_{11,4} \right]$$

For bow shape 2:

$$\overline{E_{02}} = \frac{1}{8} \cdot \left[E_{02,1} + 3 \cdot E_{02,2} + 3 \cdot E_{02,3} + E_{02,4} \right]$$

$$\overline{E_{22}} = \frac{1}{8} \cdot \left[E_{22,1} + 3 \cdot E_{22,2} + 3 \cdot E_{22,3} + E_{22,4} \right]$$

$E_{01,i}$: deformation energy for the unstrengthened ship, bow shape 1, collision case i, $i = 1 - 4$

$E_{11,i}$: deformation energy for the strengthened ship, bow shape 1, collision case i, $i = 1 - 4$

$E_{02,i}$: deformation energy for the unstrengthened ship, bow shape 2, collision case i, $i = 1 - 4$

$E_{22,i}$: deformation energy for the strengthened ship, bow shape 2, collision case i, $i = 1 - 4$

B.8 The ratios of the mean critical deformation energies are to be determined by the following formulae:

$$\overline{C_1} = \frac{\overline{E_{11}}}{\overline{E_{01}}} \quad \text{for bow shape 1}$$

$$\overline{C_2} = \frac{\overline{E_{22}}}{\overline{E_{02}}} \quad \text{for bow shape 2}$$

The characteristic ratio for the ship is the mean value resulting from the two weighted ratios $\overline{C_1}$ and $\overline{C_2}$ in accordance with the following formula:

$$C^* = \frac{1}{2} \cdot \left(\overline{C_1} + \overline{C_2}\right)$$

B.9 The index defined in A.1.1 will be fixed on the basis of the characteristic ratio C^* and the corresponding minimum value for the critical speed $v^*_{cr,min}$ according to C.3.

C Computation of the Critical Speed

C.1 The critical collision speed v_{cr} is to be determined by the following formula:

$$v_{cr} = 2.75 \cdot \sqrt{\frac{E_{cr}}{m_2} \cdot \left[1 + \frac{m_2}{m_1}\right]} \quad [kn]$$

E_{cr} : deformation energy $[kJ]$, once the critical speed has been reached

m_1 : mass $[t]$ of the striking ship, incl. $10\ \%$ hydrodynamical added mass

m_2 : mass $[t]$ of the struck ship, incl. $40\ \%$ hydrodynamical added mass

C.2 When calculating the critical speeds for the collision cases in accordance with B.5, the draughts according to Table 33.2 are to be assumed.

Table 33.2 Draughts of collision cases

Draughts	Collision case 1	Collision case 2	Collision case 3	Collision case 4
T_1	$\frac{3 \cdot T_{1,min} + T_{1,max}}{4}$	$\frac{T_{1,min} + 3 \cdot T_{1,max}}{4}$	$T_{1,max}$	$T_{1,max}$
T_2	$T_{2,max}$	$T_{2,max}$	$\frac{3 \cdot T_{2,max} + T_{2,min}}{4}$	$\frac{T_{2,max} + 3 \cdot T_{2,min}}{4}$

C.3 For the assignment of a **COLL**-notation, in addition to the characteristic ratio C^* according to Table 33.1, the minimum values for the mean critical speed v^*_{cr} as given in Table 33.2 have to be met.

Table 33.3 Minimum values for the mean critical speed v_{cr}^*

COLL-Notation	$V_{cr}^*{}_{,min}$ [kn]
COLL1	1.0
COLL2	1.5
COLL3	2.5
COLL4	4.0
COLL5	5.5
COLL6	7.0
v_{cr}^* see also 4.	

C.4 The mean critical speed $\overline{v_{cr}}$ results from the weighted critical speeds of collision conditions $1-4$ for both bow shapes, in accordance with the following formulae:

$$\overline{v_{cr1}} = \frac{1}{8} \cdot \left[v_{1cr1} + 3 \cdot v_{1cr2} + 3 \cdot v_{1cr3} + v_{1cr4} \right]$$ for bow shape 1

$$\overline{v_{cr2}} = \frac{1}{8} \cdot \left[v_{2cr1} + 3 \cdot v_{2cr2} + 3 \cdot v_{2cr3} + v_{2cr4} \right]$$ for bow shape 2

v_{1cri} : critical speed for bow shape 1, collision case i, $i = 1-4$

v_{2cri} : critical speed for bow shape 2, collision case i, $i = 1-4$

The critical speed characteristic for the ship results as mean value from the two weighted speeds $\overline{v_{cr1}}$ and $\overline{v_{cr2}}$, in accordance with the following formula:

$$v_{cr}^* = \frac{1}{2} \cdot \left(\overline{v_{cr1}} + \overline{v_{cr2}} \right) \quad [\mathrm{kn}]$$

Section 34 Special Requirements for In-Water Surveys

A General

A.1 Application

Ships intended to get the Notation **IW** (In-Water Survey) are to comply with the requirements of this Section enabling them to undergo in-water surveys.

B Special Arrangements for In-Water Surveys

B.1 The ship's underwater body is to be protected against corrosion by an appropriate corrosion protection system which consists of a coating system in combination with cathodic protection.

The coating system without antifouling is to have a minimum dry film thickness of 250 μm, is to be compatible with the cathodic protection and is to be appropriate for mechanical underwater cleaning. The cathodic protection system has to be designed for at least one docking period.

B.2 The ship's underwater body is to be provided with fixed markings and unmistakable inscriptions such as to enable the diver to determine his respective position. For this purpose the corners of tanks in the cargo hold area, and the location of the centre line and transverse bulkheads every 3 – 4 m, are to be marked.

B.3 Sea chests are to be capable of being cleaned under water, where necessary. To this effect the closures of the strainers are to be designed such that they may be opened and closed in an operationally safe manner by the diver. In general the clearance of access openings should not be less than 900 x 600 mm.

B.4 Clearances of the rudder and shaft bearings are to be capable of being measured with the ship afloat in every trim condition. If within the scope of scheduled periodical surveys drydockings are to be performed at intervals of 2.5 years or less, the installation of special underwater measuring equipment may be dispensed with. Inspection ports are to have a clearance of at least 200 mm under consideration of accessibility of measuring points.

B.5 It must be possible to present proof of tightness of the stern tube, in case of oil lubrication, by static pressure loading.

B.6 Liners of rudder stocks and pintles as well as bushes in rudders are to be marked such that the diver will notice any shifting or turning.

B.7 For other equipment, such as bow thrusters the requirements will be specially considered taking into account their design.

B.8 In case of existing ships below 100 m in length the requirements specified in paragraphs B.3, B.4 and B.6 may be dispensed with.

C Documents and Trials

C.1 Prior to commissioning of the vessel the equipment is to be surveyed and subjected to trials in accordance with the Surveyor's.

C.2 A remark in the IW Manual should be implemented that the diver or repair company have to provide relevant tools to grant a safe working condition on the vessel similar to docking condition.

C.3 For facilitating the performance of surveys, detailed instructions are to be kept aboard as guidance for the diver. These instructions should include details, such as:

- complete colour photograph documentation of all essential details of the underwater body, starting from the newbuilding condition
- plan of the underwater body showing the location and kind of inscriptions applied
- instructions regarding measures to be taken by the crew for ensuring risk-free diving operations
- description of measuring method for determination of rudder and shaft clearances
- additional instructions, where required, depending on structural characteristics
- coating specification, cathodic protection, see Section 35, H.2

Section 35 Corrosion Protection

A General Instructions

A.1 Application

A.1.1 This section deals with the corrosion protection measures specified by GL with respect to seagoing steel ships. Details of the documentation necessary for setting up the corrosion protection system are laid down herein (planning, execution, supervision).

A.1.2 Corrosion protection for other types of ship as well as other kinds of material, e.g. aluminium, is to be agreed separately in consultation with GL.

A.1.3 Requirements with respect to the contractors executing the work and the quality control are subject to the conditions laid down in the GL Rules for Classification and Surveys (I-0), Section 1, N .

A.1.4 Any restrictions which may be in force concerning the applicability of certain corrosion protection systems for special types of vessels (e.g. tankers and bulk carriers) have to be observed. GL is to be consulted when clarifying such issues.

Note

In addition, GL also offers advisory services for general questions concerning corrosion and corrosion protection.

A.2 References

Supplementary to this Section, the GL Guidelines for Corrosion Protection and Coating Systems (VI-10-2) contain further comments and recommendations for the selection of suitable corrosion protection systems, as well as their professional planning and execution.

B Shop Primers

B.1 General

B.1.1 Shop primers are used to provide protection for the steel parts during storage, transport and work processes in the manufacturing company until such time as further surface preparation is carried out and the subsequent coatings for corrosion protection are applied.

B.1.2 Customarily, coatings with a thickness of $15\ \mu m$ to $20\ \mu m$ are applied. Under normal yard conditions, this should provide corrosion protection for a period of approximately 6 months.

B.1.3 The coating is to be of good resistance to withstand the mechanical stresses incurred during the subsequent working of the steel material in the shipbuilding process.

B.1.4 Flame-cutting and welding speed are not to be unduly impaired. It is to be ensured that welding with all welding processes customary in the building of ships can be conducted without impermissibly impairing the quality of the weld seam, see the GL Rules for General Requirements, Proof of Qualifications, Approvals (II-3-1), Section 6.

B.1.5 Due to the possible strain to the system presented by cathodic protection, seawater and chemicals, only shop primers are to be used which are alkali-fast and not hydrolyzable.

B.1.6 The suitability and compatibility of shop primer for use in the corrosion protection system is to be guaranteed by the manufacturer of the coating materials.

B.2 Approvals

Only those overweldable shop primers may be used for which the Society has issued a confirmation of acceptability based on a porosity test in accordance with the GL Rules for General Requirements, Proof of Qualifications, Approvals (II-3-1), Section 6.

For the use of shop primers in combination with coating systems in ballast water tanks the GL Rules for Coating of Ballast Water Tanks (VI-10-1) are further to be observed.

C Hollow Spaces

C.1 General

Hollow spaces, such as those in closed box girders, tube supports and the like, which can either be shown to be air tight or are accepted as such from normal shipbuilding experience, need not have their internal surfaces protected. During assembling, however, such hollow spaces have to be kept clean and dry.

D Combination of Materials

D.1 General

D.1.1 Preventive measures are to be taken to avoid contact corrosion associated with the combination of dissimilar metals with different potentials in an electrolyte solution, such as seawater.

D.1.2 In addition to selecting appropriate materials, steps such as suitable insulation, an effective coating and the application of cathodic protection can be taken in order to prevent contact corrosion.

E Fitting-Out and Berthing Periods

E.1 General

E.1.1 For protection against corrosion arising from stray currents, such as those occurring due to inappropriate direct-current electrical supply to the ship for welding or mains lighting, as well as those arising from direct-current supplies to other facilities (e.g. shore cranes) and neighbouring ships, the provision of (even additional) cathodic protection by means of sacrificial anodes is not suitable.

E.1.2 Steps are to be taken to prevent the formation of stray currents, and suitable electric drainage is to be provided.

E.1.3 Particularly in the event of lengthy fitting-out periods, welding rectifiers are to be so arranged that stray currents can be eliminated.

F Corrosion Protection of Ballast Water Tanks

The GL Rules for Coating of Ballast Water Tanks (VI-10-1) are applicable.

G Corrosion Protection of Cargo Holds

G.1 General

G.1.1 On bulk carriers, all internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of the cargo holds, excluding the flat tank top areas and the hopper tanks sloping plating approximately 300 mm below the side shell frame and brackets, are to have an effective protective coating (epoxy coating, or equivalent), applied in accordance with the manufacturer's recommendation. In the selection of coating due consideration is to be given in consultation with the owner to the intended cargo and conditions expected in service.

G.1.2 The coating used is to be approved by the manufacturer for application in cargo holds.

G.1.3 The coating manufacturer's instructions with regard to surface preparation as well as application conditions and processing are to be adhered to.

G.1.4 The minimum thickness of the coating is to be 250 µm in the complete area defined under G.1.1.

G.2 Documentation

G.2.1 The coating plan is to be submitted for examination.

A description of the work necessary for setting up a coating system and the coating materials to be used is to be contained in the coating plan.

G.2.2 A coating report is to be compiled in such a way that details of all the work processes executed, including the surface preparation as well as the coating materials used, are recorded.

G.2.3 This documentation is to be compiled by the coating manufacturer and/or the contractor executing the work and/or the yard. An inspection plan is to be agreed to between the parties involved. The papers pertaining to the documentation are to be signed by these parties. On completion of the coating system, the signed papers constituting the documentation are to be handed to the surveyor for approval.

H Corrosion Protection of the Underwater Hull

H.1 General

H.1.1 Vessels intended to be assigned the Class Notation **IW** (In-Water Survey) are to provide a suitable corrosion protection system for the underwater hull, consisting of coating and cathodic protection.

H.1.2 Coatings based on epoxy, polyurethane and polyvinyl chloride are considered suitable.

H.1.3 The coating manufacturer's instructions with regard to surface preparation as well as application conditions and processing are to be observed.

H.1.4 The coating system, without antifouling, is to have a minimum dry film thickness of 250 µm on the complete surface, is to be compatible to cathodic protection in accordance with recognized standards, and is to be suitable for being cleaned underwater by mechanical means.

H.1.5 The cathodic protection can be provided by means of sacrificial anodes, or by impressed current systems. Under normal conditions for steel, a protection current density of at least $10\ \mathrm{mA} / \mathrm{m}^2$ is to be ensured.

H.1.6 In the case of impressed current systems, overprotection due to inadequately low potential is tobe avoided. A screen (dielectric shield) is to be provided in the immediate vicinity of the impressed-current anodes.

H.1.7 Cathodic protection by means of sacrificial anodes is to be designed for one dry-docking period.

H.1.8 For further instructions refer to the GL Guidelines for Corrosion Protection and Coating Systems (VI-10-2), Section 7.

H.1.9 In the case of other materials, such as aluminium for instance, special conditions are to be agreed with GL.

H.2 Documentation

H.2.1 The coating plan and the design data for the cathodic protection are to be submitted for examination.

H.2.2 In the case of impressed current systems, the following details are to also be submitted:

- arrangement of the ICCP system
- location and constructional integration (e.g. by a cofferdam) of the anodes in the vessel's shell
- descriptions of how all appendages, e.g. rudder, propeller and shafts, are incorporated into the cathodic protection
- electrical supply and electrical distribution system
- design of the dielectric shield

H.2.3 The work processes involved in setting up the coating system as well as the coating materials to be used are to be laid down in the coating plan.

H.2.4 A coating protocol is to be compiled in such a way that details of all the work processes executed, including the surface preparation as well as the coating materials used, are recorded.

H.2.5 This documentation is to be compiled by the coating manufacturer and/or the contractor executing the work and/or the yard. An inspection plan is to be agreed to between the parties involved. The papers pertaining to the documentation have to be signed by these parties. On completion of the coating system, the signed papers constituting the documentation are to be handed to the surveyor for approval.

H.2.6 In the case of impressed current systems, the functionability of the cathodic corrosion protection is to be tested during sea trials. The values obtained for the protection current and voltage are to be recorded.

I Corrosion Protection of Crude Oil Cargo Tanks

The GL Rules for Corrosion Protection of Crude Oil Cargo Tanks (VI-10-3) are applicable.

Annex A Load Line Marks

A Load Line Marks of GL

On application, GL calculates freeboards in accordance with the Regulations of the **ICLL** and with any existing relevant special national regulations, and subsequently issue the necessary Load Line Certificates wherever authorized to do so by the competent Authorities of the individual States.

Applications for issuance of Load Line Certificates or for surveys for freeboard admeasurements are to be made to either GL Head Office or to a Society's Inspection Office. Freeboards will then be calculated on the basis of the survey reports and admeasurements by the Head Office.

Subject to the "Gesetz über die Aufgaben des Bundes auf dem Gebiet der Seeschiffahrt", in the Federal Republic of Germany, BG Verkehr Dienststelle Schiffssicherheit (BG Verkehr Ship Safety Division) and GL are entrusted with the enforcement of the **ICLL**. GL carry out on behalf of BG Verkehr Dienststelle Schiffssicherheit (BG Verkehr Ship Safety Division) the survey for determining the freeboard, the calculation and checking of the freeboard and, where necessary, periodical surveys.

The load lines assigned by GL are marked amidships in accordance with the Load Line Certificate as per sketches on page A-2. Where no other mark is stipulated by national regulations of the competent Authorities, (e.g. in the Federal Republic of Germany SB-GL) there will be added the letters G–L. The ring, lines and letters are to be painted white or yellow on a dark ground or else, black on a light ground. They are to be permanently attached on both sides of the ship.

(The sketch is drawn for the starboard side.)

With ships having a restricted service range, depending on the respective range, the seasonal marks, such as for Tropical and Winter North Atlantic trade, are omitted.

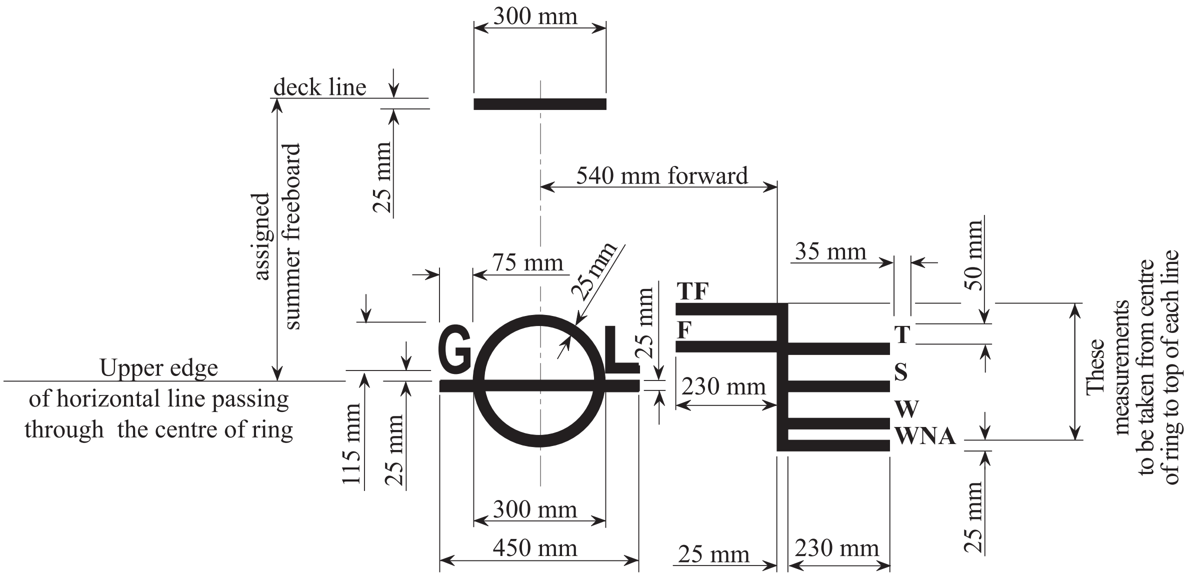
Ships of more than $100\ \mathrm{m}$ in length do not get a WNA mark. For these ships WNA is equal to W, and the LWNA- mark is affixed at the same level as the W-mark.

On German ships, the letter "L" in the timber mark is replaced by the letter "H".

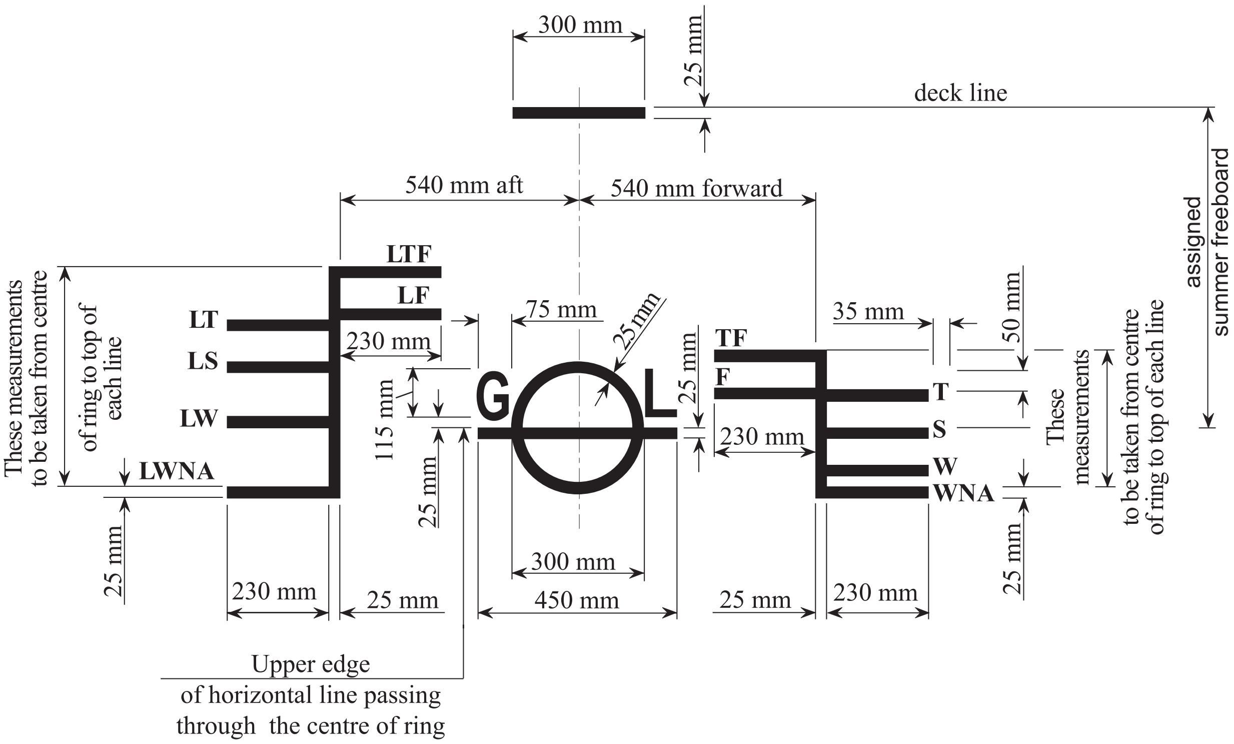
The **ICLL** entered into force on 21st July, 1968.

For ships the keels of which were laid prior to 21st July, 1968, the conditions for assignment of the freeboard subject to the Load Line Convention 1930 continue to be valid as a part of the **ICLL**. Where the advantages of the **ICLL** are intended to be utilized, the respective ships are to comply with all requirements of that Convention as for a new ship.

Load Line Marking for Seagoing Ships



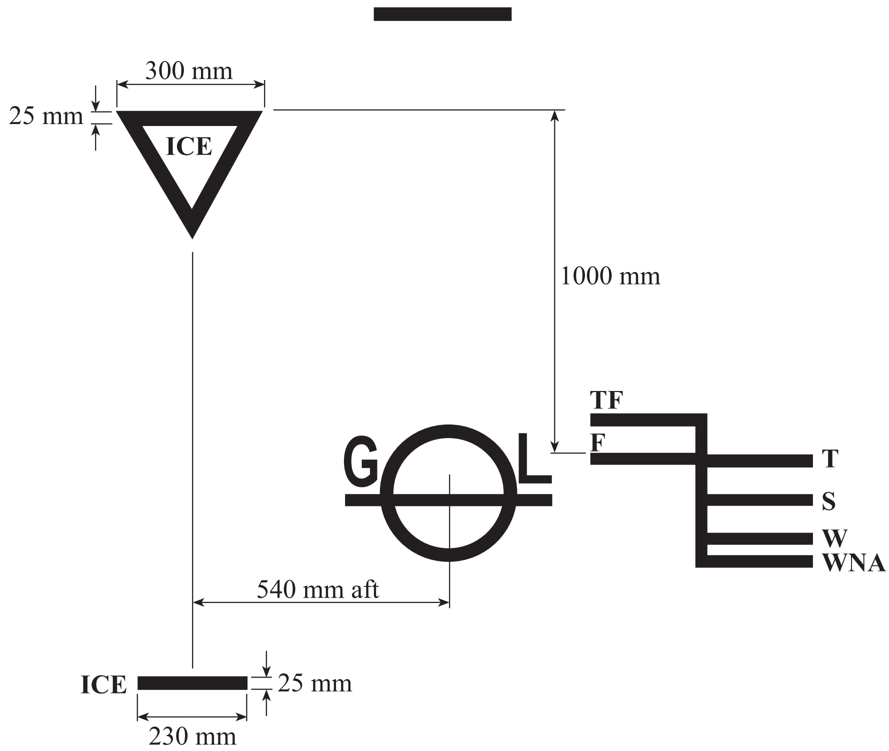
Load Line Marking for Seagoing Ships Carrying Timber Deck Cargoes



Annex B Ice Class Draught Marking

A Ice Class Draught Marking of GL

According to Section 15, A.2.2, ship's sides are to be provided with a warning triangle and with an ice class draught mark at the maximum permissible ice class draught amidships if the summer load line in fresh water is located at a higher level than the UIWL. The purpose of the warning triangle is to provide information on the draught limitation of the vessel when it is sailing in ice for masters of icebreakers and for inspection personnel in ports.



Note

1. *The ice class draught mark is to be centred 540 mm abaft the centre of the load line ring or 540 mm abaft the vertical line of the timber load line mark, if applicable (the sketch is shown for the starboard side). The ice class draught mark is to be 230 mm in length and 25 mm in width.*
2. *The upper edge of the warning triangle is to be centred above the ice class draught mark, 1 000 mm higher than the Summer Load Line in freshwater but in no case higher than the deck line. The sides of the warning triangle are to be 300 mm in length and 25 mm in width.*
3. *The dimensions of all lettering are to be the same as those used in the load line mark (see Annex A).*
4. *The warning triangle, ice class draught mark and lettering are to be cut out of 5 - 8 mm plate and then welded to the ship's side. They are to be painted in a red or yellow reflecting colour in order to be plainly visible even in ice conditions.*