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Rules for Classification and Construction

Part 1 Seagoing Ships

RULES FOR HULL

Volume II

July 2025 Edition

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Amendments to the preceding Edition are marked by red color and expanded text. However, if the changes involve the whole section or sub-section normally only the title will be in red colour.

Foreword

This Rules for Hull (Pt.1, Vol.II) July 2025 Edition replaces the Rules for Hull (Pt.1, Vol.II) January 2025 edition. In this edition, new amendments are introduced which are mainly derived from IACS publications, and inputs from BKI Branch Offices and Technical Division BKI Head Office.

The summary of the previous edition and amendments, including the implementation date, is indicated in the table below:

No.	Edition/ Rule Change Notice (RCN)	Effective Date	Link
1	January Edition 2025	1st January 2025	
2	July Edition 2024	1st July 2024	
3	Consolidated Edition 2024	-	
4	RCN No.4, October 2023	1st January 2024	
5	RCN No.3, April 2023	1st July 2023	
6	RCN No.2, October 2022	1st January 2023	
7	RCN No.1, April 2022	1st July 2022	
8	Consolidated Edition 2022	-	
9	RCN No.2 Nov 2021	1st January 2022	
10	RCN No.1 May 2021	1st July 2021	
11	Consolidated Edition 2021	-	
12	RCN No.1 July 2020	1st August 2020	
13	Edition 2019	1st July 2019	
14	Corr. No.2 Oct. 2018	-	
15	Corr. No.1 Aug 2018	-	
16	RCN No.1 Oct 2018	1st July 2019	
17	Edition 2018	1st July 2018	

A summary of amendments to the previous edition, including the implementation date for each section, is presented in **Table 1 - Amendments incorporated in This Notice**.

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Further queries or comments concerning this Rules are welcomed through communication to BKI Head Office.

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Rules Amendment Notice

Table 1 - Amendments incorporated in This Notice

These amendments will come into force on 1st July 2025, except stated otherwise as indicated in the Table

Paragraph	Title/Subject	Status/Remark
Section 3 Design Priciples		
F.1.1.2	-	A new footnote has been added to clarify the application of buckling strength calculation requirements in accordance with IACS UR S35 Corr.1
Section 11 Watertight Bulkheads		
A.	**General**	
A.2.1.6	-	New and clarified requirements for valves piercing the collision bulkhead have been added for ships constructed before 1 January 2024, in accordance with SOLAS II-1, 12.6.1 (Res.MSC.474(102))
A.2.1.7	-	New requirements have been added for valves piercing collision bulkheads on ships constructed on or after January 1, 2024, in accordance with SOLAS II-1, Regulation 12.6.2 (Res. MSC.474(102)). Additionally, a new note has been added in line with IACS UI SC306
A.2.1.8	-	Renumbered sub-section and redactional amendments
A.2.1.9 - A.2.1.11	-	Renumbered sub-section
A.2.2.2	-	A new note has been added for reference interpretation requirements of SOLAS Regulation II-1/12.11, in accordance with IACS UI SC93
Section 21 Hull Outfit		
D.	**Side Scuttles, Windows and Skylights**	
D.1	**General**	
D.1.12	-	A new note has been added for reference interpretation requirements of the ILLC Annex I, Chapter I, Regulation 23, in accordance with IACS UI LL62 Corr.2
Section 22 Structural Fire Protection		
B.	**Passenger Ships Carrying more than 36 Passenger**	
B.1.2.3	-	Added a new note for reference interpretation requirements of the SOLAS Regulation II-2/11.4.1 according to IACS UI SC302 New

Paragraph	Title/Subject	Status/Remark
C.	**Passenger Ships carrying not more than 36 Passengers**	
C.1.2.3	-	Added a new note for reference interpretation requirements of the SOLAS Regulation II-2/11.4.1 according to IACS UI SC302 New
E.	**Cargo Ships of 500 GT and over**	
E.1.2.3	-	Added a new note for reference interpretation requirements of the SOLAS Regulation II-2/11.4.1 according to IACS UI SC302 New
E.11.10	-	Added new reference for the interpretation requirements of SOLAS regulation II-2/13.4.2.2 and 13.4.2.3 according to UI SC 269 Rev.2
Section 27 Tugs		
F.	**Weathertight Integrity and Stability**	
F.2	**Stability**	
F.2.2	-	To clarify the applicability date of the stability criteria for towing operations, based on input from classification activities
H.	**Additional Requirements for Active Escort Tugs**	
H.7	**Stability of Active Escort Tugs**	To clarify the applicability date of the stability criteria for vessels engaged in escort operations, based on input from classification activities
Section 36 Subdivision and Stability		
Table 36.1	**Intact Stability Criteria**	To clarify the implementation of the requirements with respect to the two referenced documents
Table 36.2	**Damage Stability Criteria**	To clarify the implementation of the requirements with respect to the two referenced documents

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Section 1 General, Definitions

Note:

Passages printed in italics generally contain notes and recommendations which are not part of the Classification Rules.

A. Validity, Equivalence

1. The Rules apply to seagoing steel ships classed **A100** whose breadth to depth ratio is within the range common for seagoing ships and the depth **H** of which is not less than:

- **L**/16 for Unlimited Range of Service and **P** (Restricted Ocean Service)
- **L**/18 for **L** (Coasting Service)
- **L**/19 for **T** (Sheltered Water Service).

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

Hull structural design and construction of Bulk Carriers with **L** ≥ 90 m and Double Hull Oil Tankers with **L** ≥ 150 m and operated in unlimited service range, which is contracted for construction on or after 1^{st} July 2015 to be carried out on the basis Rules for Bulk Carriers and Oil Tankers (Pt.1, Vol. XVII). Those ships refers as CSR ships.

For Bulk Carriers and Double Hull Oil Tanker not covered in above paragraph the requirements in Section 23 and Section 24 are applicable respectively.

Hull structural design and construction of container ships or ships dedicated primary to carry their load in containers with **L** ≥ 90 m and operated in unlimited service range, which is contracted for construction on or after 1^{st} July 2016, is to be carried out on the basis of Rules for Container Ships (Pt.1, Vol.XVIII).

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 BKI's requirements for the respective class.

3. For Character of Classification and Class Notations see Guidance for Class Notations (Pt.0, Vol.B).

4. For ships suitable for in-water surveys which will be assigned the Class Notation "**IW**", the requirements of Section 37, are to be observed.

5. Class Notations for ships subject to extended strength analysis

RSD Cargo hold analysis carried out by the designer and examined by BKI

RSD (F25) Fatigue assessment based on $6{,}25 \cdot 10^7$ load cycles of North Atlantic Spectrum carried out by BKI

RSD (F30) Fatigue assessment based on $7{,}5 \cdot 10^7$ load cycles of North Atlantic Spectrum carried out by BKI

Fatigue assessment will be carried out for all hatch opening corners on all deck levels, longitudinal frames and butt welds of deck plating and side shell plating (where applicable).

RSD (ACM) Additional corrosion margin according to detailed listings in the technical file. Analysis carried out by BKI.

RSD (gFE) Global finite element analysis carried out in accordance with the Guidelines for Global Strength Analysis of Container Ships.

B. Restricted Service Ranges

1. For determining the scantlings of the longitudinal and transverse structures of ships intended to operate within one of the restricted service ranges **P**, **L** and **T**, the dynamic loads may be reduced as specified in Section 4 and Section 5.

2. For the definition of the restricted service ranges **P**, **L** and **T** see Guidance for Class Notation (Pt.0, Vol.B) Table 1.4.

3. For ships navigating in Indonesian waters only, Peraturan Kapal Domestik (Bag. 8, Vol. 1) applies.

C. Ships for Special Services

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.

D. Accessibility

1. All parts of the hull are to be accessible for survey and maintenance.

2. For safe access to the cargo area of oil tanker and bulk carriers see Section 21, O.

E. Stability

1. General

Ships with a length of 24 m and above will 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. BKI reserves the right to deviate there from, if required for special reasons, taking into account the ships' size and type. The level of intact stability for ships of all sizes in any case should not be less than that provided by IMO-Resolution 267(85) (Adoption of the international code on intact stability, 2008 (2008 IS Code)), unless special operational restrictions reflected in the Class Notation render this possible.

Part B Chapter 2.3 of the above Resolution has only to be taken into account on special advice of the competent Administration.

However, a preliminary stability information booklet approved by the Society in lieu of a final stability information booklet may be provided on-board for a specific period.

Special attention is to be paid to the effect of free surfaces of liquids in partly filled tanks. Special precautions shall be taken for tanks which, due to the geometry, may have excessive free surface moments, thus jeopardizing the initial stability of the vessel, e.g. tanks in the double bottom reaching from side to side. In general such tanks shall be avoided.

Evidence of approval by the competent Administration concerned may be accepted for the purpose of classification.

The above provisions do not affect any intact stability requirements resulting from damage stability calculations, e.g. for ships to which the symbol ⊠ is assigned.

2. Ships with proven damage stability

2.1 where the National Administration and all applicable mandatory international IMO's and ILO Conventions and Codes (including Amendments) require the ship to meet the damage stability requirements, the calculation of the damage stability to be proven.[1)]

2.2 The damage stability requirements will be specified in Section 36, C and Ships with proven damage stability will be assigned the symbol ☐.

2.3 The Administration of a State may, if it considers that the sheltered nature and conditions of the voyage are such as to render the application of any specific damage stability requirements unreasonable or unnecessary, exempt from those requirements individual ships or classes of ships entitled to fly the flag of that State which, in the course of their voyage, do not proceed more than 20 miles from the nearest land.

(SOLAS Ch.II-1, Regulation 1.4)

3. Anti-heeling devices

3.1 If tanks are used as anti-heeling devices, effects of maximum possible tank moments on intact stability are to be checked. A respective proof has to be carried out for several draughts and taking maximum allowable centres of gravity resulting from the stability limit curve as a basis. In general the heeling angle shall not be more than 10°.

3.2 If the ship heels more than 10°, Rules for Machinery Installations (Pt.1, Vol.III) Sec.11.P.1.4 has to be observed.

3.3 All devices have to comply with Rules for Electrical Installations (Pt.1, Vol.IV) Sec.7.G.

F. *Note for Vibrations and Noise*

1. *Mechanical Vibration*

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. Besides 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 minimization of possible cavitation. In the shaping of the bow of large ships, consideration is to be given to limit excitation from the seaway. As far as critical excitation loads cannot be eliminated, appropriate measures are to be taken on the basis of theoretical investigations at an early design stage. Fatigue considerations must be included. For machinery, equipment and other installations the vibration level is to be kept below that specified in Rules for Machinery Installations, (Pt.1, Vol. III) Sec.1, as far as possible.

The evaluation of vibrations in living and working areas should follow ISO 6954 except where other national or international rules or standards are mandatory. It is recommended to use the lower transition curve

[1)] For ships operation in domestic water Indonesia only, damage stability requirements to be complying with regulation of National Administration, if required.

of ISO 6954 as a criteria for design, whereas the upper curve may serve for the evaluation of vibration measurements.

2. *Noise*

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

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

G. Documents for Approval

1. To ensure conformity with the Rules the following drawings and documents are to be submitted in form of soft copy (electronic)[2)] showing the arrangement and the scantlings of structural members:

1.1 Midship section

The cross sectional plans (midship section, other typical sections) shall contain all necessary data on the scantlings of the longitudinal and transverse hull structure as well as details of anchor and mooring equipment.

1.2 Longitudinal Section

The plan of longitudinal sections shall contain all necessary details on the scantlings of the longitudinal and transverse hull structure and on the location of the watertight bulkheads and the deck supporting structures arrangement of superstructures and deck houses, as well as supporting structures of cargo masts, cranes etc.

1.3 Decks

Plans of the decks showing the scantlings of the deck structures, length and breadth of cargo hatches, openings above the engine and boiler room, and other deck openings. On each deck, it has to be stated which deck load caused by cargo is to be assumed in determining the scantlings of the decks and their supports. Furthermore, details on possible loads caused by forklift trucks and containers are to be stated.

1.4 Shell

Drawings of shell expansion, containing full details on the location and size of the openings and drawings of the sea chests.

1.5 Ice strengthening

The drawings listed in 1.1.-1.4, 1.6, 1.7 and 1.9 shall contain all necessary details on ice strengthening.

1.6 Bulkhead

Drawings of the transverse, longitudinal and wash bulkheads and of all tank boundaries, with details on densities of liquids, heights of overflow pipes and set pressures of the pressure-vacuum relief valves (if any).

1.7 Bottom Structure

1.7.1 Drawings of single and double bottom showing the arrangement of the transverse and longitudinal girders as well as the water and oil tight subdivision of the double bottom. For bulk and ore carriers, data are to be stated on the maximum load on the inner bottom.

1.7.2 Docking plan and docking calculation according to Section 8, E are to be submitted for information.

1.8 Engine and boiler seatings

Drawings of the engine and boiler seatings, the bottom structure under the seatings and of the transverse structures in the engine room, with details on fastening of the engine foundation plate to the seating, as well as type and output of engine.

[2)] A detailed list of documents to be submitted for approval will be provided upon request.

1.9 Stem and stern post, and rudder

Drawings of stem and stern post, of rudder, including rudder support. The rudder drawings shall contain details on the ship's speed, the bearing materials to be employed, and the ice strengthening.

Drawings of propeller brackets and shaft exits.

1.10 Hatchways

Drawings of hatchway construction and hatch covers.

The drawings of the hatch coamings shall contain all details, e.g., bearing pads with all relevant details regarding loads and substructures, including cut-outs for the fitting of equipment such as stoppers, securing devices etc. necessary for the operation of hatches.

The structural arrangement of stays and stiffeners and of their substructures shall be shown.

1.11 Longitudinal strength

All necessary documents for the calculation of bending moments, shear forces and, if necessary, torsional moments. This includes the mass distribution for the envisaged loading conditions and the distribution of section moduli and moduli of inertia over the ship's length.

Loading Guidance Information according to Section 5, A.4

1.12 Materials

The drawings mentioned in 1.1 - 1.10 and 1.15 shall contain details on the hull materials (e.g. hull structural steel grades, standards, material numbers). Where higher tensile steels or materials other than ordinary hull structural steels are used, drawings for possible repairs have to be placed on board.

1.13 Weld joints

The drawings listed in items 1.1 - 1.10 and 1.15 shall contain details on the welded joints e.g. weld shapes and dimensions and weld quality. For the relevant data for manufacturing and testing of welded joints see Rules for Welding (Pt.1, Vol.VI).

1.14 Lashing and stowage devices

Drawings containing details on stowage and lashing of cargo (e.g. containers, car decks).

In the drawings the location of the connections and the appropriate substructures at the ship shall be shown in detail.

1.15 Substructures

Drawings of substructures below steering gears, windlasses and chain stoppers as well as masts and boat davits together with details on loads to be transmitted into structural elements.

1.16 Closing condition

For assessing the closing condition, details on closing appliances of all openings on the open deck in position 1 and 2 according to ICLL and in the shell, i.e. hatchways, cargo ports, doors, windows and side scuttles, ventilators, erection openings, manholes, sanitary discharges and scuppers.

1.17 Watertight Integrity

Drawings containing the main- and local internal subdivision of the hull. Information about arrangements of watertight longitudinal- and transverse bulkheads, cargo hold entrances, air ventilation ducts, down and cross flooding arrangements.

1.18 Intact stability

Analysis of an inclining experiment to be performed upon completion of newbuildings and/or conversions, for determining the light ship data.

Intact stability particulars containing all information required for calculation of stability in different loading conditions. For initial assignment of class to new buildings preliminary particulars will be acceptable.

1.19 Damage stability

Damage stability particulars containing all information required for establishing unequivocal condition for intact stability.

A damage stability particulars containing all information required for establishing unequivocal condition for intact stability.

1.20 Structural fire protection

In addition to the fire control and safety plan also drawings of the arrangement of divisions (insulation, A-, B- and C-divisions) including information regarding BKI-approval number.

Drawings of air conditioning and ventilation plants.

1.21 Special particulars for examination

1.21.1 For ships constructed for special purposes, drawings and particulars of those parts, examination of which is necessary for judging the vessel's strength and safety.

1.21.2 Additional documents and drawings may be required, if deemed necessary.

1.21.3 Any deviations from approved drawings are subject to approval before work is commenced.

H. Definitions

1. General

Unless otherwise mentioned, the dimensions according to 2. and 3. are to be inserted [m] into the formulae stated in the following Sections.

2. Principal dimension

2.1 Length L

The rule length **L** is the distance in metres, measured on the waterline at the scantling draught from the foreside of stem to the after side of the rudder post, or the centre of the rudder stock if there is no rudder post. **L** is not to be less than 96% and need not be greater than 97% of the extreme length on the waterline at the scantling draught.

In ships without rudder stock (e.g. ships fitted with azimuth thrusters), the Rule length **L** is to be taken equal to 97% of the extreme length on the waterline at the scantling draught.

In ships with unusual stern and bow arrangement, the rule length **L** will be specially considered

(IACS UR S2.1)

2.2 Length L_c

The length $\mathbf{L_c}$ is to be taken as 96% of the total length on a waterline at 85% of the least moulded depth $\mathbf{H_c}$ 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. In ships designed with a rake of keel the waterline on which this length is measured shall be parallel to the designed waterline.

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.

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

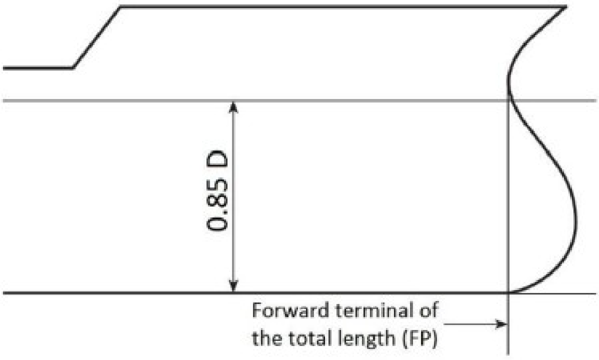

Fig. 1.1 Length L_C in case of concave stem contour

2.3 Length L*

The length **L*** of the ship is the length measured between perpendiculars taken at the extremities of the deepest subdivision load line.

(SOLAS 74 Chapter II-1, Reg. 2)

2.4 Subdivision length L_S

Reference is made to the definition in SOLAS 74, Chapter II–1, Reg. 25 – 2.2.1 and in Section 36, B.2.

2.5 Forward perpendicular FP.

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

2.6 Breadth B

The breadth **B** is the greatest moulded breadth of the ship.

2.7 Depth H

The depth **H** is the vertical distance, at the middle of the length **L**, from the base line[3)] to top of the deck beam at side on the uppermost continuous deck.

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

2.8 Depth 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 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, Ch. I, 3(5))

[3)] Base line is a line passing through top of the keel plate at the middle of the length L.

2.9 Draught T

Draught, **T**, is the summer draught, in metres, measured from top of keel, or a greater value if such a value has been specified as 'scantling draught'. Both of the draughts are to be indicated on the midship plan, irrespective of whether or not they are of the same value.

3. Frame spacing a

The frame spacing **a** will be measured from moulding edge to moulding edge of frame.

4. Block coefficient C_B

Moulded block coefficient, corresponding to the waterline at the scantling draught $\mathbf{T_{SC}}$, based on rule length **L** and moulded breadth $\mathbf{B_{SC}}$.

$$\mathbf{C_B} = \frac{\text{moulded displacement } [\mathrm{m}^3] \text{ at scantling draught } \mathbf{T_{SC}}}{\mathbf{L} \cdot \mathbf{B_{SC}} \cdot \mathbf{T_{SC}}}$$

Where;

$\mathbf{B_{SC}}$ = Greatest moulded breadth [m], measured amidships at the scantling draught, $\mathbf{T_{SC}}$.

$\mathbf{T_{SC}}$ = Scantling draught [m], at which the strength requirements for the scantlings of the ship are met and represents the full load condition. The scantling draught is to be not less than that corresponding to the assigned freeboard.

(IACS UR S2.2)

5. 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 $\mathbf{v}_0$ is to be determined on the basis of maximum pitch.

6. Definition of decks

6.1 Bulkhead deck

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

6.2 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, Ch., 3(9))

6.3 Strength deck

Strength deck is the deck or the parts of a deck which form the upper flange of the effective longitudinal structure.

6.4 Weather deck

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

6.5 Lower decks

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

6.6 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 2^{nd}, 3^{rd} superstructure deck, etc.

6.7 Positions of Hatchways, doorways and ventilators

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

Pos. 1

- on exposed freeboard decks,
- on raised quarter decks,
- on the first exposed superstructure deck above the freeboard deck within the forward quarter of $\mathbf{L_C}$.

Pos. 2

- on exposed superstructure decks aft of the forward quarter of $\mathbf{L_C}$ 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)

7. 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.

7.1 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.

7.2 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)).

J. International Conventions and Codes

Where reference made of International Conventions and Codes these are defined as follows:

1. ICLL

International Convention on Load Lines, 1966 as amended.

2. MARPOL 73/78

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

3. SOLAS 74

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

4. IBC-Code

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

5. IGC-Code

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

For interpretation of International Convention and Code, Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) is to be observed.

K. 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 millimeters 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 shall be shown in the drawings.

The section moduli of profiles usual in the trade and including the effective width according to Section 3, E and F may be 3% less than the required values according to the following Rules for dimensioning.

L. 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.

M. Computer Programs

1. General

1.1 In order to increase the flexibility in the structural design of ships BKI 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.

1.2 Direct calculations may also be used in order to optimize a design; in this case only the final results are to be submitted for examination.

2. General Programs

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

2.2 BKI is prepared to carry out the following calculations of this kind within the marine advisory services:

2.2.1 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

2.2.2 vibration

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

2.2.3 Collision resistance

Calculation of the structure’s resistance against collision for granting the additional Class Notation **”COLL”** according to Section 35.

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

N. Workmanship

1. General

1.1 Requirements to be complied with by the manufacturer

1.1.1 The manufacturing plant shall be provided with suitable equipment and facilities to enable proper handling of the materials, manufacturing processes, structural components, etc. BKI reserve the right to inspect the plant accordingly or to restrict the scope of manufacture to the potential available at the plant.

1.1.2 The manufacturing plant shall have at its disposal sufficiently qualified personnel. BKI is to be advised of the names and areas of responsibility of all supervisory and control personnel. BKI reserves the right to require proof of qualification.

1.2 Quality control

1.2.1 As far as required and expedient, the manufacturer's personnel has to examine all structural components both during manufacture and on completion, to ensure that they are complete, that the dimensions are correct and that workmanship is satisfactory and meets the standard of good shipbuilding practice.

1.2.2 Upon inspection and corrections by the manufacturing plant, the structural components are to be shown to the BKI Surveyor for inspection, in suitable Sections, normally in unpainted condition and enabling proper access for inspection.

1.2.3 The Surveyor may reject components that have not been adequately checked by the plant and may demand their re-submission upon successful completion of such checks and corrections by the plant.

2. Structural details

2.1 Details in manufacturing documents

2.1.1 All significant details concerning quality and functional ability of the component concerned shall be entered in the manufacturing documents (workshop drawings etc.). This includes not only scantlings but - where relevant - such items as surface conditions (e.g. finishing of flame cut edges and weld seams), and special methods of manufacture involved as well as inspection and acceptance requirements and where relevant permissible tolerances. So far as for this aim a standard shall be used (works or national standard etc.) it shall be harmonized with BKI. This standard shall be based on the Guidance for Marine Industry (Pt.1, Vol.AC) Sec.3, R-47 "Shipbuilding and Repair Quality Standard" for New Construction. For weld joint details, see Section 19, A.1

2.1.2 If, due to missing or insufficient details in the manufacturing documents, the quality or functional ability of the component cannot be guaranteed or is doubtful, BKI may require appropriate improvements. This includes the provision of supplementary or additional parts (for example reinforcements) even if these were not required at the time of plan approval or if - as a result of insufficient detailing such requirement was not obvious.

2.2 Cut-outs, plate edges

2.2.1 The free edges (cut surfaces) of cut-outs, hatch corners, etc. are to be properly prepared and are to be free from notches.

As a general rule, cutting drag lines etc. shall not be welded out, but are to be smoothly ground. All edges should be broken or in cases of highly stressed parts, should be rounded off.

2.2.2 Free edges on flame or machine cut plates or flanges are not to be sharp cornered and are to be finished off as laid down in 2.2.1 This also applies to cutting drag lines etc., in particular to the upper edge of sheer strake and analogously to weld joints, changes in sectional areas or similar discontinuities.

2.3 Cold forming

2.3.1 For cold forming (bending, flanging, beading) of plates the minimum average bending radius shall not fall short of $3 \cdot t$ (t = plate thickness) and shall be at least $2 \cdot t$. Regarding the welding of cold formed areas, see Section 19, B.2.6.

2.3.2 In order to prevent cracking, flame cutting flash or shearing burrs shall be removed before cold forming. After cold forming all structural components and, in particular, the ends of bends (plate edges) are to be examined for cracks. Except in cases where edge cracks are negligible, all cracked components are to be rejected. Repair welding is not permissible.

2.4 Assembly, alignment

2.4.1 The use of excessive force is to be avoided during the assembly of individual structural components or during the erection of sections. As far as possible major distortions of individual structural components should be corrected before further assembly.

2.4.2 Girders, beams, stiffeners, frames etc. that are interrupted by bulkheads, decks etc. shall be accurately aligned.

In the case of critical components, control drillings are to be made where necessary, which are then to be welded up again on completion.

2.4.3 After completion of welding, straightening and aligning shall be carried out in such a manner that the material properties will not be influenced significantly. In case of doubt, BKI may require a procedure test or a working test to be carried out.

3. Corrosion protection

For corrosion protection, see Section 38.

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Section 2 Materials

A. General

All materials to be used for the structural members indicated in the Construction Rules are to be in accordance with the Rules for Materials (Pt. 1, Vol.V). Materials the properties of which deviate from these Rules requirements may only be used upon special approval.

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

IACS UR S4 Rev.4

IACS UR S6 Rev.9.Corr.2

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.

B. Hull Structural Steel for Plates and Sections

1. Normal strength hull structural steel

1.1 Normal strength hull structural steel is a hull structural steel with a minimum nominal upper yield point R_{eH} of 235 N/mm^2 and a tensile strength R_m of 400 - 520 N/mm^2, see also Section 17, A.4.

1.2 The material factor k in the formulae of the following Sections is to be taken 1,0 for normal strength hull structural steel.

1.3 Normal strength hull structural steel is grouped into the grades KI-A, KI-B, KI-D, KI-E, which differ from each other in their toughness properties. For the application of the individual grades for the hull structural members, see 5.

1.4 If for special structures the use of steels with yield properties less than 235 N/mm^2 has been accepted, the material factor k is to be determined by:

$$k = \frac{235}{R_{eH}}$$

2. Higher strength hull structural steels

2.1 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 Rules for Materials (Pt.1, Vol.V), Sec. 4.B, for three groups of higher strength hull structural steels the nominal upper yield stress R_{eH} has been fixed at 315, 355 and 390 N/mm^2 respectively. Where higher strength hull structural steel is used, for scantling purposes the values in Table 2.1 are to be used for the material factor k mentioned in the various Sections.

For higher strength hull structural steel with other nominal yield stresses up to 390 N/mm^2 , the material factor k may be determined by the following formula:

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

(IACS UR S4)

Table 2.1 Material factor k

R_{eH} [N/mm^2]	k
315	0,78
355	0,72
390	0,66 Provide that a fatigue assessment of the structure is performed to verify compliance with the requirements of BKI
	0,68 In other cases
460	0,62

Note:

Especially when higher strength hull structural steels are used, limitation of permissible stresses due to buckling and fatigue strength criteria may be required.

2.2 Higher strength hull structural steel is grouped into the following grades, which differ from each other in their toughness properties:

KI-A 32/36/40

KI-D 32/36/40

KI-E 32/36/40

KI-F 32/36/40

In Table 2.9 the grades of the higher strength hull structural steels are marked by the letter "H".

2.3 Where structural members are completely made from higher strength hull structural steel, a suitable Notation will be entered into the Ship's Certificate.

2.4 Regarding welding of higher strength hull structural steel, see Rules for Welding (Pt.1, Vol.VI) Sec. 12.

3. High strength hull structural steel

The application of high strength steel with R_{eH} of 460 N/mm^2 is limited to ships with the ship type notation "**Container ship**" or additional notation "**ECC**" as defined in Guidance for Class Notation (Pt.0, Vol.B), Sec. 2, C and Sec. 3, A.3. For other ship types, the application of this steel is considered on a case-by-case basis.

The application of high strength steel with R_{eH} greater than 460 N/mm^2, will be considered on a case by-case basis.

4. Onboard documents

The submitted drawings for approval must indicate the types and grades of steel used for the hull structures, and these to be kept on board. Where steels other than those indicated in Table 2.1 are used, their mechanical and chemical properties, as well as any workmanship requirements or recommendations, shall be available on board together with the above plan.

5. Material selection for the hull

5.1 Material classes

For the material selection for hull structural members material classes as given in Table 2.2 are defined.

5.2 Material selection for longitudinal structural members

Materials in the various strength members are not to be of lower grades than those corresponding to the material classes and grades specified in Table 2.2 to Table 2.9 General requirements are given in Table 2.2 while additional minimum requirements are given in the following:

Table 2.3: for ships, excluding liquefied gas carriers covered in Table 2.4, with length exceeding 150 m and single strength deck,

Table 2.4: for membrane type liquefied gas carriers with length exceeding 150 m,

Table 2.5: for ships with length exceeding 250 m,

Table 2.6: for single side bulk carriers subjected to SOLAS regulation XII/6.4,

Table 2.7: for ships with ice strengthening.

Table 2.8: for ships with cranes

The material grade requirements for hull members of each class depending on the thickness are defined in Table 2.9.

For strength members not mentioned in Table 2.2 to 2.7, Grade A/AH may generally be used. The steel grade is to correspond to the as-built plate thickness and material class.

Plating materials for stern frames supporting the rudder and propeller boss, rudders, rudder horns and shaft brackets are in general not to be of lower grades than corresponding to Class II.

(IACS UR S6.1)

Table 2.2 Material classes and grades for ships in general

Structural member category		Material class or grade
Secondary :		
A1	Longitudinal bulkhead strakes, other than that belonging to the Primary category	- Class I within 0,4**L** amidships - Grade A/AH outside 0,4**L** amidships
A2	Deck plating exposed to weather, other than that belonging to the Primary or Special category	
A3	Side plating	
Primary :		
B1	Bottom plating, including keel plate	- Class II within 0,4**L** amidships - Grade A/AH outside 0,4**L** amidships
B2	Strength deck plating, excluding that belonging to the Special category	
B3	Continuous longitudinal plating of strength members above strength deck, excluding hatch coamings	
B4	Uppermost strake in longitudinal bulkhead	
B5	Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	
Special :		
C1	Sheer strake at strength deck [1]	- Class III within 0,4**L** amidships - Class II outside 0,4**L** amidships - Class I outside 0,6**L** amidships
C2	Stringer plate in strength deck [1]	
C3	Deck strake at longitudinal bulkhead excluding deck plating in way of inner-skin bulkhead of double-hull ships [1]	
C4	Strength deck plating at outboard corners of cargo hatch openings in container ships and other ships with similar hatch openings 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 openings configurations	- Class III within 0,6**L** amidships - Class II within rest of cargo region
C5.1	Trunk deck and inner deck plating at corners of openings for liquid and gas domes in membrane type liquefied gas carriers	
C6	Bilge strake in ships with double bottom over the full breadth and length less than 150 m	- 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	Longitudinal hatch coamings of length greater than 0,15**L** including coaming top plate and flange	- 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
C9	End brackets and deck house transition of longitudinal cargo hatch coamings	
1	Single strakes required to be of class III within 0,4**L** amidships are to have breadths not less than 800 + 5**L** [mm] need not be grater than 1800 mm, unless limited by the geometry of the ship's design.	

(IACS UR S6 Table 1)

Table 2.3 Minimum material grades for ships, excluding liquefied gas carriers covered in Table 2.4, with length exceeding 150 m and single strength deck

Structural member category	Material grade
• Longitudinal plating of strength deck where contributing to the longitudinal strength • Continuous longitudinal plating of 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 2.4 Minimum Material Grades for membrane type liquefied gas carriers with length exceeding 150 m*

Structural member category		Material grade
Longitudinal plating of strength deck where contributing to the longitudinal strength		Grade B/AH within 0,4**L** amidships
Continuous longitudinal plating of strength members above the strength deck	Trunk deck plating	Class II within 0,4**L** amidships
	• Inner deck plating • Longitudinal strength member plating between the trunk deck and inner deck	Grade B/AH within 0,4**L** amidships
(*) **Table 2.4** is applicable to membrane type liquefied gas carriers with deck arrangements as shown in Fig.2.1. Table 2.4 may apply to similar ship types with a double deck arrangement above the strength deck.		

(IACS UR S6 Table 3)

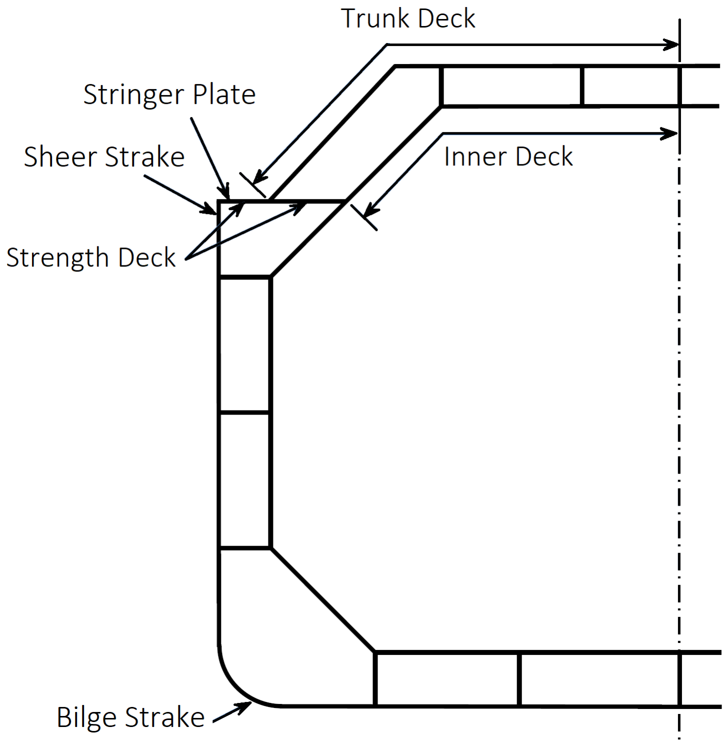

Fig. 2.1 Typical deck arrangement for membrane type Liquefied Natural Gas Carriers

Table 2.5 Minimum material grades for ships with length exceeding 250 m

Structural member category	Material grade
Sheer 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 D/DH or Grade E/EH as shown in the above table and within 0,4**L** amidships are to have breadths not less than 800 + 5**L** [mm], need not be grater than 1800 mm, unless limited by the geometry of the ship's design.

(IACS UR S6 Table 4)

Table 2.6 Minimum material grades for single-side skin bulk carriers subjected to SOLAS regulation XII/6.4

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 ℓ 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 frames up to the point of 0,125 ℓ 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 5)

Table 2.7 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 6)

Table 2.8 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 Guidelines for Loading Gear on Seagoing Ships and Offshore Installations (Pt.4, Vol. 3) are to be considered.

Table 2.9 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 BKI.
[4] For nominal yield stresses R_{eH} ≥ 390 N/mm[2] EH.

(IACS UR S6 Table 7)

5.3 Material selection for local structural members

5.3.1 The material selection for local structural members, which are not part of the longitudinal hull structure, may in general be effected according to Table 2.10. For parts made of forged steel or cast steel C is to be applied.

Table 2.10 Material selection for local structural members

Structural member	Material Class
hawse pipe, stern tube, pipe stanchion [3]	I
face plates and webs of girder systems, hatch cover	II[1]
rudder body[2], rudder horn, sole piece, stern frame, propeller brackets, 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 "normalized", "rolled normalized" or "rolled thermomechanical".
[2] See 5.3.2.
[3] For pipe stanchions for cargo reefer holds Table 2.12 is applicable.

(IACS UR S6.1)

5.3.2 For rudder and rudder body plates subjected to stress concentrations (e.g. in way of lower support of semi spade rudders or at upper part of spade rudders) Class III is to be applied.

5.3.3 For top plates of machinery foundations located outside 0,6**L** amidships, grade A ordinary hull structural steel may also be used for thicknesses above 40 mm.

For members not specifically mentioned normally grade A/AH may be used. However, BKI may require also higher grades depending on the stress level.

5.4 Material selection for structural members which are exposed to low temperatures

5.4.1 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

5.4.2 For ships intended to operate permanently in areas with low air temperatures (below -10°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 5.4.5.

Materials in the various strength members above the lowest ballast waterline (BWL) exposed to air (including the structural members covered by the Note 6 of Table 2.11) and materials of cargo tank boundary plating for which 5.4.6 is applicable are not to be of lower grades than those corresponding to classes I, II and III, as given in Table 2.11, depending on the categories of structural members (Secondary, Primary and Special). For non-exposed structures (except as indicated in Note 6 of Table 2.11) and structures below the lowest ballast waterline, 5.2 and 5.3 applies.

(IACS UR S6.2)

5.4.3 The material grade requirements for hull member of each material class depending on thickness and design temperature are defined in Table 2.12. For design temperatures t_D < - 55° C, materials are to be specially considered.

(IACS UR S6.2)

5.4.4 Single strakes required to be of class III or of grade E/EH or FH are to have breadths not less 800 + 5 × **L** [mm], maximum 1800 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 5.3.

(IACS UR S6.2)

5.4.5 The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation, see Fig.2.2. The following definitions apply:

- **Mean** : Statistical mean over an observation period
- **Average** : Average during one day and night.
- **Lowest** : Lowest during the year.

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

For the purpose of issuing a Polar Ship Certificate in accordance with the Polar Code, the design temperature t_D shall be no more than 13 °C higher than the Polar Service Temperature (PST) of the ship.

In the Polar Regions, the statistical mean over observation period is to be determined for a period of at least 10 years.

(IACS UR S6.3)

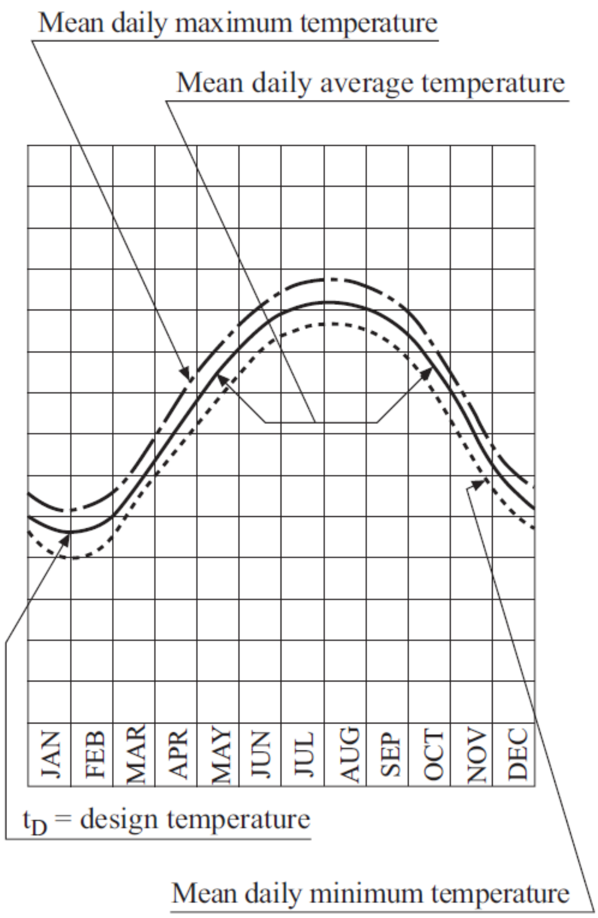

Fig. 2.2 Commonly used definitions of temperatures

5.4.6 Cold cargo for ships other than liquefied gas carriers

For ships other than liquefied gas carriers, intended to be loaded with liquid cargo having a temperature below -10 °C, e.g. loading from cold onshore storage tanks during winter conditions, the material grade of cargo tank boundary plating is defined in Table 2.12 based on the following:

— t_c design minimum cargo temperature in °C

— steel grade corresponding to Class I as given in Table 2.11

The design minimum cargo temperature, t_c is to be specified in the loading manual.

(IACS UR S6.4)

Table 2.11 Material classes and grades for structures exposed to low temperatures

Structural member category	Material class	
	Within 0,4L amidships	**Outside 0,4L amidships**
Secondary: Deck plating exposed to weather, in general Side plating above BWL[5)] Transverse bulkheads above BWL [5)] [6)] Cargo tank boundary plating exposed to cold [7)]	I	I
Primary: Strength deck plating [1)] Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings Longitudinal bulkhead above BWL [5)] [6)] Top wing tank plating above BWL [5)] [6)]	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 metres.

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

4) Not to be less than grade D/DH.

5) BWL = ballast waterline.

6) Applicable to plating attached to hull envelope plating exposed to low air temperature. At least one strake is to be considered in the same way as exposed plating and the strake is to be at least 600 mm.

7) For cargo tank boundary plating exposed to cold cargo for ships other than liquefied gas carriers, see B.5.4.6

(IACS UR S6 Table 8)

Table 2.12 Material grade requirements for classes I, II and III at low temperatures

Class I

Plate thickness	t_D **-11°C to -15°C**		t_D **-16 °C to – 25 °C**		t_D **– 26 °C to – 35 °C**		t_D **– 36 °C to – 45 °C**		t_D **– 46 °C to – 55 °C**	
	Normal strength	**Higher strength**	**Normal strength**	**Higher strength**	**Normal strength**	**Higher strength**	**Normal strength**	**Higher strength**	**Normal strength**	**Higher strength**
t ≤ 10	A	AH	A	AH	B	AH	D	DH	D	DH
10 < t ≤ 15	A	AH	B	AH	D	DH	D	DH	D	DH
15 < t ≤ 20	A	AH	B	AH	D	DH	D	DH	E	EH
20 < t ≤ 25	B	AH	D	DH	D	DH	D	DH	E	EH
25 < t ≤ 30	B	AH	D	DH	D	DH	E	EH	E	EH
30 < t ≤ 35	D	DH	D	DH	D	DH	E	EH	E	EH
35 < t ≤ 45	D	DH	D	DH	E	EH	E	EH		FH
45 < t ≤ 50	D	DH	E	EH	E	EH		FH		FH

Class II

Plate thickness	t_D **-11°C to -15°C**		t_D **-16 °C to – 25 °C**		t_D **– 26 °C to – 35 °C**		t_D **– 36 °C to – 45 °C**		t_D **– 46 °C to – 55 °C**	
	Normal strength	**Higher strength**	**Normal strength**	**Higher strength**	**Normal strength**	**Higher strength**	**Normal strength**	**Higher strength**	**Normal strength**	**Higher strength**
t ≤ 10	A	AH	B	AH	D	DH	D	DH	E	EH
10 < t ≤ 20	B	AH	D	DH	D	DH	E	EH	E	EH
20 < t ≤ 30	D	DH	D	DH	E	EH	E	EH		FH
30 < t ≤ 40	D	DH	E	EH	E	EH		FH		FH
40 < t ≤ 45	E	EH	E	EH		FH		FH		
45 < t ≤ 50	E	EH	E	EH		FH		FH		

Class III

Plate thickness	t_D **-11°C to -15°C**		t_D **-16 °C to – 25 °C**		t_D **– 26 °C to – 35 °C**		t_D **– 36 °C to – 45 °C**		t_D **– 46 °C to – 55 °C**	
	Normal strength	**Higher strength**	**Normal strength**	**Higher strength**	**Normal strength**	**Higher strength**	**Normal strength**	**Higher strength**	**Normal strength**	**Higher strength**
t ≤ 10	B	AH	D	DH	D	DH	E	EH	E	EH
10 < t ≤ 20	D	DH	D	DH	E	EH	E	EH		FH
20 < t ≤ 25	D	DH	E	EH	E	EH	E	FH		FH
25 < t ≤ 30	D	DH	E	EH	E	EH		FH		FH
30 < t ≤ 35	E	EH	E	EH		FH		FH		
35 < t ≤ 40	E	EH	E	EH		FH		FH		
40 < t ≤ 50	E	EH		FH		FH				

(IACS UR S6 Table 9)

6. Structural members which are stressed in direction of their thickness (through thickness property)

In case of high local stresses in the thickness direction or perpendicular to the rolled surfaces, e.g. due to shrinkage stresses in single bevel or double bevel T-joints or cruciform connections employ partial or full penetration welds, steels with guaranteed material properties in the thickness direction according to the Rules for Materials (Pt.1, Vol.V), Sec. 4, I are to be used. These steels shall be designated on the plans submitted for approval with the required material grade by adding the symbol Z25 and Z35 respectively to the designation of the material, e.g. Grade KI-E hull structural steel is given the designation KI-E Z25.

7. Stainless steel

7.1 Specified minimum yield strength [N/mm^2], for austenitic and duplex (austenitic-ferritic) stainless steel shall be taken as:

$$R_{eH} = R_{p0,2} \quad [\text{N/mm}^2]$$

$R_{p0,2}$ = minimum yield strength at 0.2% elongation as given in Rules for Materials (Pt.1, Vol.V), Sec. 4, G.6.2.

The material factor k shall be taken in accordance with Table 2.1, based on linear interpolation for R_{eH} > 235 N/mm^2. In case R_{eH} < 235 N/mm^2 the material factor k for strength assessment shall be taken as:

$$k = \frac{235}{R_{eH}}$$

The material factor k used for the minimum thickness requirements as given in Section 6, B.3, shall not be taken greater than 1,0.

For duplex (austenitic-ferritic) stainless steel with effective minimum yield strength exceeding 390 N/mm^2 additional fatigue assessment may be required.

7.2 For clad steel and solid stainless steel due attention shall be given to the reduction of strength of stainless steel with increasing temperature.

Such reduction in strength is applicable for design temperature (T) greater than 50 °C.

7.3 For austenitic stainless steel and duplex (austenitic-ferritic) stainless steel with design temperature T exceeding 50 °C, the effective yield strength, R_{eH} [N/mm^2], will be specially considered in each case.

Note:

For design temperature T in the range 50-100 °C, the effective minimum yield strength R_{eH} may be based on Rules for Materials (Pt.1, Vol.V), Sec. 4, G.6.2

7.4 For clad steel the effective yield strength, R_{eH} i[N/mm^2] applicable for the total plate thickness will be specially considered in each case.

The material factor k of the base material may be used for the minimum thickness requirements as given in Section 6, B.3.

8. Cold formed plating

8.1 The inside bending radius in cold-formed plating shall not be less than the requirements in Section 1, N.2.3.1.

8.2 For highly stressed components of the hull girder where notch toughness is of particular concern, e.g. items required to be class III in Table 2.2, such as radius gunwales and bilge strakes and high strength steel (R_{eH} > 390 N/mm^2), the inside bending radius R [mm] in cold formed plating, shall not be less than 10 times the gross plate thickness for carbon-manganese steels (hull structural steels). The allowable inside bending radius may be reduced below 10 times the gross plate thickness, provided that the additional requirements stated in 8.4 are complied with.

8.3 For important structural members not covered by 8.2 e.g. corrugated bulkheads and hopper knuckles, the inside bending radius in cold formed plating shall not be less than 4,5 times the as-built plate thickness for carbon-manganese steels and two times the as-built plate thickness for austenitic steel and duplex (ferritic-austenitic) stainless steel, corresponding to 10% and 20% theoretical deformation, respectively.

8.4 For carbon-manganese steels the allowable inside bending radius may be reduced below the values given in 8.2 and 8.3 provided the following additional requirements are complied with:

1) The steel is killed and fine grain treated, and of grade D/DH or higher.
2) The material is impact tested in the strain-aged condition and satisfies the requirements stated herein. The deformation shall be equal to the maximum deformation in terms of plastic strain to be applied during production, calculated by the formula:

$$\frac{t_{grs}}{(2r_{bdg} + t_{grs})}$$

t_{grs} = as-built thickness of the plate material

r_{bdg} = inside bending radius

One sample shall be plastically strained at the calculated deformation or 5%, whichever is greater and then artificially aged at 250 °C for one hour, and then subject to Charpy V-notch testing. The average impact energy after strain ageing shall meet the impact requirements specified for the grade of steel required for actual member, see 8.3.

3) 100% visual inspection of the deformed area shall be carried out. In addition, random check by magnetic particle testing shall be carried out.
4) The inside bending radius shall in no case be less than two times the as-built plate thickness.

C. Forged Steel and Cast Steel

1. General

1.1 The requirements for manufacture, condition of supply, heat-treatment, testing, inspection, tolerances, chemical composition, mechanical properties, repair, identification, certification, etc. for steel castings and forging to be used for structural members are given in Rules for Materials (Pt.1, Vol.V).

1.2 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 Rules for Materials (Pt.1, Vol.V). The tensile strength of forged steel and of cast steel is not to be less than 400 N/mm^2. Forged steel and cast steel are to be selected under consideration of B.5. In this respect beside strength properties also toughness requirements and weldability shall be observed.

2. Rolled bars in lieu of steel forgings

Rolled bars for structural application may be accepted in lieu of forged products, after consideration by BKI on a case-by-case basis. Compliance with applicable requirements for steel forgings given in Rules for Materials (Pt.1, Vol.V), Sec. 6, relevant to the quality and testing of rolled parts accepted in lieu of forged parts, may be required.

3. Steel castings for structural application

The use of cast parts welded to main plating and contributing to hull strength will be considered on a case-by-case basis.

BKI may require additional properties and tests for such casting, in particular impact properties which are appropriate to those of the steel plating to which the cast parts shall be welded and non-destructive examinations.

D. Aluminium Alloys

1. General

1.1 The characteristics of aluminium alloys are to comply with the requirements of Rules for Materials (Pt.1, Vol.V), Sec. 10. Series 5000 aluminium-magnesium alloys or series 6000 aluminium-magnesium-silicon alloys are to be used.

1.2 Aluminium alloy for marine use may be applied in superstructures, deckhouses, hatch covers, hatch beams and sundry items, provided the strength of the aluminium structure is equivalent to that required for a steel structure.

1.3 For aluminium alloy subjected to longitudinal stresses, the alloy and the scantlings shall be chosen considering the stress level concerned.

1.4 In weld zones of rolled or extruded products (heat affected zones) the mechanical properties given in 3. may in general be used as basis for the scantling requirements.

1.5 Welding consumables giving a deposit weld metal with mechanical properties not less than those specified for the weld zones of the parent material shall be chosen.

1.6 In the case of structures subjected to low service temperatures or intended for other specific applications, the type of alloys to be used is subject to BKI approval.

1.7 Unless otherwise agreed, the Young's modulus for aluminium alloys (E) is equal to 70000 N/mm^2 and the Poisson's ratio (ν) equal to 0,33.

2. Extruded plating

2.1 Extrusions with built-in plating and stiffeners, referred to as extruded plating, may be used.

2.2 In general, the application of extruded plating is limited to decks, bulkheads, superstructures and deckhouses. Other uses may be permitted by BKI on a case-by-case basis.

2.3 Extruded plating shall be oriented so that the stiffeners are parallel to the direction of main stresses.

2.4 Connections between extruded plating and primary members shall be given special attention.

3. Mechanical properties of weld joints

3.1 Welding heat input lowers locally the mechanical strength of aluminium alloys hardened by work hardening (series 5000 other than condition 0 or H111) or by heat treatment (series 6000).

3.2 The as-welded properties of aluminium alloys of series 5000 are in general those of condition 0 or H111. Higher mechanical characteristics may be considered, provided they are duly justified.

3.3 For the 6000 series alloys the most unfavourable properties corresponding to -T4 condition, see Rules for Materials (Pt.1, Vol.V) Sec. 10, shall be used.

4. Material factor, k

4.1 The material factor, k, for aluminium alloys shall be obtained from the following formula:

$$k = \frac{235}{R'_{lim}}$$

R'_{lim} = minimum guaranteed yield stress of the parent metal in welded condition $R'_{p0,2}$ [N/mm^2], but not to be taken greater than 70% of the minimum guaranteed tensile strength of the parent metal in welded condition R'_m [N/mm^2]

$R'_{p0,2}$ = minimum guaranteed yield stress [N/mm^2], of material in welded condition

= $\eta_1 \cdot R_{p0,2}$ [N/mm^2]

R'_m = minimum guaranteed tensile strength [N/mm^2], of material in welded condition

= $\eta_2 \cdot R_m$ [N/mm^2]

$R_{p0,2}$ = minimum guaranteed yield stress [N/mm^2], of the parent metal in delivery condition

R_m = minimum guaranteed tensile strength [N/mm^2], of the parent metal in delivery condition

η_1, η_2 = specified in Table 2.13.

4.2 In the case of welding of two different aluminium alloys, the material factor k to be considered for the scantlings is the greater material factor of the aluminium alloys of the assembly.

Table 2.13 Aluminium alloys coefficients for welded construction

Aluminium alloy	η_1	η_2
Alloys without work-hardening treatment (series 5000 in annealed condition 0 or annealed flattened condition H111)	1	1
Alloys hardened by work hardening (series 5000 other than condition 0 or H111)	$\frac{R'_{p0,2}}{R_{p0,2}}$	$\frac{R'_m}{R_m}$
Alloys hardened by heat treatment (series 6000) 1)	$\frac{R'_{p0,2}}{R_{p0,2}}$	0,6
1) When no information is available, coefficient η_1 shall be taken equal to the metallurgical efficiency coefficient β as defined in Table 2.14.		

Table 2.14 Aluminium alloys metallurgical efficiency coefficient β

Aluminium alloy	Temper condition	As-built thickness [mm]	β
6005A (Open sections)	T5 or T6	t ≤ 6	0.45
		t > 6	0.40
6005A (Closed sections)	T5 or T6	All	0.50
6061 (Sections)	T6	All	0.53
6082 (Sections)	T6	All	0.45

5. Connection between steel and aluminium

5.1 Details of the proposed method of joining any aluminium and steel structures shall be submitted for approval.

5.2 To prevent galvanic corrosion a non-hygroscopic insulation material shall be applied between steel and aluminium when a bolted connection is used.

5.3 Aluminium plating connected to steel boundary bar at deck is as far as possible to be arranged on the side exposed to moisture.

5.4 An aluminium-steel transition joint in accordance with Rules for Materials (Pt.1, Vol.V), Sec. 4, H may be used in a welded connection after special consideration.

5.5 Steel-aluminium transition joints shall not be used in areas with high tensile stresses.

5.6 Direct contact between exposed wooden materials, e.g. deck planking, and aluminium shall be avoided.

5.7 Bolts with nuts and washers shall either be of stainless steel or cadmium plated or hot galvanized steel. The bolts shall be fitted with sleeves of insulating material. The spacing is normally not to exceed 4 times the bolt diameter.

5.8 For earthing of insulated aluminium superstructures, see Rules for Electrical Installations (Pt.1, Vol.IV).

E. Austenitic Steels

Where austenitic steels are applied having a ratio $R_{p0,2}/R_{m0,5}$, after special approval the 1% proof stress $R_{p1,0}$ may be used for scantling purposes instead of the 0,2% proof stress $R_{p0,2}$.

F. Other Materials and Products

1. Other materials and products such as parts made of iron castings, where allowed, products made of copper and copper alloys, rivets, anchors, chain cables, cranes, masts, derrick posts, derricks, accessories and wire ropes are to comply with the applicable requirements of Rules for Materials (Pt.1, Vol.V).

2. The use of plastics or other special materials not covered by these Rules is to be considered by BKI on a case by case basis. In such cases, the requirements for the acceptance of the materials concerned are to be agreed by BKI.

3. Materials used in welding processes are to comply with the applicable requirements of the Rules for Materials (Pt.1, Vol.V).

4. As a rule, the use of grey iron, malleable iron or spherical graphite iron cast parts with combined ferritic/perlitic structure is allowed only for manufacturing low-stress elements of secondary importance.

5. Ordinary iron cast parts may not be used for windows or side scuttles. The use of high grade iron cast parts of a suitable type will be considered by BKI on a case by case basis.

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Section 3 Design Principles

A. General

1. Scope

This Section contains definitions and general design criteria for hull structural elements as well as indications concerning structural details, based on the following international convention(s) and/or code(s):

IACS UR S11 Rev.7

IACS UR S35

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

2. 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.

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

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

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.

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

Note:

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

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

3. Plate panels 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 ≥ 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:

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

C	=	constant, e.g. C = 1,1 for tank plating
f_1	=	curvature factor, defined as:
	=	$1 - \frac{a}{2r} \geq 0{,}75$
f_2	=	aspect ratio factor, defined as:
	=	$\sqrt{1{,}1 - 0{,}5 \cdot \left[\frac{a}{b}\right]^2} \leq 1{,}0$
r	=	radius of curvature
a	=	smaller breadth of plate panel
b	=	larger breadth of plate panel
p	=	applicable design load
t_K	=	corrosion addition according to K.

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

4. Fatigue strength

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

B. Upper and Lower Hull Flange

1. All continuous longitudinal structural members up to z_0 below the strength deck at side and up to z_u above baseline are considered to be the upper and lower hull flange respectively.

2. Where the upper and/or the lower hull flange are made from normal strength hull structural steel their vertical extent $z_0 = z_u$ equals 0,1 $\cdot$ **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 between neutral axis of the midship section and baseline [m]

e'_D see Section 5, C.4.1.

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:

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

e	=	distance of deck at side or of the baseline from the neutral axis of the midship section. For ships with continuous longitudinal structural members above the strength deck, see Section 5, C.4.1

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, C.1.

C. Unsupported Span

1. Stiffeners, frames

The unsupported span ℓ is the true length of the stiffeners between two supporting girders or else their length including end attachments (brackets). 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 shall 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.

2. Corrugated bulkhead elements

The unsupported span ℓ of corrugated bulkhead elements 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.

3. Transverses and girders

The unsupported span ℓ of transverses and girders is to be determined according to Fig.3.1, 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.

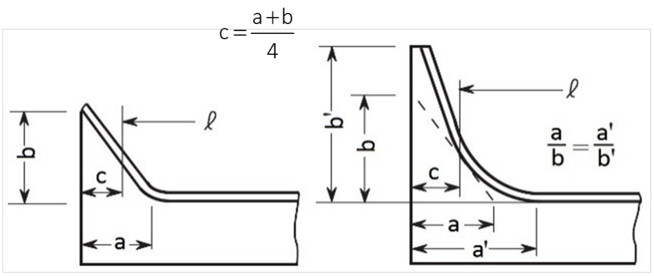


Fig. 3.1 Unsupported span ℓ

D. End Attachments

1. Definitions

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

"Constraint" will be assumed where for instance 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 for instance the stiffener ends are sniped or the stiffeners are connected to plating only, see also 3.

2. Brackets

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.

2.2 The thickness of brackets is not to be less than:

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

c = 1,2 for non-flanged brackets

= 0,95 for flanged brackets

k_1 = material factor k for the section according to Section 2, B.2.

t_k = corrosion addition according to K.

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

t_{min} = $5,0 + t_K$ mm

t_{max} = web thickness of smaller section.

For minimum thicknesses in tanks and in cargo holds of bulk carriers see Section 12, A.7, Section 23, B.5.3, and Section 24, A.12.

2.3 The arm length of brackets is not to be less than:

$$\ell = 46,2 \cdot \sqrt[3]{\frac{W}{k_1}} \cdot \sqrt{k_2} \cdot c_t \quad [mm]$$

ℓ_{min} = 100 mm

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

ta = "as built" thickness of bracket [mm]

$\geq$ t according to 2.2

W = see 2.2

k_2 = material factor k for the bracket according to Section 2, B.2

The arm length ℓ 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.

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

2.5 Where flanged brackets are used the width of flange is to be determined according to the following formulae:

$$b = 40 + \frac{W}{30} \quad [mm]$$

b is not to be taken less than 50 mm and need not be taken greater than 90 mm.

3. Sniped ends of stiffeners

Stiffeners may be sniped at the ends, if the thickness of the plating supported by stiffeners is not less than:

$$t = c \cdot \sqrt{\frac{p \cdot \mathbf{a} \cdot (\ell - 0{,}5 \cdot \mathbf{a})}{R_{eH}}} \quad [mm]$$

p	=	design load [kN/m^2]
l	=	unsupported length of stiffener [m]
a	=	spacing of stiffeners [m]
R_{eH}	=	minimum nominal upper yield point of the plating material [N/mm^2] according to Section 2, B
c	=	15,8 for watertight bulkheads and for tank bulkheads when loaded by p_2 according to Section 4, D.1.2
	=	19,6 otherwise

4. Corrugated bulkhead elements

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, B.4.3 the section modulus of a corrugated element is then to be determined by the following formulae:

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

E. Effective Breadth of Plating

1. Frames and stiffeners

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

2. Girders

2.1 The effective breadth of plating "e_m" of frames and girders may be determined according to Table 3.1 considering the type of loading.

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

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

2.3 Where the angle α between web of stiffeners or else of girders and the attached plating is less than 75° the required section modulus is to be multiplied by the factor 1/sin α.

2.4 The effective width of stiffeners and girders subjected to compressive stresses may be determined according to F.5.2.3.5, but is in no case to be taken greater than the effective breadth determined by 2.1.

Table 3.1 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

e_{m1} is to be applied where girders are loaded by uniformly distributed loads or else by not less than 6 equally spaced single loads.

e_{m2} is to be applied where girders are loaded by 3 or less single loads.

Intermediate values may be obtained by direct interpolation.

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.

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

3. Cantilevers

Where cantilevers are fitted at every frame, the effective width 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.

F. Proof of Buckling Strength

1. Application and Definitions

1.1 Application

1.1.1 All structural members which are subjected to compressive and/or shear stresses are to be examined for sufficient resistance to buckling in according to the following strength criteria for buckling and ultimate strength.

1.1.2 The buckling checks are to be performed according to:[1)]

— 2. for the slenderness requirements of plates, longitudinal and transverse stiffeners, primary supporting members and brackets.

— 3. for the hull girder buckling requirements of plates, longitudinal and transverse stiffeners, primary supporting members and other structures subject to hull girder stresses.

— 4. for direct strength analysis (usually by finite element method) buckling requirements analysis for the plates, stiffened panels and other structures.

— 5. for the determination of buckling capacities of prescriptive and FE buckling requirements.

(IACS UR S35. Sec.1, 1.2.1)

1.1.3 In this Sub-Section, compressive and shear stresses are to be taken as positive, tension stresses are to be taken as negative.

(IACS UR S35. Sec.1, 2.4.1)

1) Upon the Owner's request and subject to approval by BKI, buckling strength evaluation in accordance with the 2022 Consolidated Edition of the Rules for Hull (Pt.1, Vol.II), Sec.3, F may be accepted as an alternative to the buckling checks specified in items 2. and 3.

1.2 Alternative methods

This Sub-section contains the general methods for the determination of buckling capacities of plate panels, stiffeners, primary supporting members, and columns. For special cases not covered in this Sub-section, such as a whole plate structure with stiffeners in two directions (i.e., a stiffened panel with both primary and secondary stiffeners), other more advanced methods, such as finite element analysis methods, can be used as deemed appropriate by BKI.

(IACS UR S35. Sec.1, 1.2.3)

1.3 Definitions

1.3.1 Buckling strength

Buckling strength or capacity refers to the strength of a structure under in-plane compressions and/or shear and lateral load. Buckling strength with consideration of the buckling behaviour in 1.3.2 gives a lower bound estimate of ultimate capacity, or the maximum load a structural member can carry without suffering major permanent set.

For each structural member, its buckling strength is to be taken as corresponding to the most unfavourable or critical buckling mode.

(IACS UR S35. Sec.1, 2.1.1)

1.3.2 Buckling behaviour

Buckling strength assessment takes into account both elastic buckling and post-buckling behaviours. Post-buckling can consider the internal redistribution of loads depending on the load situation, slenderness and type of structure. Such as for the buckling assessment of plates, generally, its positive elastic post-buckling effect can be utilized.

As such, for slender structures, the calculated buckling strength is typically higher than the ideal elastic buckling stress (minimum eigenvalue). Accepting elastic buckling of slender plate panels implies that large elastic deflections and reduced in-plane stiffness may occur at higher buckling utilization levels.

(IACS UR S35. Sec.1, 2.1.2)

1.3.3 Net Scantling Approach

Unless otherwise specified, all the scantling requirements, including slenderness requirements, are based on net scantlings obtained by removing full corrosion addition (t_K) from the gross offered thicknesses, t_K referred to K.

he structural models used for the calculation of stresses to be applied for buckling assessment, which are usually based on net scantlings, are defined in the Relevant Section in this Rules.

(IACS UR S35. Sec.1, 2.2)

1.3.4 Elementary plate panel (EPP)

An elementary plate panel is the unstiffened part of the plating between stiffeners and/or primary supporting members. The plate panel length, a, and breadth, b, of the EPP are defined respectively as the longest and shortest plate edges, as shown in Fig. 3.2.

(IACS UR S35. Sec.1, 2.3.1)

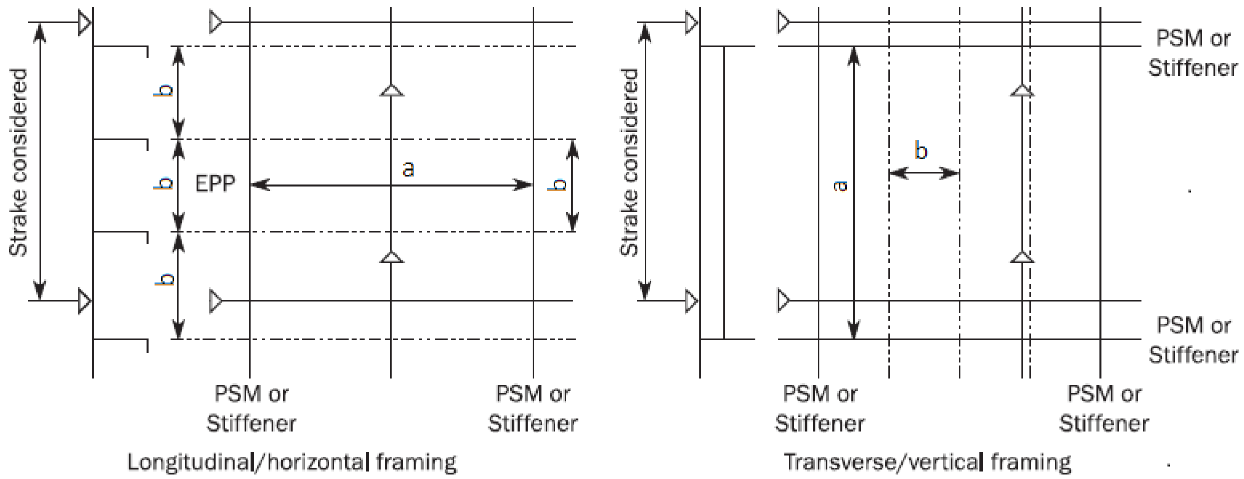


Fig. 3.2 Elementary plate panel (EPP) definition

(IACS UR S35. Sec.1, Figure 2)

1.3.5 Load calculation point

The load calculation points (LCP) for both elementary plate panels (EPP) and stiffeners are defined as follows:

1) LCP for hull girder stresses of EPP

The hull girder stresses for EPP are to be calculated at the load calculation points defined in Table 3.2

Table 3.2 Load calculation points (LCP) coordinates for plate buckling assessment

LCP Coordinates	Hull girder bending stress		Hull girder shear stress
	Non horizontal plating	Horizontal plating	
x coordinate	Mid-length of the EPP		
y coordinate	Both upper and lower ends of the EPP (points A1 and A2 in Fig. 3.3)	Outboard and inboard ends of the EPP (points A1 and A2 in Fig. 3.3)	Mid-point of EPP (point B in Fig. 3.3)
z coordinate	Corresponding to x and y values		

(IACS UR S35. Sec.3, Table 1)

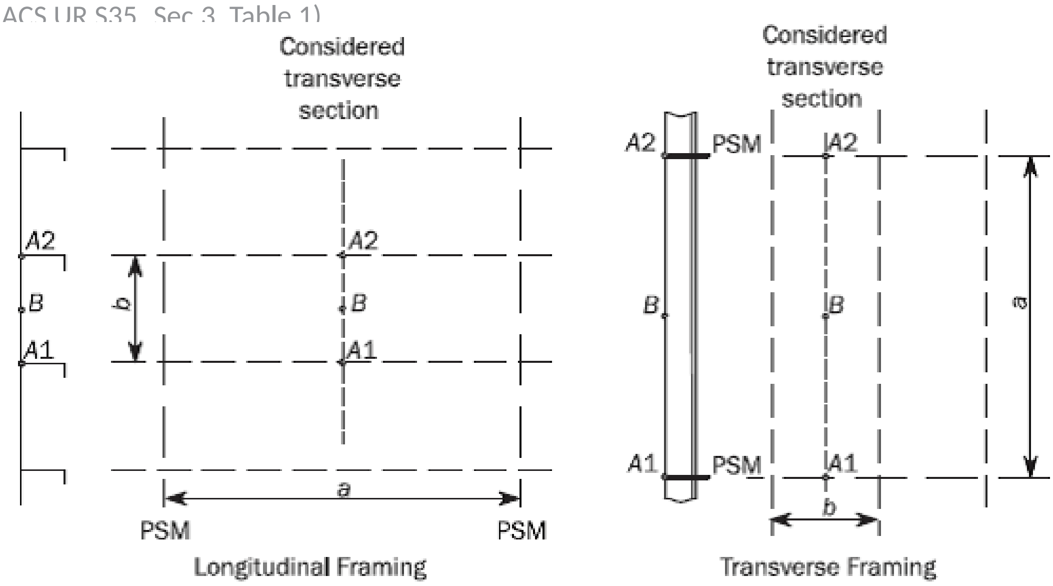


Fig. 3.3 LCP for plate buckling assessment

(IACS UR S35. Sec.3, Figure 1)

2) LCP for hull girder stresses of longitudinal stiffeners
The hull girder stresses for longitudinal stiffeners are to be calculated at the following load calculation point:

— at the mid length of the considered stiffener.

— at the intersection point between the stiffener and its attached plate

3) LCP for pressure of horizontal stiffener
The load calculation point for the pressure is located at:

— middle of the full length, ℓ, of the considered stiffener.

— the intersection point between the stiffener and its attached plate.

4) LCP for pressure of non-horizontal stiffeners
The lateral pressure, P is to be calculated as the maximum between the value obtained at middle of the full length, ℓ, and the value obtained from the following formulae:

$P = \frac{P_U + P_L}{2}$ when the upper end of the vertical stiffener is below the lowest zero pressure level

$P = \frac{\ell_1}{\ell} \cdot \frac{P_L}{2}$ when the upper end of the vertical stiffener is at or above the lowest zero pressure level, see Fig. 3.4

where

ℓ_1 = distance [m], between the lower end of vertical stiffener and the lowest zero pressure level

P_U, P_L = lateral pressures at the upper and lower end of the vertical stiffener span ℓ, respectively.

(IACS UR S35. Sec.3, 1.2.1)

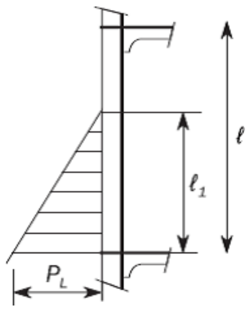


Fig. 3.4 Definition of pressure for vertical stiffeners

(IACS UR S35. Sec.3, Figure 2)

1.3.6 Standard types of stiffeners

Definitions of the cross-sectional dimensions of typical stiffener types are shown in Fig. 3.5, which are flat bars, bulb flats, angles, L2 and T bars. If applicable, other types of stiffeners can be idealized to one of the typical types in Fig. 3.5 for buckling check. For the U-type stiffener which is usually fitted in some hatch covers, the definition of its cross-sectional dimensions is shown in Fig. 3.6.

Unless otherwise specified, the full span or full length ℓ[mm], of a stiffener is to be used for buckling check, which equals to the spacing between primary supporting members

Symbolic dimensions of the cross-sections are as below:

b_1 = breadth of the attached plate enclosed by the U-type stiffener [mm], as shown in Fig. 3.6

b_2 = breadth of the attached plate between adjacent U-type stiffeners [mm], as shown in Fig. 3.6.

b_f = breadth of the flange or face plate of the stiffener [mm], as shown in Fig. 3.5 and Fig. 3.6

b_{f-out} = maximum distance [mm], from mid thickness of the web to the flange edge [mm], as shown in Fig. 3.5

d_f = breadth of the extended part of the flange for L2 profiles [mm], as shown in Fig. 3.5

e_f = distance from attached plating to centre of flange [mm], as shown in Fig. 3.5. For its detailed definition, refer to 5., Symbols

h_w = depth of stiffener web [mm], as shown in Fig. 3.5 and Fig. 3.6

t_f = flange thickness [mm]

t_p = net thickness of plate [mm]

t_w = net web thickness [mm]

(IACS UR S35. Sec.1, 2.3.2)

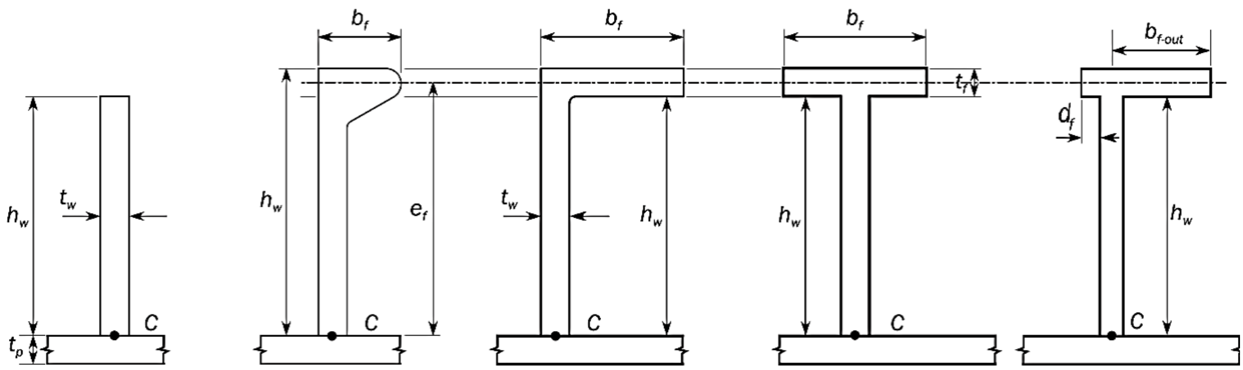


Fig. 3.5 Dimensions of typical stiffener cross sections

(IACS UR S35. Sec.1, Figure 3)

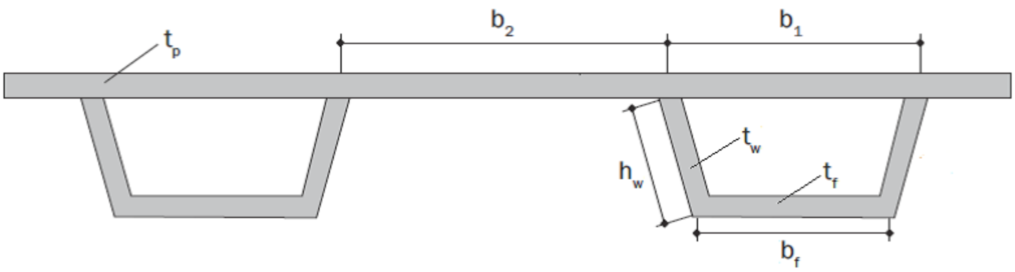


Fig. 3.6 Dimensions of a U-type stiffener cross section

(IACS UR S35. Sec.1, Figure 4)

1.3.7 Stiffened panel (SP) and unstiffened panel (UP)

For a panel with relatively strong interactive effect between the stiffener and its attached plate, each stiffener with its attached plate as a whole is to be modelled as a stiffened panel (SP), so as to be able to consider both of its local and global buckling modes.

However, for an EPP, if its buckling strength can be checked without considering its interactive effect with stiffeners fitted along its edges, it’s to be modelled as an unstiffened panel (UP).

(IACS UR S35. Sec.1, 2.3.3)

1.3.8 Assessment Methods

.1 The buckling assessment is to be carried out according to one of the following two methods taking into account different boundary condition types:

— **Method A:** All the edges of the EPP are forced to remain straight (but free to move in the in-plane directions) due to the surrounding structure/neighbouring plates. The elementary plate is integrated in the structure, which means that it is surrounded by plates that give a strong in plane support. A typical example is a double bottom girder supporting a longitudinal bulkhead.

— **Method B:** The edges of the EPP are not forced to remain straight due to low in-plane stiffness at the edges and/or no surrounding structure/neighbouring plates. The elementary plate is not surrounded by plates which means that the in-plane support is weak. A typical example is a double bottom girder not supporting a longitudinal bulkhead

(IACS UR S35. Sec.1, 3.1.1)

.2 SP-A, SP-B, UP-A and UP-B models

For the buckling assessment of the stiffened panel (SP) and unstiffened panel (UP) structural models defined in 1.3.7, with application of either Method A or Method B for the plate buckling assessment, the following four buckling assessment models are established:

— SP-A: a stiffened panel with application of Method A

— SP-B: a stiffened panel with application of Method B

— UP-A: an unstiffened panel with application of Method A

— UP-B: an unstiffened panel with application of Method B

(IACS UR S35. Sec.1, 3.1.2)

1.3.9 Buckling Utilisation Factor

.1 The utilisation factor (η), is defined as the ratio between the applied loads and the corresponding buckling capacity

(IACS UR S35. Sec.1, 3.2.1)

.2 For combined loads, the utilisation factor, η_{act}, is to be defined as the ratio of the applied equivalent stress and the corresponding buckling capacity, as shown in Fig. 3.7, and is to be taken as:

$$\eta_{act} = \frac{W_{act}}{W_U} = \frac{1}{\gamma_c}$$

where

W_{act}	=	equivalent applied stress. The actual applied stresses are given in 3. and 4. respectively for buckling assessment by prescriptive and direct strength analysis.
W_U	=	equivalent buckling capacity. For plates and stiffeners, their respective buckling or ultimate capacities are given in 5.
γ_c	=	stress multiplier factor at failure

For each typical failure mode, the corresponding buckling capacity of the panel is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until collapse occurs, i.e., when the increased or decreased stresses are on a buckling strength interaction curve or surface.

Fig. 3.7 illustrates the buckling capacity and the buckling utilisation factor of a structural member subject to σ_x and σ_y stresses.

(IACS UR S35. Sec.1, 3.2.2)

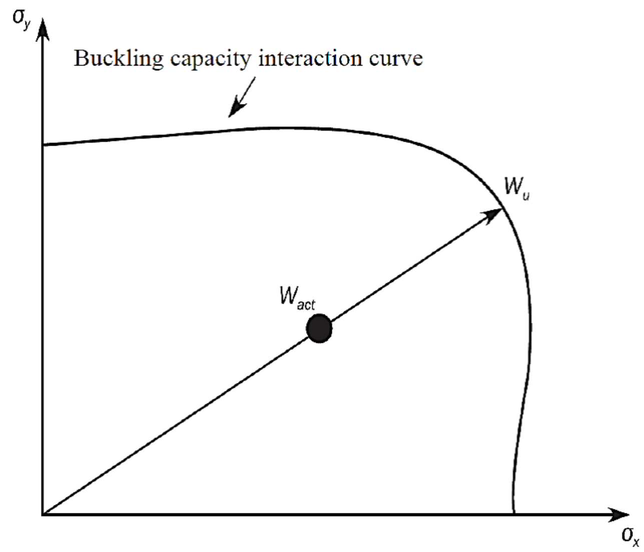


Fig. 3.7 Illustration of buckling capacity and buckling utilisation factor

(IACS UR S35. Figure 5)

1.3.10 Allowable Buckling Utilisation Factor

The allowable buckling utilisation factor η_{all} is to be taken according to the Table 3.3 by following acceptance criteria are categorized into four sets:

1) The acceptance criteria set AC-1- is typically applied for the static design load scenarios (S) and for the sloshing design loads.

   — repeated yield

   — allowance for some dynamics

   — margins for some selected limited operational mistakes

2) The acceptance criteria set AC-2 is typically applied for the static + dynamic design load scenarios (S+D), where the considered loads are extreme loads with a low probability of occurrence.

3) The acceptance criteria set AC-3 is typically applied for exceptional static conditions load scenarios (A: S and T: S), such as flooding or tank testing loads.

4) The acceptance criteria set AC-4 is typically applied for impact design load scenarios (I), such as bottom slamming and bow impact loads.

Table 3.3 Allowable buckling utilisation factor η_{all}

Structural component	Acceptance criteria	η_{all}
Plates and stiffeners	AC-1	0,80
Stiffened and unstiffened panels Vertically stiffened side shell plating of single side skin ship Web plate in way of openings Web and flange of primary supporting members	AC-2 AC-3 AC-4	1,00
Pillars	AC-1	0,75
	AC-2 AC-3	0,85
Struts and cross ties	AC-1	0,65
	AC-2 AC-3	0,75
Corrugation of vertically corrugated bulkheads with lower stool and horizontally corrugated bulkhead, under lateral pressure from liquid loads, for shell elements only. Supporting structure in way of lower end of corrugated bulkheads without lower stool	AC-1	0,72
	AC-2 AC-3	0,90
Corrugation of vertically corrugated bulkheads without lower stool under lateral pressure from liquid loads, for shell elements only	AC-1	0,65
	AC-2 AC-3	0,81

Notes:

1 *Supporting structure for a transverse corrugated bulkhead refers to the structure in longitudinal direction within half a web frame space forward and aft of the bulkhead, and within a vertical extent equal to the corrugation depth.*

2. *Supporting structure for a longitudinal corrugated bulkhead refers to the structure in transverse direction within three longitudinal stiffener spacings from each side of the bulkhead, and within a vertical extent equal to the corrugation depth*

1.3.11 Buckling Acceptance Criteria

A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$$\eta_{act} \leq \eta_{all}$$

where

η_{act} = buckling utilisation factor based on the applied stress, defined in 1.3.9.2

η_{all} = allowable buckling utilisation factor as defined in 1.3.10

(IACS UR S35. Sec.1, 3.4)

2. Slenderness Requirements

2.1 General

2.1.1 All the structural elements are to comply with the applicable slenderness and proportion requirements given in 2.2 to 2.6, except for the ones listed below:

— bilge plates within the cylindrical part of the ship and radiused gunwale

— corrugation

— structural members in superstructures and deck houses, not contributing to the longitudinal strength

— U-stiffener

Pillars in superstructures and deckhouses are to comply with the applicable slenderness and proportion requirements given in 2.6.1.

2.1.2 A lower specified minimum yield stress may be used in this slenderness criterion provided the requirements specified in 3. and 4. are satisfied for the strake assumed in the same lower specified minimum yield stress value.

2.2 Plates

2.2.1 Net thickness of plate panels

The net thickness of plate panels is to satisfy the following criterion:

$$t_p \geq \frac{b}{C}\sqrt{\frac{1}{k}} \quad [mm]$$

where:

b	=	breadth of the unstiffened part of the plating between stiffeners and/or primary supporting members [mm]
C	=	slenderness coefficient taken as:
	=	100 for hull envelope
	=	125 for the other structures
k	=	material factor according to Section 2, B

2.3 Stiffeners

2.3.1 Proportions of Stiffeners

.1 Net thickness of all stiffener types

The net thickness of stiffeners is to satisfy the following criteria:

1) Stiffener web plate:

$$t_w \geq \frac{h_w}{C_w}\sqrt{\frac{1}{k}} \quad [mm]$$

2) Flange:

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{1}{k}} \quad [mm]$$

where:

C_w, C_f = slenderness coefficients given in Table 3.4

If requirement 2) is not fulfilled, the effective free flange outstand [mm], used in strength assessment including the calculation of actual net section modulus, is to be taken as:

$$b_{f-out-max} = C_f \cdot t_f \sqrt{\frac{1}{k}} \quad [mm]$$

For built-up profile where the relevant yielding strength for the web of built-up profile without the edge stiffener is acceptable, as an alternative the web can be assessed according to the web requirements of Angle and L2 bars in Table 3.4, and the edge stiffener can be assessed as a flat bar stiffener according to 2.3.1.1. The requirement to flange in 2.3.1.2 shall still apply.

(IACS UR S35. Sec.2, 2.1.1)

Table 3.4 Slenderness coefficients

Type of Stiffener	C_w	C_f
Angle and L2 bars	75	12
T-bars	75	12
Bulb flats	45	-
Flat bars	22	-

(IACS UR S35. Sec.2, Table 1)

.2 Net dimensions of angle and T-bars

The total flange breadth b_f [mm], for angle and T-bars is to satisfy the following criterion: $b_f \geq 0{,}2 \cdot h_w$

(IACS UR S35. Sec.2, 2.1.2)

2.4 Primary Supporting Members

2.4.1 Proportions and Stiffness

.1 Proportions of web plate and flange

The net thicknesses (web plate and flange) of primary supporting members are to satisfy the following criteria:

1) Stiffener web plate:

$$t_w \geq \frac{s_w}{C_w}\sqrt{\frac{1}{k}} \quad [\text{mm}]$$

2) Flange:

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{1}{k}} \quad [\text{mm}]$$

where:

s_w = plate breadth [mm], taken as the spacing of the web stiffeners
C_w = slenderness coefficient for the web plates taken as: 100
C_f = slenderness coefficient for the flanges taken as: 12

If requirement 2) is not fulfilled, the effective free flange outstand [mm], used in strength assessment including the calculation of actual net section modulus, is to be taken as:

$$b_{f-out-max} = C_f \cdot t_f \sqrt{\frac{1}{k}} \quad [\text{mm}]$$

(IACS UR S35. Sec.2, 3.1.1)

.2 Stiffness of deck transverse primary supporting members

The net moment of inertia $I_{psm-n50}$ [cm^4], of deck transverse primary members supporting deck longitudinals subject to axial compressive hull girder stress is to comply, within the central half of the bending span, with the following criterion:

$$I_{psm-n50} \geq 300 \cdot \frac{b_{bdg}^4}{e^3 \cdot a} \cdot I_{st} \quad [\text{mm}]$$

where

$I_{psm-n50}$ = net moment of inertia [cm^4], of deck transverse primary supporting members with an effective width of attached plating equal to $0{,}8 \cdot e$
ℓ = effective bending span of deck transverse primary supporting members [m], as defined in C.3

e = spacing of deck transverse primary supporting members [m]

I_{st} = net moment of inertia of deck stiffeners [cm^4], within the central half of the bending span, taken equal to:

= $1{,}43 \cdot \ell^2 \cdot \dfrac{A_{eff}}{k}$

A_{eff} = net sectional area of the stiffener [cm^2], including its effective attached plating $\mathbf{a}_{eff} = 0{,}8 \cdot \mathbf{a}$

a_{eff} = $0{,}8 \cdot \mathbf{a}$ [mm]

2.4.2 Web stiffeners fitted on primary supporting members

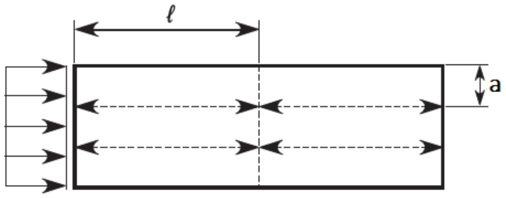
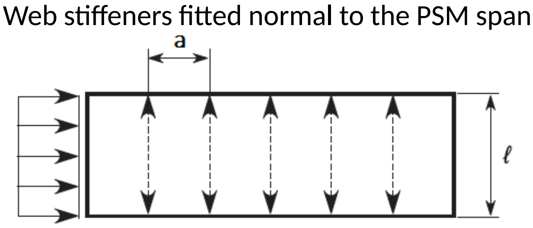
.1 Proportions of web stiffeners

The net thicknesses (web plate and flange) and dimensions of the web stiffeners fitted on primary supporting members are to satisfy the requirements specified in 2.3.1.1 and 2.3.1.2

.2 Stiffness of web stiffeners

The net moment of inertia I_{st} [cm^4], of web stiffeners fitted on primary supporting members, with effective attached plating a_{eff}, is not to be less than the minimum moment of inertia defined in Table 3.5

Table 3.5 Stiffness criteria for web stiffeners fitted on primary supporting members (PSM)

<table>
<tr><th colspan="2">Stiffener arrangement</th><th>Minimum moment of inertia of web stiffeners [cm^4]</th></tr>
<tr><td>A</td><td>Web stiffeners fitted along the PSM span
</td><td>$I_{st} \geq 1,72 \cdot \ell^2 \cdot \dfrac{A_{eff}}{k}$</td></tr>
<tr><td>B</td><td>Web stiffeners fitted normal to the PSM span
</td><td>$I_{st} \geq$ $1,14 \cdot \ell \cdot \mathbf{a}^2 \cdot t_w \left(\dfrac{2500 \cdot \ell}{\mathbf{a}} \cdot \dfrac{2 \cdot \mathbf{a}}{1000 \cdot \ell}\right) \dfrac{R_{eH}}{235} \cdot 10^{-5}$</td></tr>
<tr><td colspan="3">
Note 1:
ℓ = length of the web stiffeners [m]:
- for web stiffeners welded to local supporting members, the length is to be measured between the flanges of the local support members
- for sniped web stiffeners, the length is to be measured between the lateral supports, i.e. corresponds to the total distance between the flanges of the primary supporting member, as shown for stiffener arrangement B
Note 2:
A_{eff}= net sectional area [cm^2], of the web stiffener, including its effective attached plating s_{eff}
t_w = net web thickness of the primary supporting member [mm]
R_{eH}= specified minimum yield stress [N/mm^2] of the material of the web plate of the PSM
</td></tr>
</table>

2.5 Brackets

2.5.1 Tripping brackets

.1 Unsupported flange length

The unsupported length of the flange of the primary supporting members [m], i.e. the distance between tripping brackets, is to satisfy the following criterion:

$$S_b \leq \max\left(b_f \cdot C\sqrt{\frac{A_{f-n50}}{\left(A_{f-n50} + \frac{A_{w-n50}}{3}\right)}\left(\frac{235}{R_{eH}}\right)}; S_{b-min}\right) \quad [mm]$$

where:

b_f	=	flange breadth of primary supporting members [mm]
C	=	slenderness coefficient taken as:
	=	0,022 for symmetrical flanges
	=	0,033 for asymmetrical flanges
A_{f-n50}	=	net cross-sectional area of the flange [cm^2]
A_{w-n50}	=	net cross-sectional area of the web plate [cm^2]
R_{eH}	=	specified minimum yield stress of the PSM material [N/mm^2]
S_{b-min}	=	minimum unsupported flange length [m], taken as:]
	=	3,0 m for tank/hold boundaries or hull envelope including external decks
	=	4,0 m for the other areas

.2 Edge stiffening

The tripping brackets on primary supporting members are to be stiffened by a flange or an edge stiffener if the effective length [mm] of the edge ℓ_b, as defined in Table 3.6, is greater than $75 \cdot t_b$, where:

t_b	=	net web thickness of the brackets [mm]

2.5.2 End brackets

.1 Proportions

The net web thickness [mm], of the end brackets subjected to compressive stresses is to satisfy the following criterion:

$$t_b = \frac{d_b}{C}\sqrt{\frac{R_{eH}}{235}} \quad [mm]$$

where:

d_b	=	bracket depth [mm], as defined in Table 3.6
C	=	slenderness coefficient as defined in Table 3.6
R_{eH}	=	specified minimum yield stress of the end bracket material [N/mm^2]

2.5.3 Edge reinforcement

.1 Reinforcement of bracket edges

The web depth h_w [mm], of the edge stiffeners in way of brackets is to satisfy the following criterion:

$$t_b = \frac{d_b}{C}\sqrt{\frac{R_{eH}}{235}} \quad [mm]$$

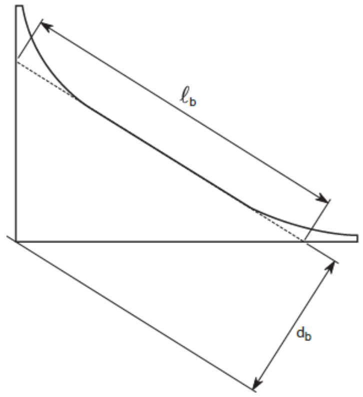
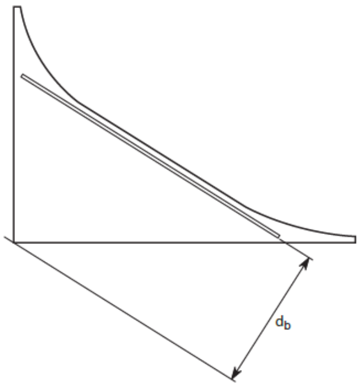
where:

C	=	Slenderness coefficient, taken as:
	=	0,022 for end brackets
	=	0,033 for tripping brackets
R_{eH}	=	specified minimum yield stress of the stiffener material [N/mm^2]

.2 Proportions of edge stiffeners

The net thicknesses (web plate and flange) and dimensions of the edge stiffeners are to satisfy the requirements specified in 2.3.1.1 and 2.3.1.2

Table 3.6 Slenderness coefficient C for proportions of brackets

Mode	C
Brackets without edge stiffener 	$C = 20 \cdot \left(\frac{d_b}{\ell_b}\right) + 16$ with $0,25 \leq \frac{d_b}{\ell_b} \leq 1$
Brackets with edge stiffener 	C = 70

2.6 Other structures

2.6.1 Pillars

.1 Proportions of I-section pillars

The net thicknesses (web plate and flanges) and dimensions of I-section pillars are to comply with the requirements specified in 2.3.1.1 and 2.3.1.2

.2 Proportions of box section pillars

The net thickness of thin-walled box section pillars is to comply with the requirements specified in 2.3.1.1, 1)

.3 Proportions of circular section pillars

The net thickness t [mm], of circular section pillars is to comply with the following criterion:

$$t \geq \frac{r}{50} \quad [mm]$$

where:

r = mid-thickness radius of the circular section [mm]

2.6.2 Edge reinforcement in way of openings

.1 Depth of edge stiffeners

When fitted as shown in Fig. 3.8, the web depth h_w [mm] of edge stiffeners in way of openings is to satisfy the following criterion:

$$h_w \geq \max\left[C \cdot \ell_b \sqrt{\frac{R_{eH}}{235}};\ 50\right] \quad [\text{mm}]$$

where:

C	=	slenderness coefficient taken as = 50
R_{eH}	=	specified minimum yield stress of the edge stiffener material [N/mm^2]
ℓ	=	length of edge stiffener in way of opening [m], as defined in Fig. 3.8

.2 Proportions of edge stiffeners

The net thicknesses (web plate and flange) and dimensions of the edge stiffeners are to satisfy the requirements specified in 2.3.1.1 and 2.3.1.2

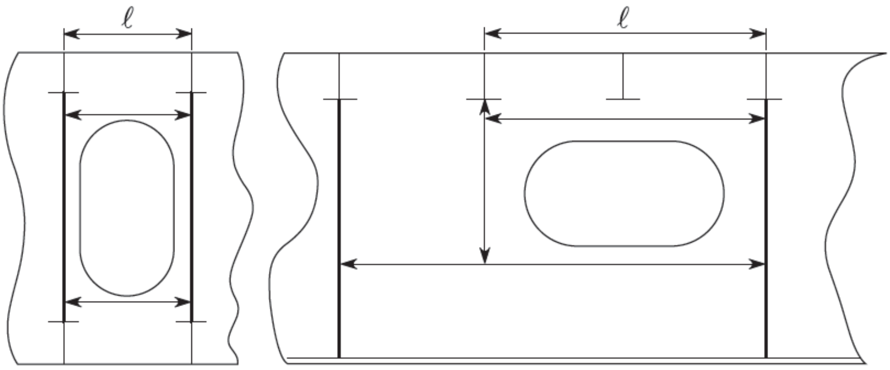


Fig. 3.8 Typical edge reinforcements

3. Hull Girder Buckling

3.1 General

3.1.1 Scope

.1 These requirements applies to plate panels and stiffeners subjected to hull girder compression and shear stresses, see Section 5, C.7. In addition the following structural members shall be checked:

— vertically corrugated longitudinal bulkheads subjected to hull girder shear stresses

— horizontally corrugated longitudinal bulkheads subjected to hull girder compression and shear stresses.

(IACS UR S35. Sec.3, 1.1.1)

.2 The hull girder buckling strength requirements apply along the full length of the ship.

3.1.2 Design load sets

The buckling check shall be performed for all longitudinal strength members and all applicable loading conditions. For combination of hull girder stress and lateral pressure, see design load sets defined in Section 5, D.

For each design load set, for all dynamic load cases, the lateral pressure shall be determined at the load calculation point (LCP) defined in 1.3.5, and shall be applied together with the hull girder stress combinations given in Section 5, D..

(IACS UR S35. Sec.3, 1.1.3)

3.1.3 Equivalent plate panels

.1 Longitudinal stiffening with varying plate thickness

When the plate thickness varies over the width b, of a plate panel, the buckling check shall be performed for an equivalent plate panel width, combined with the smaller plate thickness, t_1. The width of this equivalent plate panel b_{eq} [mm], is defined by the following formula:

$$b_{eq} = \ell_1 + \ell_2 \left(\frac{t_1}{t_2}\right)^{1,5} \quad [\text{mm}]$$

where:

ℓ_1 = width of the part of the plate panel with the smaller net plate thickness, t_1 [mm], as defined in Fig. 3.9

ℓ_2 = width of the part of the plate panel with the greater net plate thickness, t_2 [mm], as defined in Fig. 3.9

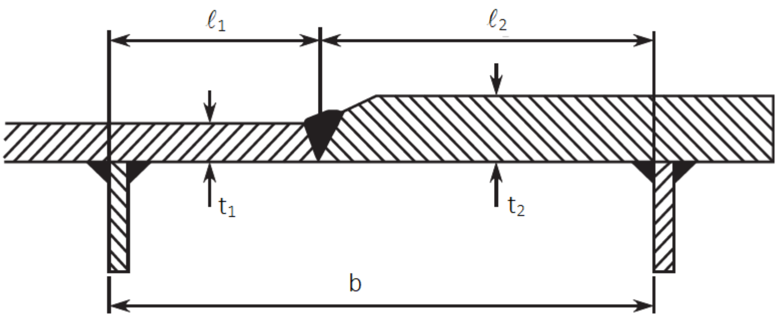


Fig. 3.9 Plate thickness change over the width

(IACS UR S35. Sec.3, 1.3.1)

.2 Transverse stiffening with varying plate thickness

In case of transverse butt weld, when an EPP is made with different thicknesses, the buckling check of the plate and stiffeners shall be made for each thickness considered constant on the EPP, the stresses and pressures being estimated for the EPP at the LCP.

(IACS UR S35. Sec.3, 1.3.2)

.3 Plate panel with different materials

When the plate panel is made of different materials, the minimum yield strength shall be used for the buckling assessment.

(IACS UR S35. Sec.3, 1.3.3)

3.2 Buckling criteria

3.2.1 Overall stiffened panel

The buckling strength of overall stiffened panels shall comply with:

$$\eta_{Overall} \le \eta_{all}$$

where:

$\eta_{Overall}$ = maximum utilisation factor as defined in 5.2.1

(IACS UR S35. Sec.3, 2.1)

3.2.2 Plates

The buckling strength of elementary plate panels shall comply with:

$$\eta_{Plate} \le \eta_{all}$$

where:

η_{Plate} = maximum plate utilisation factor calculated according to SP-A, see 5.2.2.1.

For the determination of ηPlate for the vertically stiffened side shell plating of single side skin bulk carrier between hopper and topside tanks, the load cases 12 and 16 of Table 3.12 corresponding to the shorter edge of the plate panel clamped, may be considered together with a mean σy stress and ψ_y = 1.

(IACS UR S35. Sec.3, 2.2)

3.2.3 Stiffeners

The buckling strength of stiffeners shall comply with:

$$\eta_{Stiffener} \le \eta_{all}$$

where:

$\eta_{Stiffener}$ = maximum stiffener utilisation factor, see 5.2.3

Notes:

1) *This buckling check can only be fulfilled when the overall stiffened panel buckling check, as defined in 3.2.1, is satisfied.*
2) *The buckling check of the stiffeners is only applicable to the stiffeners fitted along the long edge of the buckling panel.*

(IACS UR S35. Sec.3, 2.3)

3.2.4 Vertically corrugated longitudinal bulkheads

The shear buckling strength of vertically corrugated longitudinal bulkheads shall comply with:

$$\eta_{Shear} \le \eta_{all}$$

where:

η_{Shear} = maximum shear corrugated bulkhead utilisation factor as defined:

$= \dfrac{\tau_{bhd}}{\tau_c}$

τ_{bhd} = shear stress [N/mm^2], in the bulkhead taken as the hull girder shear stress defined in the following Section

τ_c = shear critical stress [N/mm^2]

$= \kappa_\tau \cdot \dfrac{R_{eH}}{\sqrt{3}}$ κ_τ as defined in Table 3.12

((IACS UR S35. Sec.3, 2.4)

3.2.5 Horizontally corrugated longitudinal bulkhead

Each corrugation, within the extension of half flange, web and half flange, shall comply with:

$$\eta \leq \eta_{all}$$

where:

η = overall column utilisation factor, as defined in 5.3.1

End constraints factor corresponding to pinned ends shall be applied except for fixed end support to be used in way of stool with width exceeding two (2) times the depth of the corrugation.

(IACS UR S35. Sec.3, 2.5)

3.2.6 Struts, pillars and cross ties

.1 The compressive buckling strength of struts, pillars and cross ties is to satisfy the following criterion:

$$\eta \leq \eta_{all}$$

where:

η = maximum buckling utilisation factor of struts, pillars or cross ties, as defined in 5.3.1.

.2 The buckling strength of pillars subject to axial force and bending moments may be required to be checked based on direct calculations. The buckling criterion is to be especially considered by BKI.

3.2.7 Deck primary supporting members

.1 Deck primary supporting members supporting longitudinals subjected to axial compressive hull girder stresses shall have sufficient buckling capacity to be effective support for the stiffened deck panels.

For deck transverse the buckling capacity is acceptable if complying with the following criterion:

$$I_{psm-ns50} \geq 300 \frac{\ell^4}{e^3 \cdot a} \cdot I_{st} \quad [cm^4]$$

where:

$I_{psm-ns50}$ = net moment of inertia [cm^4], of deck transverse primary supporting member, with effective width of attached plate equal to $0{,}8 \cdot e$

ℓ = length between zero-points of bending moment curve of deck transverse primary supporting member with uniformly distributed load [m]:

= ℓ_0 for deck transverse primary supporting member arranged above the deck without strong rotational support at ends

= $0{,}7 \cdot \ell_0$ for deck transverse primary supporting member arranged above the deck without strong rotational support at ends

e = spacing of deck transverse primary supporting members [m], as defined in Section 10

I_{st} = net moment of inertia [cm^4], of longitudinal or stiffener necessary to satisfy the lateral buckling mode:

$$= \frac{\sigma_{st} \cdot A \cdot e^2}{0,001 \cdot E} \quad [cm^4]$$

σ_{st} = $1,18 \cdot \sigma_{hg-cp}$ [N/mm^2] for $\sigma_E < 0,5 \cdot R_{eH}$

= $\dfrac{R_{eH}^2}{4\left(R_{eH} - 1,18 \cdot \sigma_{hg-cp}\right)}$ [N/mm^2] for $\sigma_E > 0,5 \cdot R_{eH}$

σ_E = $0,001 \cdot \dfrac{E \cdot I_A}{A \cdot e^2}$ [N/mm^2]

I_A = net moment of inertia of the stiffener [cm^4], about the axis perpendicular to the expected direction of buckling

A = net cross sectional area of the stiffener including effective attached plate [cm^2]

R_{eH} = specified minimum yield stress of the material of the attached plate [N/mm^2]

σ_{hg-cp} = maximum compressive stress [N/mm^2], in considered deck

Alternatively, direct assessment of the buckling strength of the deck primary supporting members may be used, e.g. buckling strength derived from overall eigenvalue (elastic buckling stress) of a deck grillage structure obtained from finite element analysis. The allowable utilisation factors for overall buckling of deck primary supporting members are:

η_{all} = 0,72 for acceptance criterion AC-I

η_{all} = 0,90 for acceptance criteria AC-II and AC-III

4. Buckling Requirements for Direct Strength Analysis

4.1 General

4.1.1 These requirements apply for the buckling assessment of direct strength analysis subjected to compressive stress, shear stress and lateral pressure.

(IACS UR S35. Sec.4, 1.1.1)

4.1.2 All structural elements in the FE analysis are to be assessed individually. The buckling checks are to be performed for the following structural elements:

— stiffened and unstiffened panels, including curved panels

— web plates in way of openings

— corrugated bulkheads

— vertically stiffened side shell, between hopper and topside tanks, of single-side skin ships

— struts, pillars and cross ties

(IACS UR S35. Sec.4, 1.1.2)

4.1.3 Verification of buckling strength in accordance with the following requirements is also applicable for the structure analysed by beam elements when structural elements are subjected to compressive and shear stresses.

4.2 Stiffened and unstiffened panels

4.2.1 General

.1 The plate panels of hull structure are to be modelled as stiffened or unstiffened panels. Method A or Method B as defined in 1.3.8.1 is to be used according to Table 3.7.

(IACS UR S35. Sec.4, 2.1.1)

Table 3.7 Selection of structural members for direct strength analysis panels

Structural elements	Assessment method	Normal panel definition
Longitudinal structure (see Fig. 3.13, Fig. 3.14 and Fig. 3.19)		
Longitudinally stiffened panels Shell envelope Deck Inner hull Hopper tank sides Longitudinal bulkheads	SP-A	length: between web frames width: between primary supporting members
Double bottom longitudinal girders in line with longitudinal bulkheads or connected to hopper tank sides	SP-A	length: between web frames width: full web depth
Web of double bottom longitudinal girders not in line with longitudinal bulkheads or not connected to hopper tank sides	SP-B	length: between web frames width: full web depth
Web of horizontal girders in double side spaces connected to hopper tank sides	SP-A	length: between web frames width: full web depth
Web of horizontal girders in double side spaces not connected to hopper tank sides	SP-B	length: between web frames width: full web depth
Web of single skin longitudinal girders or stringers	UP-B	plate between local stiffeners/face plate/PSM
Transverse structure (see Fig. 3.15, Fig. 3.16, Fig. 3.17, Fig. 3.20 and Fig. 3.23)		
Web of transverse deck frames, including brackets	UP-B	plate between local stiffeners/face plate/PSM
Vertical web in double side spaces	SP-B	length: full web depth width: between primary supporting members
Irregularly stiffened panels, e.g. web panels in way of hopper tanks and bilges	UP-B	plate between local stiffeners/face plate/PSM
Double bottom floors	SP-B	length: full web depth width: between primary supporting members
Vertical web frames, including brackets	UP-B	plate between vertical web stiffeners/face plate/PSM
Cross tie web plates	UP-B	plate between vertical web stiffeners/face plate/PSM
Transverse watertight bulkheads (see Fig. 3.18, Fig. 3.21 and Fig. 3.22)		
Regularly stiffened bulkhead panels including the secondary buckling stiffeners perpendicular to the regular stiffeners (such as carlings)	SP-A	length: between primary supporting members width: between primary supporting members
Irregularly stiffened bulkhead panels, e.g. web panels in way of hopper tanks and bilges	UP-B	plate between local stiffeners/face plate
Web plate of bulkhead stringers, including brackets	UP-B	plate between web stiffeners/face plate
Transverse corrugated bulkheads and cross deck		
Cross deck	SP-A	plate between local stiffeners/PSM
Notes: *SP, UP : stiffened panel and Unstiffened panel, respectively* *A,B : method A and Method B, respectively* *PSM : Primary Supporting Member*		

.2 Average thickness of plate panel

Where the plate thickness along a plate panel is not constant, the panel used for the buckling assessment is to be modelled according to the applicable Rules, with a weighted average thickness t_{avr} [mm], taken as:

$$t_{avr} = \frac{\sum_{n}^{i=1} A_i \cdot t_i}{\sum_{n}^{i=1} A_i} \quad [mm^4]$$

where:

A_i = area of the i-th plate element [mm^2]
t_i = net thickness of the i-th plate element [mm]
n = number of finite elements defining the buckling plate panel

(IACS UR S35. Sec.4, 2.1.2)

.3 Yield stress of plate panel and stiffener

The plate panel yield stress R_{eH_P} [N/mm^2], of a plate panel is taken as the minimum value of the specified yield stresses of the elements within the plate panel.

The stiffener yield stress R_{eH_S} [N/mm^2], is taken as the minimum value of the specified yield stresses of the elements within the stiffener.

(IACS UR S35. Sec.4, 2.1.3)

4.2.2 Stiffened panels

.1 For a stiffened panel (SP), each stiffener with attached plate is to be idealized as a stiffened panel model of the extent defined in the Table 3.7.

.2 If the stiffener properties or stiffener spacing varies within the stiffened panel, the calculations are to be performed separately for all configurations of the panels, i.e. for each stiffener and plate between the stiffeners. Plate thickness, stiffener properties, and stiffener spacing at the considered location are to be assumed for the whole panel.

.3 The buckling check of the stiffeners of stiffened panels is only applicable to the stiffeners fitted along the longer side edges of the buckling panel.

(IACS UR S35. Sec.4, 2.3)

4.2.3 Unstiffened panels

.1 Irregular plate panel

In way of web frames and brackets, the geometry of the panel (i.e. plate bounded by web stiffeners/face plate) may not have a rectangular shape. In this case, for FE analysis, an equivalent rectangular panel is to be defined according to 4.2.3.2 for irregular geometry and 4.2.3.3 for triangular geometry and to comply with buckling assessment.

(IACS UR S35. Sec.4, 2.3.1)

.2 Modelling of an unstiffened panel with irregular geometry

Unstiffened panels with irregular geometry are to be idealised to equivalent rectangular panels for plate buckling assessment according to the following procedure:

1) The four corners closest to a right angle (90°) in the bounding polygon for the plate are identified as shown in Fig. 3.10a).

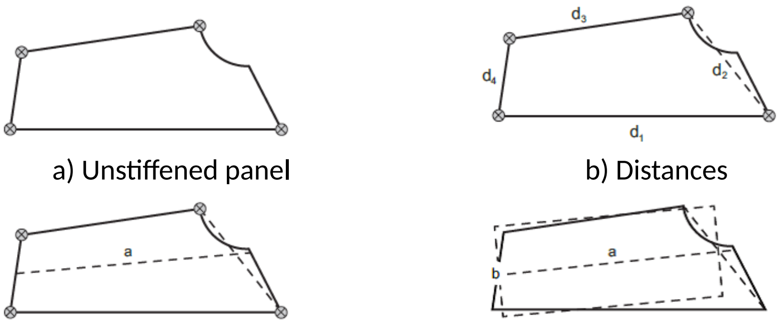
2) The distances along the plate bounding polygon between the corners (as shown in Fig. 3.10b)) are calculated, i.e. the sum of all the straight line segments between the end points.

3) The pair of opposite edges with the smallest total length is identified, i.e. the minimum of (d_1 + d_3) and (d_2 + d_4)

4) A line joins the middle points of the chosen opposite edges as shown in Fig. 3.10c) (a middle point is defined as the point at half the distance from one end). This line defines the longitudinal direction for the capacity model. The length of the line defines the length a of the capacity model, measured from one end point.

5) The length b of the shorter side, in mm, as shown in Fig. 3.10d), is to be taken as: b = A/a
where:
A = area of the plate [mm²]
a = length [mm], defined in item 4).

6) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel. These stresses are to be used for the buckling assessment.



a) Unstiffened panel
b) Distances
c) Join line a
d) Side b

Figure 3.10 Irregular unstiffened panel modelling

(IACS UR S35. Sec.4, 2.3.2)

.3 Modelling of an unstiffened panel with triangular geometry

Unstiffened panels with triangular geometry are to be idealised to equivalent rectangular panels for plate buckling assessment according to the following procedure:

1) Medians are constructed as shown in Fig. 3.11a).

2) The longest median is identified as shown in Fig. 3.11b). This median, the length of which is ℓ_1 [mm], defines the longitudinal direction for the capacity model.

3) The width ℓ_1 of the model [mm], as shown in Fig. 3.11c), is to be taken as: ℓ_2 = A/ℓ_1
where:
A = area of the plate [mm²]

4) The lengths of the shorter side b and the longer side a [mm], of the equivalent rectangular panel are to be taken as:

$$b = \frac{\ell_2}{C_{tri}}$$

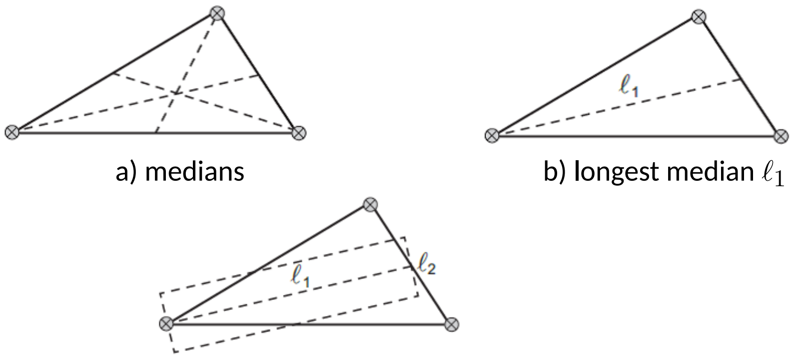
$$a = \ell_1 \cdot C_{tri}$$

where:

C_{tri} = 0,4 + 0,6

5) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel. These stresses are to be used for the buckling assessment.

(IACS UR S35. Sec.4, 2.3.3)



a) medians

b) longest median ℓ_1

c) width ℓ_2 of the model

Figure 3.11 Triangular unstiffened panel modelling

4.2.4 Reference stresses

.1 The stress distribution is to be taken from the direct strength analysis and applied to the buckling model.

.2 The reference stresses are to be calculated using the stress based reference stresses, as defined in 6.

(IACS UR S35. Sec.4, 2.4)

4.2.5 Lateral pressure

.1 The lateral pressure applied to the direct strength analysis is also to be applied to the buckling assessment unless otherwise stated in the applicable Sections.

(IACS UR S35. Sec.4, 2.5.1)

.2 Where the lateral pressure is not constant over a buckling panel defined by a number of finite plate elements, an average lateral pressure P_{avr} [N/mm^2], is calculated using the following formula:

$$P_{avr} = \frac{\sum_n^{i=1} A_i \cdot P_i}{\sum_n^{i=1} A_i} \quad [N/mm^2]$$

where:

A_i	=	area of the i-th plate element [mm^2]
P_i	=	lateral pressure of the i-th plate element [N/mm^2]
n	=	number of finite elements defining the buckling panel

(IACS UR S35. Sec.4, 2.5.1)

4.2.6 Buckling Criteria

.1 UP-A

The compressive buckling strength of UP-A is to satisfy the following criterion:

$$\eta_{UP-A} \leq \eta_{all}$$

where:

η_{UP-A}	=	maximum plate panel utilisation factor calculated according to Method A, as defined in 5.2.2

(IACS UR S35. Sec.4, 2.6.1)

.2 UP-B

The compressive buckling strength of UP-B is to satisfy the following criterion:

$$\eta_{UP-B} \leq \eta_{all}$$

where:

η_{UP-B} = maximum plate panel utilisation factor calculated according to Method B, as defined in 5.2.2.

(IACS UR S35. Sec.4, 2.6.2)

.3 SP-A

The compressive buckling strength of SP-A is to satisfy the following criterion:

$$\eta_{SP-A} \leq \eta_{all}$$

where:

η_{SP-A} = maximum stiffened panel utilisation factor taken as the maximum of:

- the overall stiffened panel capacity, as defined in 5.2.1
- the plate capacity calculated according to Method A, as defined in 5.2.2
- the stiffener buckling strength as defined in 5.2.3, considering separately the properties (thickness, dimensions), the pressures defined in 4.2.5.2 and the reference stresses of each EPP at both sides of the stiffener.

Note 1:
The stiffener buckling capacity check can only be fulfilled when the overall stiffened panel capacity, as defined in 5.2.1, is satisfied.

(IACS UR S35. Sec.4, 2.6.3)

.4 SP-B

The compressive buckling strength of SP-B is to satisfy the following criterion:

$$\eta_{SP-B} \leq \eta_{all}$$

where:

η_{SP-B} = maximum stiffened panel utilisation factor taken as the maximum of:

- the overall stiffened panel capacity, as defined in 5.2.1
- the plate capacity calculated according to Method B, as defined in 5.2.2
- the stiffener buckling strength as defined in 5.2.3, considering separately the properties (thickness, dimensions), the pressures defined in 4.2.5.2 and the reference stresses of each EPP at both sides of the stiffener.

Note 1:
The stiffener buckling capacity check can only be fulfilled when the overall stiffened panel capacity, as defined in 5.2.1, is satisfied.

(IACS UR S35. Sec.4, 2.6.4)

.5 Web plate in way of openings

The web plate of primary supporting members in way of openings is to satisfy the following criterion:

$$\eta_{opening} \leq \eta_{all}$$

where:

$\eta_{opening}$ = Maximum web plate utilisation factor in way of openings, as defined in 5.2.4

(IACS UR S35. Sec.4, 2.6.5)

4.3 Corrugated bulkheads

4.3.1 General

.1 Three buckling failure modes are to be assessed on corrugated bulkheads:

— corrugation overall column buckling

— corrugation flange panel buckling

— corrugation web panel buckling

4.3.2 Reference stresses

.1 Each corrugation flange and web panel is to be assessed.

.2 The membrane stresses at element centroid are to be used.

.3 For the application of this requirement:

b = width of the considered member (flange or web) of the corrugation.

The maximum normal stress σx parallel to the corrugation is the maximum of the two following stresses:

— the normal stress parallel to the corrugation taken at b/2 from the corrugation ends

— the normal stress parallel to the corrugation within the mid-span of the corrugation.

When a corrugation end is fitted with a shedder plate, the normal stress parallel to the corrugation at this end is to be taken at b/2 from the intersection of the shedder plate with the point at mid-breadth of the flange or of the web, as the case may be.

The maximum shear stress is the shear stress which is maximum at the corrugation flange or web at the point b/2 from ends as defined above for the normal stress parallel to the corrugation.

The in-plane stresses σx and σy and the shear stress τ are to be taken as the element stresses averaged over the width of the considered member (flange or web) at the considered location.

When the stress value at b/2 from ends cannot be obtained directly from FEA element, the stress at this location is to be obtained by interpolation. This interpolation is to be made on elements extending over a distance equal to 3 b at a point located at b/2 from the end of the corrugation or from the intersection of the shedder plate if fitted, measured at mid-breadth of the flange or of the web. The interpolation of the in-plane stresses σ_x and σ_y is to be made in accordance with 6.2.1.

The shear stress at b/2 is obtained by linear interpolation between the elements the closest to b/2 location.

.4 Where more than one plate thickness is used for a flange or web panel, the maximum stress is to be obtained for each thickness range and is to be checked with the buckling criteria for each thickness.

4.3.3 Overall column buckling

.1 The overall buckling failure mode of corrugated bulkheads subjected to axial compression shall be checked for column buckling, e.g. horizontally corrugated bulkheads and vertically corrugated bulkheads subjected to local vertical forces, see Table 3.8.

Table 3.8 Application of overall column buckling for corrugated bulkhead

Bulkhead orientation	Corrugation orientation	
	Horizontal	Vertical
Longitudinal or Transverse bulkhead	Required	Required, when subjected to local vertical forces, e.g. crane loads

.2 Each corrugation unit within the extension of half flange, web and half flange, i.e. single corrugation as shown in grey in Fig. 3.12, shall comply with:

$$\eta_{overall} \leq \eta_{all}$$

where:

$\eta_{overall}$ = maximum overall column utilisation factor, see 5.3.1, considered as a pillar with an unsupported length taken as the length of the corrugation except for vertically corrugated bulkheads where the length, ℓ, shall be applied as defined in C.2

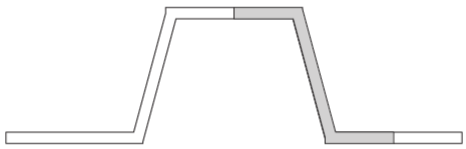


Fig. 3.12 Single corrugation

.3 End constraint factor, fend corresponding to pinned ends shall be applied except for fixed end support to be used in way of stool with width exceeding 2 times the depth of the corrugation.

4.3.4 Local buckling

.1 The compressive buckling strength of a unit flange and a unit web of corrugation bulkheads shall comply with:

$$\eta_{Corr} \leq \eta_{all}$$

where:

η_{Corr} = maximum unit flange or unit web utilisation factor, see 5.3.2

Two stress combinations shall be considered:

- the maximum normal stress parallel to the corrugation plus the shear stress at the location where the maximum normal stress parallel to the corrugation occurs
- the maximum shear stress plus the normal stress parallel to the corrugation at the location where the maximum shear stress occurs.

The buckling assessment shall be performed for an aspect ratio α equal to 2, and for the thickness of the member where the maximum compressive/shear stress occurs, see 4.3.2.4.

4.4 Vertically stiffened side shell of single-side skin ships

4.4.1 Buckling criteria

.1 Plating

The compressive buckling strength of the vertically stiffened side shell plating of single-side skin ships, between hopper and topside tanks, is to satisfy the following criterion:

$$\eta_{vsp} \leq \eta_{all}$$

where:

η_{vsp} = maximum utilization factor calculated according to method A as defined in 1.3.8 and considering the following boundary conditions and stress combinations:

1) 4 edges simply supported, see load cases 1, 2 and 15 in Table 3.12:

   — Pure vertical stress:
   The maximum vertical stress of stress elements is used with $\alpha = 1$ and $\psi_x = 1$

   — Maximum vertical stress combined with longitudinal and shear stress:
   The maximum vertical stress in the buckling panel plus the shear and longitudinal stresses at the location where the maximum vertical stress occurs is used with $\alpha = 2$ and $\psi_x = \psi_y = 1$
   The plate thickness to be considered in the buckling strength check is the one where the maximum vertical stress occurs.

   — Maximum shear stress combined with longitudinal and vertical stress:
   The maximum shear stress in the buckling panel plus the longitudinal and vertical stresses at the location where maximum shear stress occurs is used with $\alpha = 2$ and $\psi_x = \psi_y = 1$
   The plate thickness to be considered in the buckling strength check is the one where the maximum shear stress occurs.

2) The 2 shorter edges of the plate panel clamped, see load cases 11, 12 and 16 in Table 3.12:

   — Distributed longitudinal stress associated with vertical and shear stress:
      — the actual size of the buckling panel is used to define α
      — the average values for longitudinal, vertical and shear stresses shall be used $\psi_x = \psi_y = 1$
      — the plate thickness to be considered in the buckling strength check is based on 3.1.3.

.2 Side frames

The buckling strength of side frames of single-side skin ships, between hopper and topside tanks, is to satisfy the following criterion:

$$\eta_{Stiffener} \leq \eta_{all}$$

where:

$\eta_{Stiffener}$ = Maximum stiffener utilisation factor, as defined in 5.2.3

4.5 Struts, pillars and cross ties

4.5.1 Buckling criteria

.1 The compressive buckling strength of struts, pillars and cross ties is to satisfy the following criterion:

$$\eta_{Pillar} \leq \eta_{all}$$

The buckling strength of elementary plate panels of cross ties is to satisfy the following criterion:

$$\eta_{Plate} \leq \eta_{all}$$

where:

η_{Pillar} = Maximum utilisation factor of struts, pillars or cross ties, as defined in 5.3.1
η_{Plate} = Maximum plate utilisation factor calculated according to UP-B, as defined in 5.2.2

.2 The buckling strength of pillars subject to axial force and bending moments may be required to be checked based on direct calculations. The buckling criterion is to be especially considered by BKI.

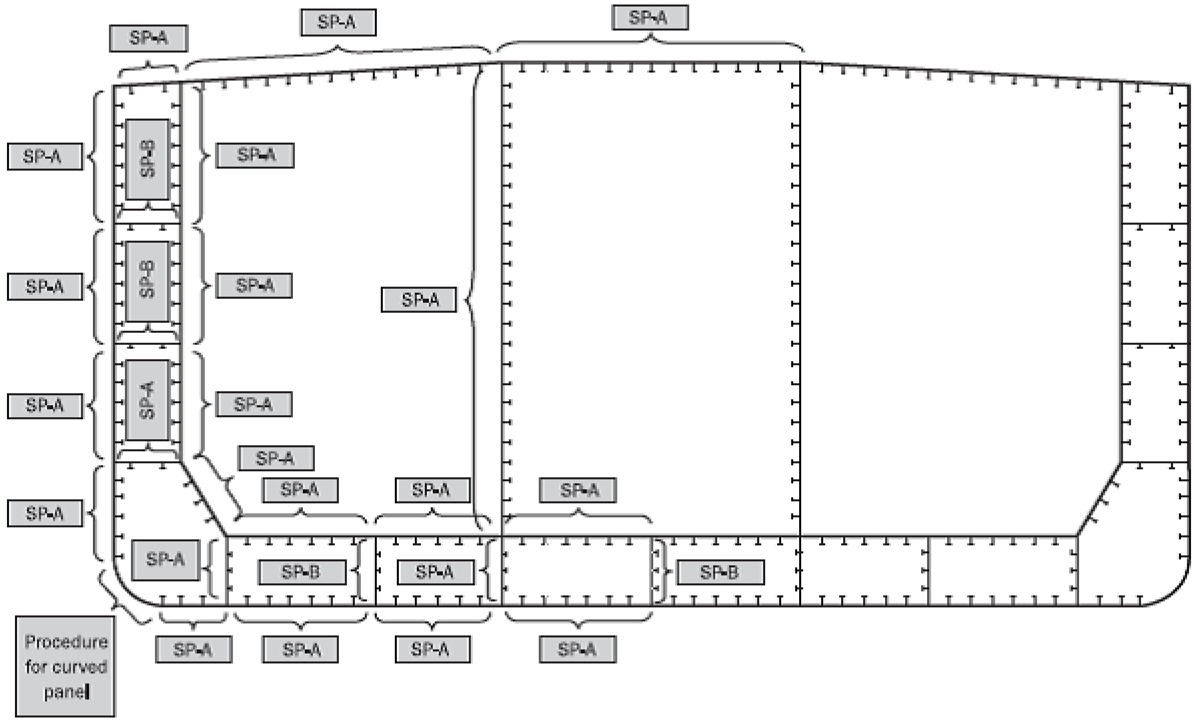


Fig. 3.13 Longitudinal plates for double bottom offshore units

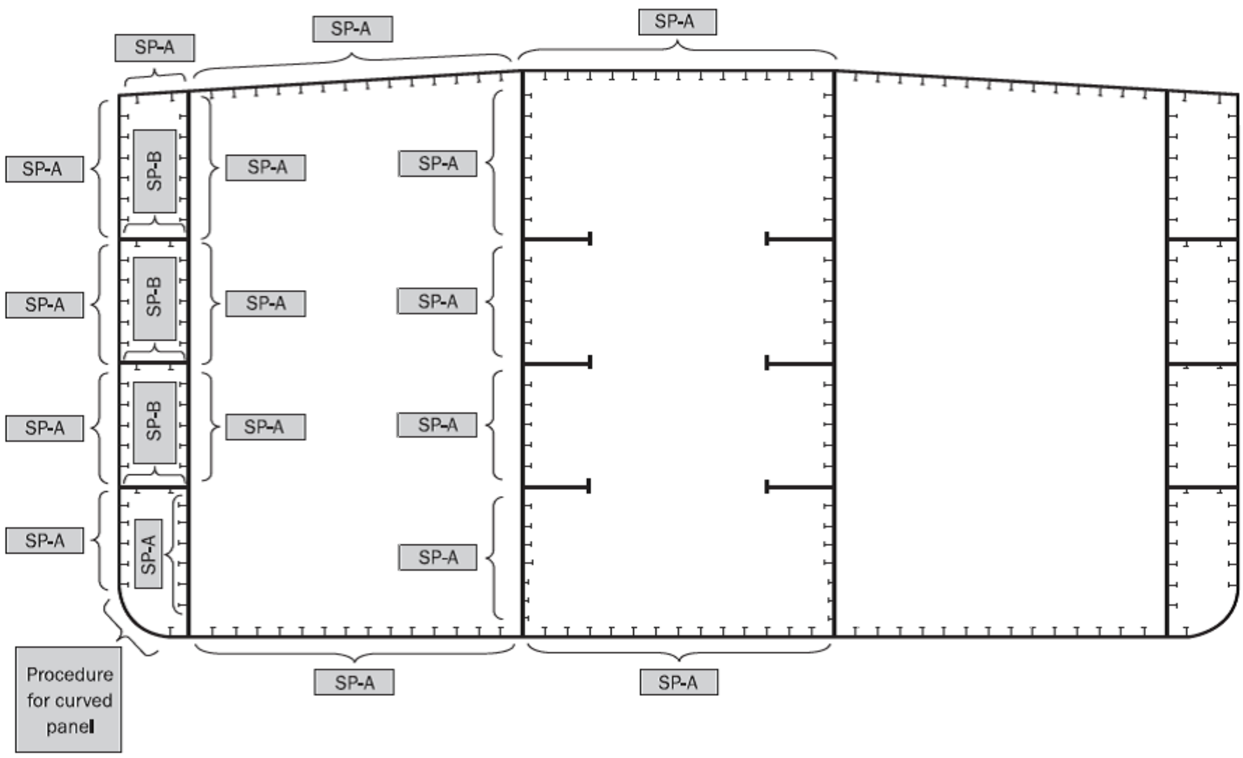


Fig. 3.14 Longitudinal plates for single bottom offshore units

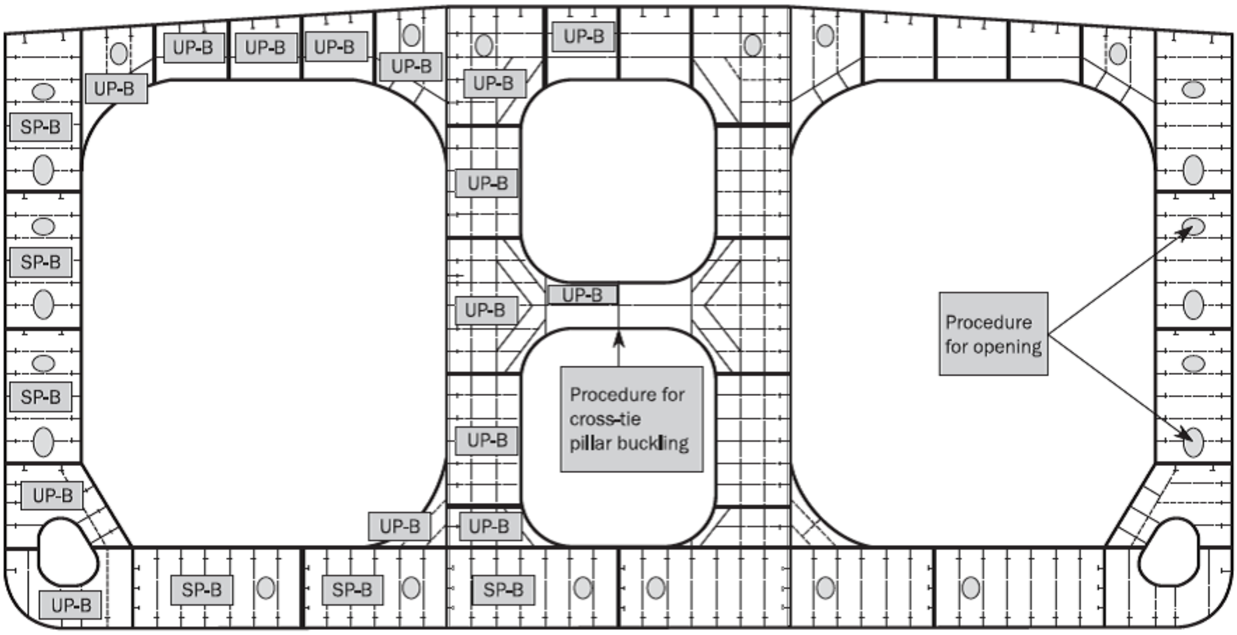


Fig. 3.15 Transverse web frames for double bottom offshore units

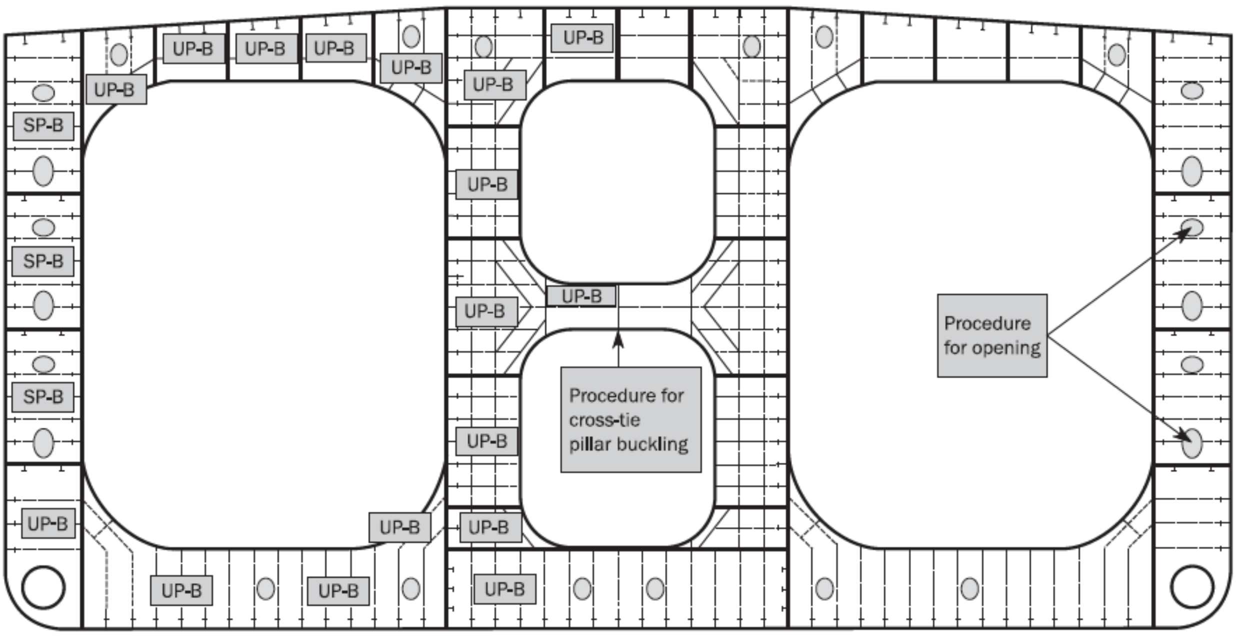


Fig. 3.16 Transverse web frames for single bottom offshore units

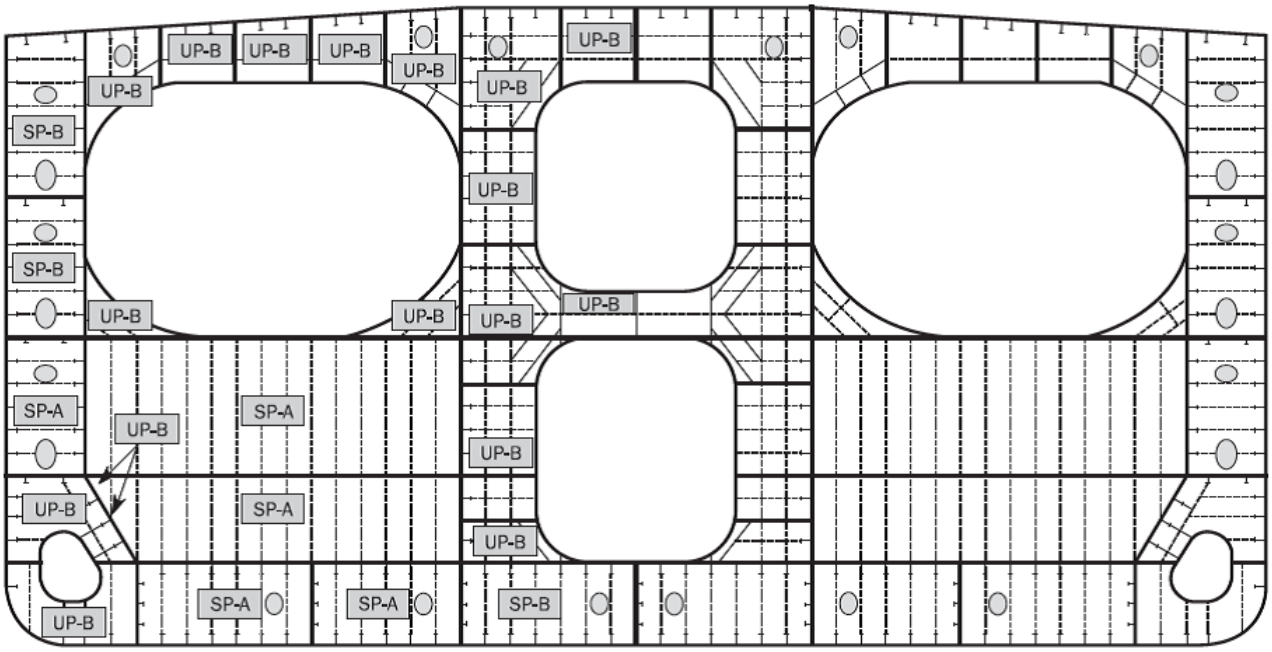


Fig. 3.17 Cross tie

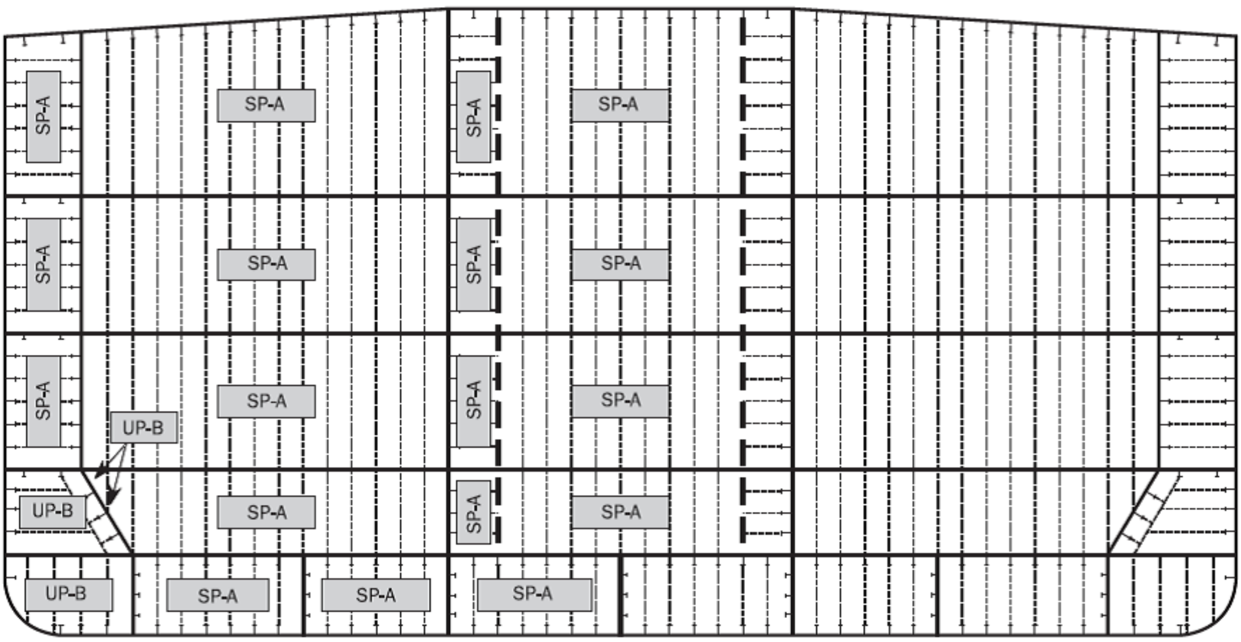


Fig. 3.18 Transverse bulkhead for offshore units

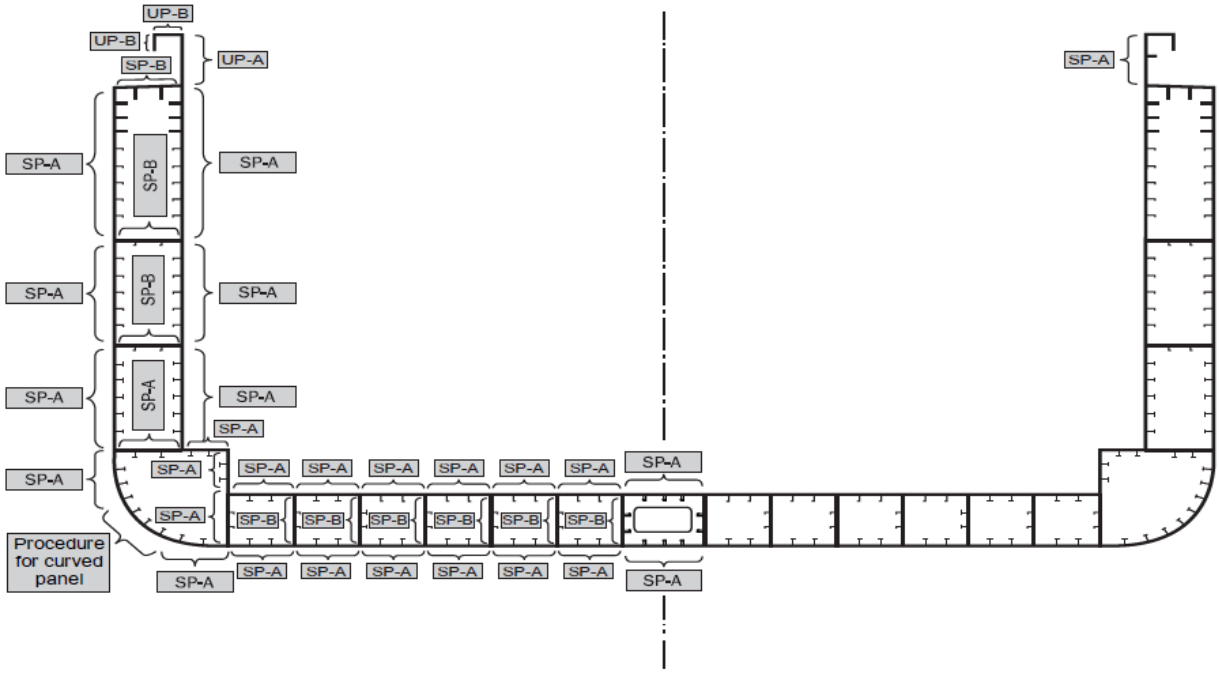


Fig. 3.19 Longitudinal plates for container ships

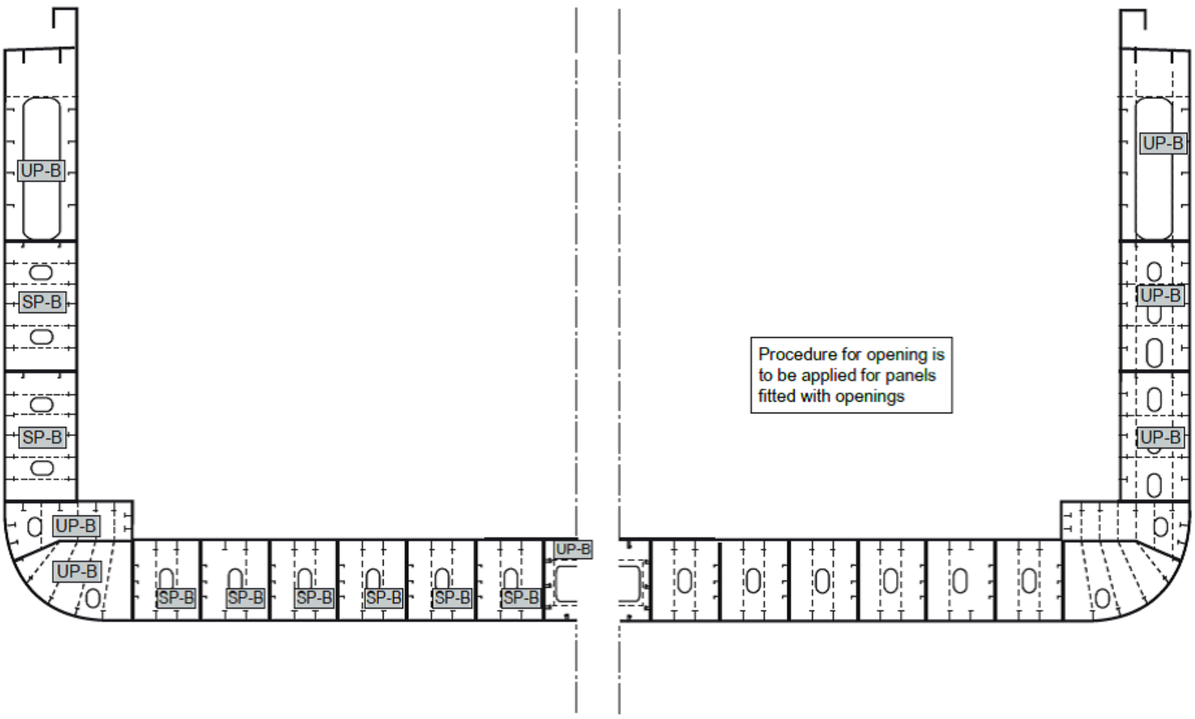


Fig. 3.20 Transverse web frames for container ships

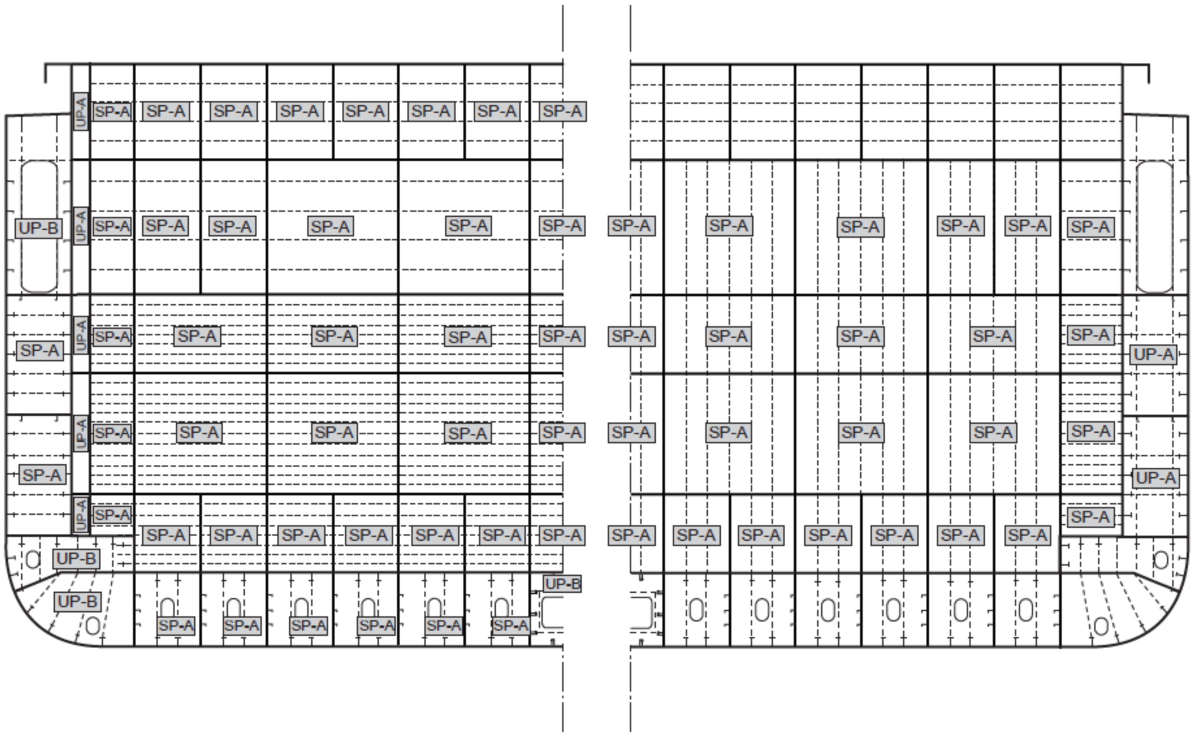


Fig. 3.21 Transverse bulkhead for container ships

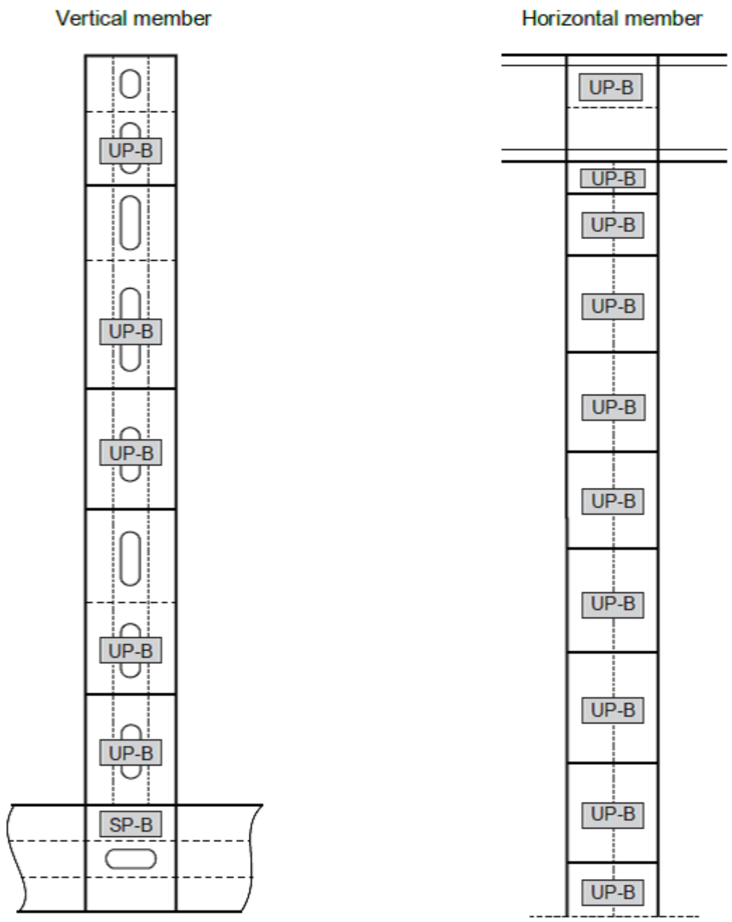


Fig. 3.22 Bulkhead internal members for container ships

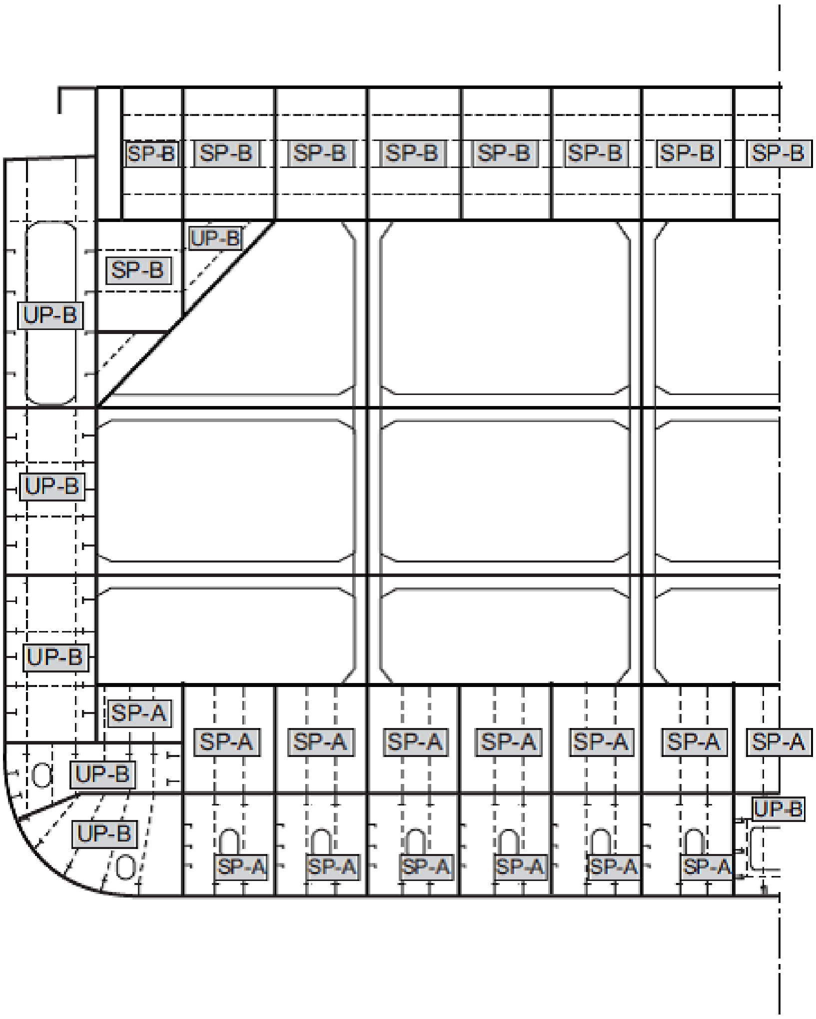


Fig. 3.23 Support bulkhead for container ships

5. Buckling Capacity

5.1 General

5.1.1 These requirements contain the methods for determination of the buckling capacity of plate panels, stiffeners, primary supporting members, struts, pillars, cross ties and corrugated bulkheads.

(IACS UR S35. Sec.5, 1.1.1)

5.1.2 For the application of this Sub-Section, the stresses σ_x, σ_y and τ applied on the structural members are defined in:

- 3. for the prescriptive requirements
- 4. for the FE analysis requirements

(IACS UR S35. Sec.5, 1.1.2)

5.1.3 Ultimate buckling capacity

The ultimate buckling capacity is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until the interaction formulae defined in 5.2.1.1, 5.2.2.1 and 5.2.3.4 are equal to 1,0.

(IACS UR S35. Sec.5, 1.1.3)

5.1.4 Buckling utilisation factor

The buckling utilisation factor η of the structural member is equal to the highest utilisation factor obtained for the different buckling modes.

(IACS UR S35. Sec.5, 1.1.4)

5.1.5 Lateral pressure

The lateral pressure is to be considered as constant in the buckling strength assessment.

(IACS UR S35. Sec.5, 1.1.5)

5.1.6 Definitions

A_p = net sectional area of the stiffener attached plating [mm^2]

= $s \cdot t_p$ [mm^2]

s = stiffener spacing [mm]

A_s = net sectional area of the stiffener without attached plating [mm^2]

a = length of the longer side of the plate panel [mm]

b = breadth of the shorter side of the plate panel [mm]

b_m = effective width of the attached plating of a stiffener [mm], as defined in 5.2.3.5

b_{m1} = effective width of the attached plating of a stiffener [mm], without the shear lag effect:

for $\sigma_x > 0$

$b_{m1} = \dfrac{\kappa_{x_1} \cdot b_1 + \kappa_{x_2} \cdot b_2}{2}$ [mm] for prescriptive assessment

$b_{m1} = \kappa_x \cdot b$ [mm] for FE analysis

for $\sigma_x \leq 0$

$b_{m1} = b$ [mm]

b_f = breadth of the stiffener flange [mm]

b_1, b_2 = width of plate panel on each side of the considered stiffener [mm]

κ_{x1}, κ_{x2} = reduction factor defined in Table 3.12 calculated for the EPP1 and EPP2 on each side of the considered stiffener according to load case 1

d = length [mm], of the side parallel to the axis of the cylinder corresponding to the curved plate panel, as shown in Table 3.13

d_f = distance [mm], for the extension of flange for L2 profiles, as shown in Fig. 3.5

e_f = distance [mm], from the attached plating to the flange centre, as shown in Fig. 3.5, depending on the profile type:

= h_w for flat bars

= $h_w - 0{,}5 \cdot t_f$ for bulb bars

= $h_w + 0{,}5 \cdot t_f$ for angle bars, T-bars and L2 bars

F_{long} = coefficient defined in 5.2.2.2

F_{tran} = coefficient defined in 5.2.2.3

h_w	=	depth of stiffener web [mm], as shown in Fig. 3.5.
ℓ	=	span [mm], of stiffener equal to spacing between primary supporting members or span of side frame equal to the distance between the hopper tank and top wing tank in way of the side shell.
R	=	radius of curved plate panel [mm]
α	=	aspect ratio of single plate field
	=	$\frac{a}{b}$
β	=	$\frac{1 - \psi}{\alpha}$
ω	=	coefficient
	=	min (3; α)
t	=	net thickness of plate [mm]
	=	$t_a - t_k$
t_a	=	plate thickness as built [mm]
t_k	=	corrosion addition according to K [mm]
t_w	=	net thickness of the stiffener web [mm]
t_f	=	net thickness of the stiffener flange [mm]
x-axis	=	for a rectangular buckling panel, local axis parallel to its long edge
y-axis	=	for a rectangular buckling panel, local axis perpendicular to its long edge
σ_x	=	membrane stress in x-direction [N/mm^2]
σ_y	=	membrane stress in y-direction [N/mm^2]
σ_1	=	maximum stress [N/mm^2], along a panel edge
σ_2	=	minimum stress [N/mm^2], along a panel edge
τ	=	shear stress in the x-y plane [N/mm^2]
ψ	=	edge stress ratio according to Table 3.12
σ_E	=	elastic buckling stress [N/mm^2]
	=	$0{,}9 \cdot E \left(\frac{t}{b}\right)^2$ [N/mm^2] for the application of plate limit state [5.2.2.1]
	=	$0{,}9 \cdot E \left(\frac{t}{d}\right)^2$ [N/mm^2] for the application of curved plate panels [5.2.2.4]
E	=	Young's modulus
	=	$2{,}06 \cdot 10^5$ [N/mm^2] for steel
	=	$0{,}69 \cdot 10^5$ [N/mm^2] for aluminium alloys
R_{eH}	=	nominal yield point [N/mm^2] for hull structural steels according to Section 2, B.2
	=	0,2 % proof stress [N/mm^2] for aluminium alloys
	=	1,0 % proof stress [N/mm^2] for austenitic steels and austenitic-ferritic (=duplex) steel

See also Rules for Materials (Pt.1, Vol.V).

R_{eH_P} = specified minimum yield stress of the plate [N/mm^2]

R_{eH_S} = specified minimum yield stress of the stiffener [N/mm^2]

S = safety factor

= 1,1 in general

= 1,2 for structures which are exclusively exposed to local concentrated loads

= 1,05 for stiffeners located on the hatchway coamings, the sloping plate of the topside and hopper tanks, the inner bottom, the inner side if any, the side shell of single-side skin construction between hopper and topside tanks and the transverse bulkheads top and bottom stools of ships carrying dry cargo in bulk and having a length greater than 150 m

λ = reference degree of slenderness

$$= \sqrt{\frac{R_{eH}}{K \cdot \sigma_E}}$$

K = buckling factor according to Table 3.12 and 3.13

γ = stress multiplier factor acting on loads. When γ is such that the loads reach the interaction formulae:

= γ_c

γ_c = stress multiplier factor at failure

γ_{GEB} = stress multiplier factor of global elastic buckling capacity

(IACS UR S35. Sec.5, Symbols)

5.2 Buckling capacity of plates and stiffeners

5.2.1 Overall stiffened panel capacity

.1 The elastic stiffened panel limit state is based on the following interaction formula, which sets a precondition for the buckling check of stiffeners in accordance with 5.2.3.4:

$$\frac{\gamma}{\gamma_{GEB}} = 1$$

where the stress multiplier factor corresponding to global elastic buckling capacity, γ_{GEB}, is to be calculated based on the following formulae:

- for $\tau \neq 0$ and ($\sigma_x > 0$ or $\sigma_y > 0$) : $\gamma_{GEB} = \gamma_{GEB,bi+\tau}$
- for $\tau = 0$ and ($\sigma_x > 0$ or $\sigma_y > 0$) : $\gamma_{GEB} = \gamma_{GEB,bi}$
- for $\tau \neq 0$ and ($\sigma_x \leq 0$ and $\sigma_y \leq 0$) : $\gamma_{GEB} = \gamma_{GEB,\tau}$

where:

$\gamma_{GEB,bi+\tau}$, $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$ are stress multiplier factors for different load combinations as defined in 5.2.1.2, 5.2.1.3 and 5.2.1.4, respectively

(IACS UR S35. Sec.5, 2.1.1)

.2 The stress multiplier factor $\gamma_{GEB,bi}$ for the stiffened panel subjected to biaxial loads is taken as:

$$\gamma_{GEB,bi} = \frac{\pi^2}{L_{B1}^2 \cdot L_{B2}^2} \frac{\left[D_{11} \cdot L_{B2}^4 + 2\,(D_{12} + D_{33})\, n^2 \cdot L_{B1}^2 \cdot L_{B2}^2 + n^4 \cdot D_{22} \cdot L_{B1}^4\right]}{L_{B2}^2 \cdot N_x + n^2 \cdot L_{B1}^2 \cdot N_y}$$

where:

N_x = Load per unit length applied on the edge along x axis of the stiffened panel [N/mm]

= $\sigma_{x,\,av} \dfrac{A_p + A_s}{s}$ [N/mm]

s = stiffener spacing [mm]

= $b_1 + b_2$ [mm] for stiffened panels with U-type stiffeners

N_y = load per unit length applied on the edge along y axis of the stiffened panel [N/mm]

= $c \cdot \sigma_y \cdot t_p$ [N/mm]

L_{B1} = stiffener span [mm], equal to spacing between primary supporting members

= ℓ [mm] in general

= $0,8 \cdot \ell$ [mm] for vertically stiffened side shell of single side skin bulk carriers

L_{B2} = width of the stiffened panel [mm], taken as 6 times of the stiffener spacing, i.e. $6 \cdot s$

n = number of half waves along the direction perpendicular to the stiffener axis. The factor $\gamma_{GEB,bi}$ is to be minimized with respect to the wave parameter n, i.e. to be taken as the smallest value larger than zero

c = factor taking into account the stresses in the attached plating acting perpendicular to the stiffener axis:

= $0,5\,(1 + \Psi)$ for $0 \le \Psi \le 1$

= $\dfrac{1}{2(1-\psi)}$ for $\Psi < 0$

$\sigma_{x,av}$ = average stress for both plate and stiffener with Poisson correction, taken as:

= $\sigma_x - \upsilon \cdot c \cdot \sigma_y \cdot \dfrac{A_s}{(A_p + A_s)} \ge 0$ for $\sigma_x > 0$ or $\sigma_y > 0$

= σ_y for $\sigma_x \le 0$ or $\sigma_y \le 0$

D_{11}, D_{12}, D_{22}, D_{33} = Bending stiffness coefficients [Nmm], of the stiffened panel, defined in general as:

$$D_{11} = \frac{E \cdot I_{eff} \cdot 10^4}{s} \quad [\text{Nmm}]$$

$$D_{12} = \frac{E \cdot t_p^3 \cdot \nu}{12(1 - \nu^2)} \quad [\text{Nmm}]$$

$$D_{22} = \frac{E \cdot t_p^3}{12(1 - \nu^2)} \quad [\text{Nmm}]$$

$$D_{33} = \frac{E \cdot t_p^3 \cdot \nu}{12(1 + \nu^2)} \quad [\text{Nmm}]$$

For stiffened panels fitted with U-type stiffeners, D_{12} and D_{22} are defined as:

$$D_{12} = \upsilon \cdot D_{22} \quad [\text{Nmm}]$$

$$D_{22} = \frac{E \cdot t_p^3}{12(1 - \nu^2)} \left[1,2 + 4,8 \cdot \min\left(1,0\ \frac{b_1^2}{h_w(b_1 + b_2)}\right) \cdot \left(1,0 \left(\frac{t_w}{t_p}\right)^2\right)\right] \quad [\text{Nmm}]$$

h_w = breadth of U-type stiffener web [mm], as defined in Fig. 3.6

I_{eff} = moment of inertia [cm^4], of the stiffener including effective width of attached plating, the same as I defined in 5.2.3.4

(IACS UR S35. Sec.5, 2.1.2)

.3 The stress multiplier factor $\gamma_{GEB,\tau}$ for the stiffened panel subjected to pure shear load is taken as:

– for $D_{11}D_{22} \geq (D_{12} + D_{33})^2$:

$$\gamma_{GEB,\tau} = \frac{\sqrt[4]{D_{11}^3 D_{22}}}{(L_{B1}/2)^2\, N_{xy}} \left[8{,}125 + 5{,}64\sqrt{\frac{(D_{12} + D_{33})^2}{D_{11}D_{22}}} - 0{,}6\frac{(D_{12} + D_{33})^2}{D_{11}D_{22}}\right]$$

– for $D_{11}D_{22} < (D_{12} + D_{33})^2$:

$$\gamma_{GEB,\tau} = \frac{\sqrt{2D_{11}(D_{12} + D_{33})}}{(L_{B1}/2)^2\, N_{xy}} \left[8{,}30 + 1{,}525\frac{D_{11}D_{22}}{(D_{12} + D_{33})^2} - 0{,}493\frac{D_{11}^2 D_{22}^2}{(D_{12} + D_{33})^4}\right]$$

where:

N_{xy} = $\tau \cdot t_p$ [Nmm]

(IACS UR S35. Sec.5, 2.1.3)

.4 The stress multiplier factor $\gamma_{GEB,bi+\tau}$ for the stiffened panel subjected to combined loads is taken as:

$$\gamma_{GEB,bi+\tau} = \frac{1}{2}\gamma_{GEB,\tau}^2 \left[-\frac{1}{\gamma_{GEB,bi}} + \sqrt{\frac{1}{\gamma_{GEB,bi}^2} + 4\frac{1}{\gamma_{GEB,\tau}^2}}\right]$$

where $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$ are as defined in 5.2.1.2 and 5.2.1.3, respectively.

(IACS UR S35. Sec.5, 2.1.4)

5.2.2 Plate capacity

.1 Plate limit state

The plate limit state is based on the following interaction formulae:

$$\left(\frac{\gamma_{c1}\cdot\sigma_x\cdot S}{\kappa_x\cdot R_{eH}}\right)^{e_0} + \left(\frac{\gamma_{c1}\cdot\sigma_y\cdot S}{\kappa_y\cdot R_{eH}}\right)^{e_0} - B\left(\frac{\gamma_{c1}\cdot\sigma_x\cdot S}{\kappa_x\cdot R_{eH}}\right)^{e_0/2}\left(\frac{\gamma_{c1}\cdot\sigma_y\cdot S}{\kappa_y\cdot R_{eH}}\right)^{e_0/2} + \left(\frac{\gamma_{c1}\cdot|\tau|\cdot S\cdot\sqrt{3}}{\kappa_\tau\cdot R_{eH}}\right)^{e_0} = 1{,}0$$

$$\left(\frac{\gamma_{c2}\cdot|\sigma_x|\cdot S}{\kappa_x\cdot R_{eH}}\right)^{\frac{2}{\beta_p^{0,25}}} + \left(\frac{\gamma_{c2}\cdot|\tau|\cdot S\cdot\sqrt{3}}{\kappa_\tau\cdot R_{eH}}\right)^{\frac{2}{\beta_p^{0,25}}} = 1{,}0 \quad \text{for } \sigma_x \geq 0$$

$$\left(\frac{\gamma_{c3}\cdot|\sigma_y|\cdot S}{\kappa_y\cdot R_{eH}}\right)^{\frac{2}{\beta_p^{0,25}}} + \left(\frac{\gamma_{c3}\cdot|\tau|\cdot S\cdot\sqrt{3}}{\kappa_\tau\cdot R_{eH}}\right)^{\frac{2}{\beta_p^{0,25}}} = 1{,}0 \quad \text{for } \sigma_y \geq 0$$

$$\frac{\gamma_{c4}\cdot|\tau|\cdot S\cdot\sqrt{3}}{\kappa_\tau\cdot R_{eH}} = 1{,}0$$

γ_c = min [γ_{c1}; γ_{c2}; γ_{c3}; γ_{c4}]

$\eta_{Plate} = \dfrac{1}{\gamma_c}$

where:

$\gamma_{c1}; \gamma_{c2}; \gamma_{c3}; \gamma_{c4}$ = stress multiplier factors at failure for each of the above different limit states

γ_{c2} and γ_{c3} are to be considered only when $\sigma_x \geq 0$ and $\sigma_y \geq 0$, respectively

$\kappa_x, \kappa_y, \kappa_\tau$ = reduction factors are given in Table 3.12

when $\sigma_x \geq 0$ or $\sigma_y \geq 0$, $\kappa_x, \kappa_y, \kappa_\tau = 1$

for other cases, κ_y is calculated according to Table 3.12 using values of c_1 given in Table 3.10

B, e_0 = coefficients given in Table 3.9

β_p = plate slenderness parameter taken as:

$$= \frac{b}{t_p}\sqrt{\frac{R_{eH}}{E}}$$

(IACS UR S35. Sec.5, 2.2.1)

Table 3.9 Exponents e_0 and factor B

Applied stress	B	e_0
$\sigma_x \geq 0$ and $\sigma_y \geq 0$	$0{,}7 - 0{,}3\,\frac{\beta_p}{\alpha^2}$	$\frac{2}{\beta_p^{0,25}}$
$\sigma_x < 0$ and $\sigma_y < 0$	1,0	2,0

Table 3.10 Coefficient c_1

Plate panels	c_1
SP-A	max $\left[0; \left(1 - \frac{1}{\alpha}\right)\right]$
UP-A	
Vertically stiffened single-side skin between hopper and topside tanks	
Corrugations of corrugated bulkhead	
SP-B	1,0
UP-B	

.2 Correction factor F_{long}

The correction factor F_{long} depending on the edge stiffener types on the longer side of the buckling panel is defined in Table 3.11. An average value of F_{long} is to be used for the plate panels having different edge stiffeners. For stiffener types other than those mentioned in Table 3.11, the value of c is to be agreed by BKI. In such a case, a value of c higher than those mentioned in Table 3.11 can be used, provided it is verified by buckling strength check of panel using non-linear FEA and deemed appropriate by BKI.

(IACS UR S35. Sec.5, 2.2.4)

.3 Correction factor F_{tran}

The correction factor F_{tran} is to be taken as:

- For transversely framed EPP of single-side skin ships, between the hopper and top wing tank:
  - when the two adjacent frames are supported by one tripping bracket fitted in way of the adjacent plate panels:
    $F_{tran} = 1{,}25$
  - when the two adjacent frames are supported by two tripping brackets each fitted in way of the adjacent plate panels:
    $F_{tran} = 1{,}33$

- elsewhere:
  F_{tran} = 1,15

— For the attached plate of a U-type stiffener fitted on a hatch cover:
$F_{tran} = \max\,[3 - 0{,}08\,(F_{tran} - 6)^2;\ 1{,}0] \le 2{,}25$
where:

$$F_{tran} = \min\left[\frac{b_2}{b_1} + \frac{6 \cdot b_2^2}{\pi^2 \cdot h_w \cdot (b1 + b2)}\left(\frac{t_w}{t_p}\right)^3 ; 6\right] \quad \text{for EPP } b_2$$

$$F_{tran} = \min\left[\frac{b_1}{b_2} + \frac{6 \cdot b_1^2}{\pi^2 \cdot h_w \cdot (b1 + b2)}\left(\frac{t_w}{t_p}\right)^3 ; 6\right] \quad \text{for EPP } b_1$$

with b_1, b_2 and h_w as defined in Fig. 3.6

Coefficient F defined in Case 2 of Table 3.12 is to be replaced by the following formula:

$$F = \left[1 - \left(\frac{K_y}{0,91 \cdot F_{tran}} - 1\right)/\lambda_p^2\right] c_1 \ge 0$$

— For other cases:
F_{tran} = 1,0

(IACS UR S35. Sec.5, 2.2.5)

Table 3.11 Correction factor F_{long}

Structural element types			F_{long}	c
Unstiffened panel			1,0	-
Stiffened panel	Stiffener not fixed at both ends		1,0	-
	Stiffener fixed at both ends	Flat bar[1]	$F_{long} = c + 1$ for $\frac{t_w}{t_p} > 1$ $F_{long} = c\left(\frac{t_w}{t_p}\right)^3 + 1$ for $\frac{t_w}{t_p} \le 1$	0,10
		Bulb profile		0,30
		Angle and L2 profile		0,40
		T Profile		0,30
		Girder of high rigidity (e.g: bottom transverse)	1,4	-
		U-type profile fitted on hatch cover[2]	- Plate on which the U type stiffener is fitted, including EPP b_1 dan EPP b_2: for $b_2 < b_1$: F_{long} =1 for $b_2 \ge b_1$: $F_{long} = \left(1,55 - 0,55\frac{b_1}{b_2}\right)\left[1 + c\left(\frac{t_w}{t_p}\right)^3\right]$ - Other plate of the U-type profile: 1	0,20

[1] t_w is the net web thickness [mm], without the correction defined in 5.2.3.2
[2] b_1, b_2 and t_w are defined in Fig. 3.6

(IACS UR S35. Sec.5, Table 2)

Table 3.12 Plane Plate Fields

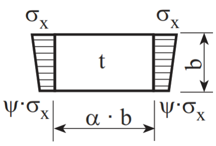
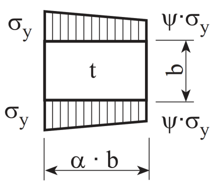
Load case	**Edge Stress ratio Ψ**	**Aspect ratio α**	**Buckling factor K**	**Reductions factor κ**
[1] 	$1 \geq \Psi \geq 0$	$\alpha \geq 1$	$K = F_{Long}\dfrac{8,4}{\Psi + 1,1}$	$\kappa_x = 1$ for $\lambda \leq \lambda_c$
	$0 > \Psi > -1$		$K = F_{Long}[7,63 - \Psi(6,26 - 10\Psi)]$	$\kappa_x = c\left(\dfrac{1}{\lambda} - \dfrac{1}{\lambda^2}\right)$ for $\lambda > \lambda_c$
	$\Psi \leq -1$		$K = F_{Long}\left[(1-\Psi)^2 \cdot 5,975\right]$	$C = (1,25 - 0,12.\Psi) \leq 1,25$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0,88}{c}}\right)$
[2] 	$1 \geq \Psi \geq 0$		$K = \dfrac{F_{tran} \cdot 2\left(1 + \frac{1}{\alpha^2}\right)^2}{1 + \Psi + \frac{(1-\Psi)}{100} + \left(\frac{2,4}{\alpha^2} + 6,9 \cdot f_1\right)}$	$\kappa_y = c\left(\dfrac{1}{\lambda} - \dfrac{R + F^2\,(H - R)}{\lambda^2}\right)$ $c = (1,25 - 0,12.\Psi) \leq 1,25$ $R = \lambda\left(1 - \dfrac{\lambda}{c}\right)$ for $\lambda < \lambda_c$ $R = 0,22$ for $\lambda \geq \lambda_c$ $F = \left(1 - \dfrac{\frac{K}{0,91} - 1}{\lambda_p^2}\right)$ $c_1 \geq 0$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0,88}{c}}\right)$ $\lambda_p^2 = \lambda^2 - 0,5 \quad 1 \leq \lambda_p^2 \leq 3$ c_1 as defined in Table 3.10 $H = \lambda - \dfrac{2.\lambda}{c\left(T + \sqrt{T^2 - 4}\right)} \geq R$ $T = \lambda + \dfrac{14}{15.\lambda} + \dfrac{1}{3}$
		$\alpha \leq 6$	$f_1 = (1 - \Psi)(\alpha - 1)$	
		$\alpha > 6$	$f_1 = 0,6\left(1 - \dfrac{6 \cdot \Psi}{\alpha}\right)\left(\alpha + \dfrac{14}{\alpha}\right)$ but not greater than: $14.5 - \dfrac{0,35}{\alpha^2}$	
	$1 - \dfrac{4\alpha}{3} \leq \psi < 0$		$K = \dfrac{200 \cdot F_{tran}\left(1 + \beta^2\right)^2}{(1 - f_3)\left(100 + 2,4\,\beta^2 + 6,9\,f_1 + 23\,f_2\right)}$	
		$\alpha > 6(1 - \Psi)$	$f_1 = 0,6\,\dfrac{1}{\beta} + 14\,\beta \leq (14,5 - 0,35\,\beta^2)$ $f_2 = f_3 = 0$	
		$3(1 - \Psi) \leq \alpha \leq 6(1 - \Psi)$	$f_1 = \dfrac{1}{\beta} - 1$ $f_2 = f_3 = 0$	
		$1,5(1 - \psi)$ $\alpha \leq 3(1 - \Psi)$	$f_1 = \dfrac{1}{\beta} - (2 - \omega\beta)^4$ $-9(\omega\beta - 1)\left(\dfrac{2}{3} - \beta\right)$ $f_2 = f_3 = 0$	
		$1 - \Psi \leq \alpha \leq 1,5(1 - \Psi)$	For $\alpha > 1,5$: $f_1 = 2\left(\dfrac{1}{\beta} - 16\left(1 - \dfrac{\omega}{3}\right)^4\right)$ $\left(\dfrac{1}{\beta} - 1\right)$ $f_2 = 3\,\beta - 2$ $f_3 = 0$ For $\alpha \leq 1,5$: $f_1 = 2\left(\dfrac{1,5}{1 - \Psi} - 1\right)\left(\dfrac{1}{\beta} - 1\right)$ $f_2 = \dfrac{\Psi\left(1 - 16\,f_4^2\right)}{1 - \alpha}$ $f_3 = 0$ $f_4 = [1,5 - \min(1,5;\alpha)]^2$	
		$0,75(1 - \Psi) \leq \alpha \leq (1 - \Psi)$	$f_1 = 0$ $f_2 = 1 + 2,31\,(\beta - 1) - 48\left(\dfrac{4}{3} - \beta\right) f_4^2$ $f_3 = 3 \cdot f_4(\beta - 1) - \left(\dfrac{f_4}{1,81} - \dfrac{\alpha - 1}{1,31}\right)$ $f_4 = [1,5 - \min(1,5;\alpha)]^2$	

Table 3.12 Plane Plate Fields *(continued)*

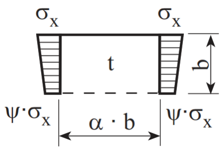
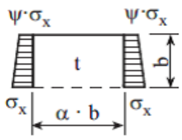
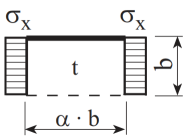
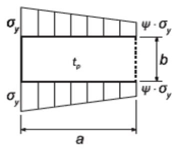
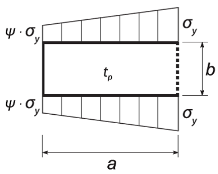
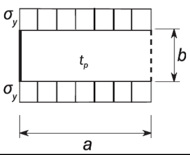
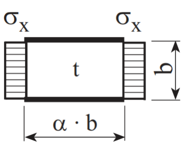
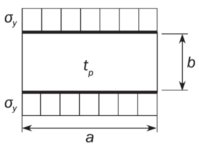
Load case	Edge Stress ratio ψ	Aspect ratio α	Buckling factor K	Reductions factor κ
	$\psi < \left(1 - \frac{4\,\alpha}{3}\right)$	$K = 5,972 \cdot F_{tran}\left(\frac{\beta^2}{1 - f_3}\right)$ where: $f_3 = f_5 \cdot \left(\frac{f_4}{1,81} - \frac{1+3\psi}{5,24}\right)$ $f_5 = \frac{9}{16}\,[1,5 - \min(1,5;\alpha)]^2$		
[3] 	$1 \geq \psi \geq 0$	$\alpha \geq 1$	$K = \frac{4\left(0,425 + \frac{1}{\alpha^2}\right)}{3 \cdot \psi + 1}$	For UP-A: $\kappa_x = 1$ for $\lambda \leq 0,75$ $\kappa_x = \frac{0,75}{\lambda}$ for $\lambda \leq 0,75$ For UP-B: $\kappa_x = 1$ for $\lambda \leq 0,7$ $\kappa_x = \frac{1}{\lambda^2 + 0,51}$ for $\lambda \leq 0,7$
	$0 > \psi > -1$		$K = 4\left(0,425 + \frac{1}{\alpha^2}\right)(1+\psi)$ $-5 \cdot \psi(1 - 3,42 \cdot \psi)$	
[4] 	$1 \geq \psi \geq -1$	$\alpha > 0$	$K = \left(0,425 + \frac{1}{\alpha^2}\right)\frac{3-\psi}{2}$	
[5] 	-	$\alpha \geq 1,64$	K = 1,28	
		$\alpha < 1,64$	$K = \frac{1}{\alpha^2} + 0,56 + 0,13\alpha^2$	
[6] 	$1 \geq \psi \geq 0$	$\alpha > 0$	$K = \frac{4\left(0,425 + \alpha^2\right)}{(3 \cdot \psi + 1)\,\alpha^2}$	$\kappa_y = 1$ for $\lambda \leq 0,7$ $\kappa_y = \frac{1}{\lambda^2 + 0,51}$ for $\lambda \leq 0,7$
	$0 > \psi \geq -1$		$K = 4\left(0,425 + \alpha^2\right)(1+\psi)\frac{1}{\alpha^2}$ $-5\psi(1 - 3,42 \cdot \psi)\frac{1}{\alpha^2}$	
[7] 	$0 > \psi > -1$	$\alpha > 0$	$K = \left(0,425 + \alpha^2\right)\frac{(3-\psi)}{2 \cdot \alpha^2}$	
[8] 	-	$\alpha > 0$	$K = 1 + \frac{0,56}{\alpha^2} + \frac{0,13}{\alpha^4}$	
[9] 	-	-	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 $\lambda > 0,83$
[10] 	-	-	$K = 4 + \frac{2,07}{\alpha^2} + \frac{0,67}{\alpha^4}$	$\kappa_y = 1$ for $\lambda \leq 0,83$ $\kappa_y = 1,13\left[\frac{1}{\lambda} - \frac{0,22}{\lambda^2}\right]$ for $\lambda > 0,83$

Table 3.12 Plane Plate Fields *(continued)*

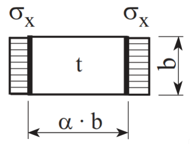
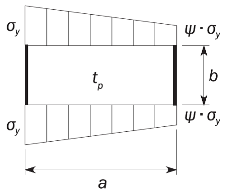
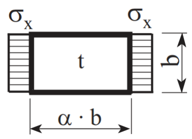
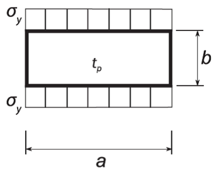
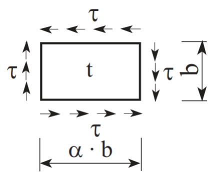
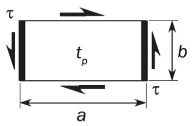
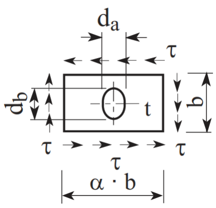
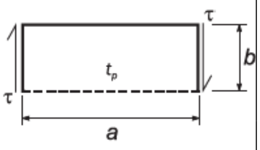
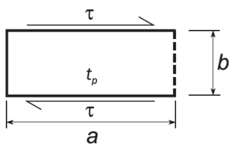
Load case	Edge Stress ratio Ψ	Aspect ratio α	Buckling factor K	Reductions factor κ
[11] 	-	$\alpha \geq 4$	K = 4	κ_x= 1 for $\lambda \leq$ 0,83
		$4 > \alpha > 1$	$K = 4 + \left[\frac{4-\alpha}{3}\right]^4 2,74$	$\kappa_x = 1,13\left[\frac{1}{\lambda} - \frac{0,22}{\lambda^2}\right]$ for $\lambda > 0,83$
[12] 	-	$\alpha < 2$		$\kappa_y = \kappa_{loadcase2}$
		$\alpha \geq 2$	K = $[K_{loadcase2}]^2$	$\kappa_y = \left(1,06 + \frac{1}{10 \cdot \alpha}\right) \kappa_{loadcase2}$
[13] 	-	$\alpha \geq 4$	K = 6,97	κ_x= 1 for $\lambda \leq$ 0,83
		$4 > \alpha > 1$	$K = 6,97 + \left[\frac{4-\alpha}{3}\right]^4 3,1$	$\kappa_x = 1,13\left[\frac{1}{\lambda} - \frac{0,22}{\lambda^2}\right]$ for $\lambda > 0,83$
[14] 	-	-	$K = 6,97 + \left[\frac{4-\alpha}{3}\right]^4 3,1$	κ_y= 1 for $\lambda \leq$ 0,83 $\kappa_y = 1,13\left[\frac{1}{\lambda} - \frac{0,22}{\lambda^2}\right]$ for $\lambda > 0,83$
[15] 	-	$\alpha \geq 1$	$K = K_\tau \cdot \sqrt{3}$	κ_τ= 1 for $\lambda \leq$ 0,84 $\kappa_\tau = \frac{0,84}{\lambda}$ for $\lambda >$ 0,84
			$K_\tau = 5,34 + \frac{4}{\alpha^2}$	
[16] 	-	-	K = $\sqrt{3}\left[5,34 + \max\left(\frac{4}{\alpha^2}; \frac{7,15}{\alpha^{2,5}}\right)\right]$	
[17] 	-	-	K = K' · r	
			K' = K according to load case 15	
			r = Reduction factor $= \left(1 - \frac{d_a}{a}\right)\left(1 - \frac{d_b}{b}\right)$	
			with $\frac{d_a}{a} \leq 0,7$ and $\frac{d_b}{b} \leq 0,7$	

Table 3.12 Plane Plate Fields *(continued)*

Load case	Edge Stress ratio Ψ	Aspect ratio α	Buckling factor K	Reductions factor κ
[18] 	-	-	$K = \sqrt{3}\left(0,6 + \frac{4}{\alpha^2}\right)$	κ_τ = 1 for $\lambda \le$ 0,84
[19] 	-	-	K = 8	$\kappa_\tau = \frac{0,84}{\lambda}$ for λ > 0,84
Explanations for boundary conditions: - - - - - - - - plate edge free; ———— plate edge simply supported; ▬▬▬▬ plate edge clamped				

(IACS UR S35. Sec.5, Table 3)

.4 Curved plate panels

This requirement for curved plate limit state is applicable when R/tp ≤ 2500. Otherwise, the requirement for plate limit state given in 5.2.2.1 is applicable.

The curved plate limit state is based on the following interaction formula:

$$\left(\frac{\gamma_{c1} \cdot \sigma_x \cdot S}{\kappa_x \cdot R_{eH}}\right)^{1,25} + \left(\frac{\gamma_c \cdot \sigma_y \cdot S}{\kappa_y \cdot R_{eH}}\right)^{1,25} - 0,5\left(\frac{\gamma_c \cdot \sigma_x \cdot S}{\kappa_x \cdot R_{eH}}\right)\left(\frac{\gamma_c \cdot \sigma_y \cdot S}{\kappa_y \cdot R_{eH}}\right) + \left(\frac{\gamma_c \cdot |\tau| \cdot S \cdot \sqrt{3}}{\kappa_\tau \cdot R_{eH}}\right)^2 = 1,0$$

$$\eta_{curvedPlate} = \frac{1}{\gamma_c}$$

where:

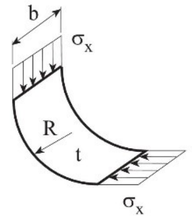
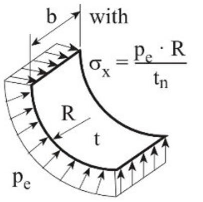
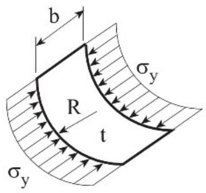
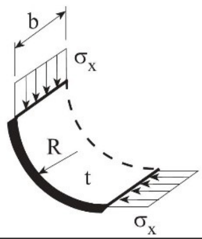
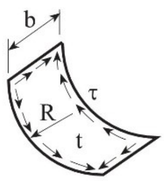
$\kappa_x, \kappa_y, \kappa_\tau$ = buckling reduction factors of curved plate panel are given in Table 3.13

σ_x, σ_y, τ = applied stress and shear stress as defined in Table 3.13

The stress multiplier factor γ_c of the curved plate panel need not be taken less than the stress multiplier factor γ_c obtained from 5.2.2.1 for an expanded plane panel.

(IACS UR S35. Sec.5, 2.2.6)

Table 3.13 Curved plate field R/t 2500[1)]

Load case	Aspect ratio b/R	Buckling factor K	Reduction factor κ
[1a] 	$\frac{b}{R} \leq 1,63\sqrt{\frac{R}{t}}$	$K = \frac{b}{\sqrt{R.t}} + 3\frac{(R.t)^{0,175}}{b^{0,35}}$	$\kappa_x = 1^{2)}$ for $\lambda \leq 0,4$ $\kappa_x = 1,274 - 0,686\,\lambda$ for $0,4 < \lambda \leq 1,2$ $K = 0,3\frac{b^2}{R^2} + 2,25\left(\frac{R^2}{b.t}\right)^2$ for $\lambda > 1,2$
[1b] 	$\frac{b}{R} > 1,63\sqrt{\frac{R}{t}}$	$K = 0,,3\frac{b^2}{R^2} + 2,25\left(\frac{R^2}{b.t}\right)^2$	
[2] 	$\frac{b}{R} \leq 0,5\sqrt{\frac{R}{t}}$	$K = 1 + \frac{2}{3}\frac{b^2}{R.t}$	$\kappa_y = 1^{2)}$ for $\lambda \leq 0,25$ $\kappa_y = 1,233 - 0,933$ for $\lambda < \lambda \leq 1$ $\kappa_y = 0,3/\lambda^3$ for $\lambda \leq 0,25$ $\kappa_y = 0,2/\lambda^2$ for $\lambda > 1,5$
	$\frac{b}{R} > 0,5\sqrt{\frac{R}{t}}$	$K = 0,267\frac{b^2}{R.t}\left[3 - \frac{b}{R}\sqrt{\frac{t}{R}}\right]$ $\geq 0,4\frac{b^2}{R.t}$	
[3] 	$\frac{b}{R} \leq \sqrt{\frac{R}{t}}$	$K = \frac{0,6.b}{\sqrt{R.t}}$	as in load case 1a
	$\frac{b}{R} \leq \sqrt{\frac{R}{t}}$	$K = 0,3\frac{b^2}{R^2} + 0,291\left(\frac{R^2}{b.t}\right)$	
[4] 	$\frac{b}{R} \leq 8,7\sqrt{\frac{R}{t}}$	$K = \kappa_\tau.\sqrt{3}$ $\kappa_\tau = \left[28,3 + \frac{0,67.b^3}{R^{1,5}.t^{1,5}}\right]^{0,5}$	$\kappa_\tau = 1$ for $\lambda \leq 0,4$ $\kappa_\tau = 1,274 - 0,686\,\lambda$ for $0,4 < \lambda \leq 1,2$ $\kappa_\tau = \frac{0,65}{\lambda^2}$ for $\lambda > 1,2$
	$\frac{b}{R} > 8,7\sqrt{\frac{R}{t}}$	$K_\tau = 0,28\frac{b^2}{R\sqrt{R.t}}$	

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 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 be taken as follows:
Load case 1b : $\kappa_x = 0,8/\lambda^2 \leq 1,0$; Load case 2: $\kappa_y = 0,65/\lambda^2 \leq 1,0$.

.5 Normal and shear stresses applied to plate panels

.5.1 The normal stresses σ_x and σ_y, [N/mm^2], to be applied for the overall stiffened panel capacity and the plate panel capacity calculations, as given in 5.2.1.1 and 5.2.2.1 respectively, are to be taken as follows:

— For FE analysis, the reference stresses as defined in 4.2.4

— For prescriptive assessment of the overall stiffened panel capacity and the plate panel capacity, the axial or transverse compressive stresses at load calculation points of the considered stiffener or the considered elementary plate panel, as defined in the applicable Rules, respectively. However, in case of transverse stiffening arrangement, the transverse compressive stress used for the assessment of the overall stiffened panel capacity is to be taken as the compressive stress calculated at load calculation points of the stiffener attached plating, as defined in applicable Rules.

— For grillage analysis where the stresses are obtained based on the beam theory, the following values:

$$\sigma_x = \frac{\sigma_{xb} + \nu\,\sigma_{yb}}{1 - \nu^2} \quad [\mathrm{N/mm^2}]$$

$$\sigma_y = \frac{\sigma_{yb} + \nu\,\sigma_{xb}}{1 - \nu^2} \quad [\mathrm{N/mm^2}]$$

where:

σ_{xb}, σ_{yb} = stresses [N/mm^2], from grillage beam analysis, respectively along x-axis and y-axis of the plate attached to the PSM

.5.2 The shear stress τ [N/mm^2], to be applied for the overall stiffened panel capacity and the plate panel capacity calculations, as given in 5.2.1.1 and 5.2.2.1 respectively, is to be taken as follows:

— for FE analysis, the reference shear stresses as defined in 4.2.4

— for prescriptive assessment of the plate panel capacity, the shear stresses at load calculation points of the considered elementary plate panel, as defined in the applicable Rules

— for prescriptive assessment of the overall stiffened panel capacity, the shear stresses calculated according to Section 5, D., at the following load calculation point:

  — at the middle of the full span, ℓ, of the considered stiffener

  — at the intersection point between the stiffener and its attached plating

— for grillage beam analysis, $\tau = 0$ in the plate attached to the PSM

(IACS UR S35. Sec.5, 2.2.7)

5.2.3 Stiffeners

.1 Buckling modes

The following buckling modes are to be checked:

— stiffener induced failure (SI)

— associated plate induced failure (PI)

(IACS UR S35. Sec.5, 2.3.1)

.2 Effective web thickness of flat bars

For accounting the decrease of stiffness due to local lateral deformation in the case of flat bars, their net sectional area A_s, net section modulus w and moment of inertia I, when applied in the formulae of 5.2.1 and 5.2.3.4, are to be calculated using, instead of t_w, the effective web thickness $t_{w,red}$, in mm, equal to:

$$t_{w,red} = t_w \left[1 - \frac{2\pi^2}{3}\left(\frac{h_w}{s}\right)^2\left(1 - \frac{b_{eff1}}{s}\right)\right] \quad [mm]$$

(IACS UR S35. Sec.5, 2.3.2)

.3 Idealisation of bulb bars

Bulb profiles are to be considered as equivalent angle profiles. The net dimensions of the equivalent built-up section are to be obtained, in mm, from the following formulae.

$$h_w = h'_w - \frac{h'_w}{9,2} + 2 \quad [mm]$$

$$b_f = c\left(t'_w + \frac{h'_w}{6,7} - 2\right) \quad [mm]$$

$$t_f = \frac{h'_w}{9,2} - 2 \quad [mm]$$

$$t_w = t'_w \quad [mm]$$

where:

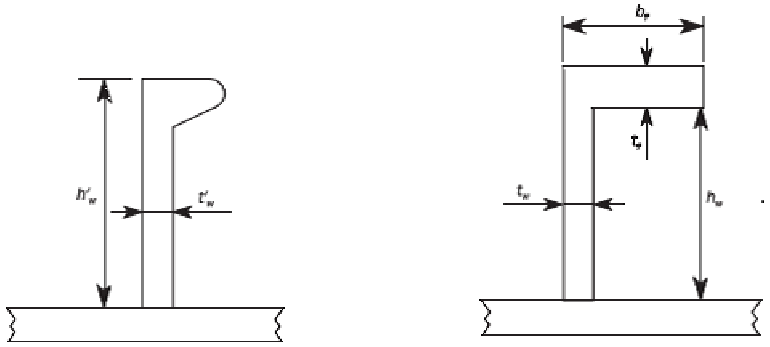
h'_w, t'_w = net height and thickness of a bulb section [mm], as shown in Fig. 3.24

c = coefficient equal to:

$= 1,1 + \frac{(120 - h_w)^2}{3000}$ for $h'_w \le 120$

= 1,0 for $h'_w > 120$

(IACS UR S35. Sec.5, 2.3.3)



Bulb flat Equivalent angle bar

Figure 3.24 Idealisation of bulb stiffener

(IACS UR S35. Sec.5, Figure 2)

.4 Ultimate buckling capacity

$$\frac{\lambda_c \cdot \sigma_a + \sigma_b + \sigma_w}{R_{eH}} S = 1,0$$

where:

σ_a = effective axial stress [N/mm^2], at mid span of the stiffener, acting on the stiffener with its attached plating:

$$= \sigma_x \frac{s \cdot t_p + A_s}{b_{eff1} \cdot t_p + A_s} \quad [N/mm^2]$$

σ_x = nominal axial stress [N/mm^2], acting on the stiffener with its attached plating:

- for FE analysis, σ_x is the FE corrected stress, as defined in 5.2.3.6, in the attached plating in the direction of the stiffener axis
- for prescriptive assessment, σ_x is the axial stress at load calculation point of the stiffener, as defined in 1.3.5
- for grillage beam analysis, σ_x is the stress acting along the x-axis of the attached buckling panel

σ_b = bending stress in the stiffeners [N/mm^2]

$$= \frac{M_o + M_1 + M_2}{W_{st} \cdot 10^3} \quad [N/mm^2]$$

M_o = bending moment due to deformation w of stiffener

$$= F_E \cdot C_{sl} \frac{\gamma}{\gamma_{GEB} - \gamma} w_0 \quad [N/mm^2]$$

with precondition $\gamma_{GEB} - \gamma > 0$, where γ_{GEB} is the stress multiplier factor of global elastic buckling capacity as defined in 5.2.1.

F_{KiE} = ideal buckling force of the stiffener [N]

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

I_x = moments of inertia of the longitudinal or transverse stiffener including effective width of plating according to 5.2.3.5 [cm^4]

$$I_x \geq \frac{b \cdot t^3}{12 \cdot 10^4}$$

t_p = net thickness of the attached plating [mm], to be taken as:

- for prescriptive requirements: the mean thickness of the two attached plating panels
- for FE analysis: the thickness of the considered EPP on one side of the stiffener

C_{sl} = Deformation reduction factor to account for global slenderness, to be taken as:

$$= 1 - \frac{1}{12}\lambda_G^4 \quad \text{for } \lambda_G \leq 1{,}56$$

$$= \frac{3}{\lambda_G^4} \quad \text{for } \lambda_G > 1{,}56$$

λ_G = the reference degree of global slenderness of the stiffened panel, to be taken as:

$$= \sqrt{\frac{\gamma_c}{\gamma_{ReH}}}$$

$$\gamma_{ReH} = \frac{\min\left(R_{eHp};\ R_{eHs}\right)}{\sqrt{\sigma_{x,av}^2 + \sigma_y^2 - \sigma_{x,av}\,\sigma_y + 3\,\tau_{xy}^2}}$$

w_0 = assumed imperfection [mm], to be taken as:

$$= \frac{\ell}{1000}$$

M_1 = bending moment due to the lateral load p for defined as:

= $C_i \dfrac{|p| \cdot s \cdot \ell^2}{24 \cdot 10^3}$ [Nmm] for continuous stiffeners

= $C_i \dfrac{|p| \cdot s \cdot \ell^2}{8 \cdot 10^3}$ [Nmm] for sniped stiffeners

= $C_i \dfrac{|p| \cdot s \cdot \ell^2}{14,2 \cdot 10^3}$ [Nmm] for sniped stiffeners at one end and continuous at the other end

p = lateral load [kN/m^2], defined as follows:

= for prescriptive analysis, p lateral load [kN/m^2] according to Section 4

= for FE analysis, P = P_{avr} as defined in 4.2.5.2 in the attached plating

C_i = pressure coefficient:

= C_{SI} for stiffener induced failure (SI)

= C_{PI} for associated plate induced failure (PI)

C_{SI} = stiffener induced failure pressure coefficient:

= -1 if the lateral pressure is applied on the side opposite to the stiffener

= 1 if the lateral pressure is applied on the same side as the stiffener

C_{PI} = associated plate induced failure pressure coefficient:

= 1 if the lateral pressure is applied on the side opposite to the stiffener

= -1 if the lateral pressure is applied on the same side as the stiffener

M_2 = bending moment [Nmm], due to eccentricity of sniped stiffeners, to be taken as:

= 0 [Nmm] for continuous stiffeners

= $C_{snip} \cdot w_{na} \cdot \gamma \cdot \sigma_x (A_p + A_s)$ [Nmm] for stiffeners sniped at one or both ends

C_{snip} = coefficient to account for the end effect of the stiffener sniped at one or both ends, to be taken as:

= -1,2 for stiffener induced failure (SI)

= 1,2 for plate induced failure (PI)

w_{na} = distance [mm], from the mid-point of attached plating to the neutral axis of the stiffener calculated with the effective width of the attached plating according to 5.2.3.5

σ_W = Stress due to torsional deformation [N/mm^2], to be taken as:

– For stiffener induced failure (SI):

– for $\sigma_a > 0$:

$\sigma_W = E \cdot y_w \cdot e_f \cdot \Phi_0 \left(\dfrac{m_{tor}\,\pi}{\ell_{tor}}\right)^2 \left(\dfrac{1}{1 - \frac{\gamma \sigma_a}{\sigma_{ET}}} - 1\right)$ [N/mm^2] with precondition $\sigma_{ET} - \gamma\,\sigma_a > 0$

– for $\sigma_a \leq 0$:

$\sigma_W = 0$ [N/mm^2]

– For plate induced failure (PI):

$\sigma_W = 0$ [N/mm^2]

y_w = distance [mm], from the centroid of the stiffener cross-section to the free edge of the stiffener flange, to be taken as:

= $\dfrac{t_w}{2}$ [mm] for flat bars

= $b_f - \dfrac{h_w\, t_w^2 + t_f\, b_f^2}{2\, A_s}$ [mm] for angle and bulb bars

= $\dfrac{b_f}{2}$ [mm] for T-bars

$= b_{f-out} + 0{,}5 t_w - \dfrac{h_w\, t_w^2 + t_f\left(b_f^2 - 2 b_f d_f\right)}{2\, A_s}$ [mm] for L2 bars

ℓ_{tor} = stiffener span [mm], taken equal to spacing between primary supporting members, i.e. $\ell_{tor} = \ell$ when the stiffener is supported by tripping brackets, ℓ_{tor} should be taken as the maximum spacing between the adjacent primary supporting members and fitted tripping brackets

Φ_0 = coefficient taken as:

$$= \frac{\ell_{tor}}{m_{tor}\, h_w}\, 10^{-4}$$

σ_{ET} = reference stress for torsional buckling [N/mm^2]:

$$= \frac{E}{I_P}\left[\left(\frac{m_{tor}\,\pi}{\ell_{tor}}\right)^2 I_w \cdot 10^2 + \frac{1}{2(1+\nu)}\, I_T + \left(\frac{\ell_{tor}}{m_{tor}\,\pi}\right)^2 \varepsilon \cdot 10^{-4}\right] \quad [\text{N/mm}^2]$$

I_P = net polar moment of inertia of the stiffener [cm^4], about point C (see Fig. 3.25 and Table 3.14)

I_T = net Saint Venant's moment of inertia of the stiffener [cm^4], as defined in Table 3.14

I_ω = net sectorial moment of inertia of the stiffener [cm^4], about point C (see Fig. 3.25 and Table 3.14)

m_{tor} = number of half waves within ℓ_{tor}, taken as a positive integer so as to give smallest reference stress for torsional buckling

ε = degree of fixation [mm^2], to be taken as:

$$= \left(\frac{3\,b}{t_p^3} + \frac{2\,h_w}{t_w^3}\right)^{-1} \quad \text{for bulb, angle, L2, L3 and T profiles}$$

$$= \left(\frac{t_p^3}{3\,b}\right) \quad \text{for flat bars}$$

A_w = net area of the stiffener web [mm^2]

A_f = net area of the stiffener flange [mm^2]

W_{st} = section modulus of stiffener (longitudinal or transverse) [cm^3] including effective width of plating according to 5.2.3.5

(IACS UR S35. Sec.5, 2.3.4)

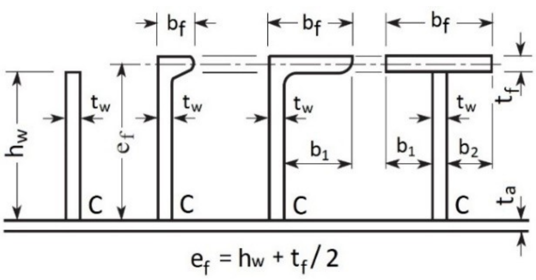


Fig. 3.25 Main dimensions of typical longitudinal stiffeners

Table 3.14 Formulas for the calculation of moments of inertia I_P, I_T, and I_ω

Profile	I_P	I_T	I_ω
flat bar	$\dfrac{h_w^3 \cdot t_w}{3 \cdot 10^4}$	$\dfrac{h_w \cdot t_w^3}{3 \cdot 10^4}\left[1 - 0,63\dfrac{t_w}{h_w}\right]$	$\dfrac{h_w^3 \cdot t_w^3}{36 \cdot 10^6}$
Profile with bulb or flange, L2 and T bar	$\left[\dfrac{A_w \cdot h_w^2}{3} + A_f \cdot e_f^2\right] 10^{-4}$	$\dfrac{h_w \cdot t_w^3}{3 \cdot 10^4}\left[1 - 0,63\dfrac{t_w}{h_w}\right]$ + $\dfrac{b_f \cdot t_f^3}{3.10^4}\left[1 - 0,63\dfrac{t_f}{b_f}\right]$	for bulb and angle profiles: $\dfrac{A_f \cdot e_f^2 \cdot b_f^2}{12 \cdot 10^6}\left[\dfrac{A_f + 2,6A_W}{A_f \cdot A_W}\right]$ for T-profiles: $\dfrac{b_f^3 \cdot t_f \cdot e_f^2}{12 \cdot 10^6}$

(IACS UR S35. Sec.5, Table 5)

.5 Effective width of attached plating

The effective width b_m [mm], of the stiffener attached plating is to be taken as:

— when $\sigma_x > 0$:
$b_m = \min(\kappa_x\, b\,;\, \chi_s\, s)$ [mm] for FE analysis

$$b_m = \min\left(\frac{\kappa_{x1}\, b_1 + \kappa_{x2}\, b_2}{2}; \chi_s\, s\right) \quad \text{[mm] for prescriptive assessment}$$

— when $\sigma_x \le 0$:
$b_m = \chi_s\, s$ [mm]

where:

χ_s = effective width coefficient to be taken as:

$$= \min\left[\frac{1,12}{1 + \frac{1,75}{\left(\frac{\ell_{eff}}{s}\right)^{1,6}}};\ 1,0\right] \quad \text{for } \ell_{eff}/s \ge 1$$

$$= 0,407\left(\frac{\ell_{eff}}{s}\right) \quad \text{for } \ell_{eff}/s < 1$$

ℓ_{eff} = effective length of the stiffener [mm], taken as:

= $\dfrac{\ell}{\sqrt{3}}$ [mm] for a stiffener fixed at both ends

= $0,75 \cdot \ell$ [mm] for a stiffener simply supported at one end and fixed at the other

= ℓ [mm] for a stiffener simply supported at both ends

κ_{x1}, κ_{x2} and s are defined in 5.1.6

(IACS UR S35. Sec.5, 2.3.5)

.6 FE corrected stresses for stiffener capacity

When the reference stresses σ_x and σ_y obtained by FE analysis according to 4.2.4 are both compressive, σ_x is to be corrected according to the following formula:

— if $\sigma_x < \sigma_y$: $\sigma_{xcor} = 0$

— if $\sigma_x \ge \sigma_y$: $\sigma_{xcor} = \sigma_x - \nu\, \sigma_y$

(IACS UR S35. Sec.5, 2.3.6)

5.2.4 Primary supporting members

.1 Web plate in way of openings

The web plate of primary supporting members with openings is to be assessed for buckling based on the combined axial compressive and shear stresses.

The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels as shown in Table 3.15.

The interaction formulae of 5.2.2.1 are to be used with:

$\sigma_x = \sigma_{av}$

$\sigma_y = 0$

$\tau = \tau_{av}$

where:

σ_{av} = weighted average compressive stress [N/mm^2], in the area of web plate being considered, i.e. P1, P2 or P3 as shown in Table 3.15

τ_{av} = weighted average shear stress [N/mm^2]:

- for opening modelled in primary supporting members:
- τ_{av} is the weighted average shear stress in the area of web plate being considered, i.e. P1, P2 or P3 as shown in Table 3.15
- for opening not modelled in primary supporting members:
- τ_{av}v is the weighted average shear stress given in Table 3.15.

(IACS UR S35. Sec.5, 2.4.1)

.2 Reduction factors of web plate in way of openings

The reduction factors, κ_x or κ_x in combination with κ_τ, of the plate panel(s) of the web adjacent to the opening is to be taken as shown in Table 3.15.

(IACS UR S35. Sec.5, 2.4.2)

.3 The equivalent plate panel of web plate of primary supporting members crossed by perpendicular stiffeners is to be idealised as shown in Fig. 3.26.

The correction of panel breadth is also applicable for other slot configurations, provided the web or the collar plate is attached to at least one side of the passing stiffener.

(IACS UR S35. Sec.5, 2.4.3)

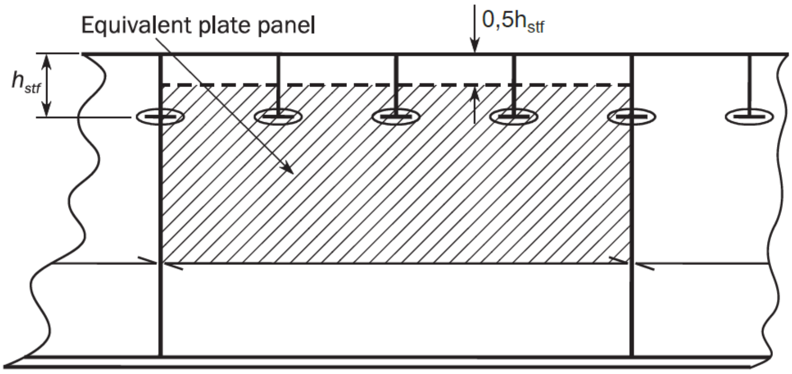
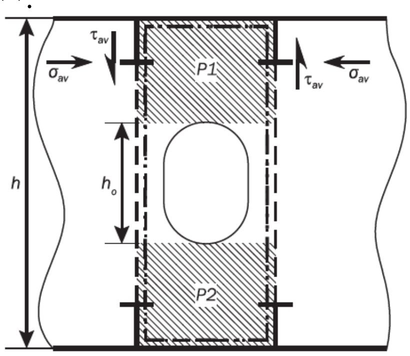
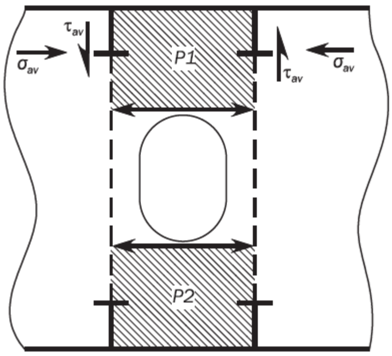
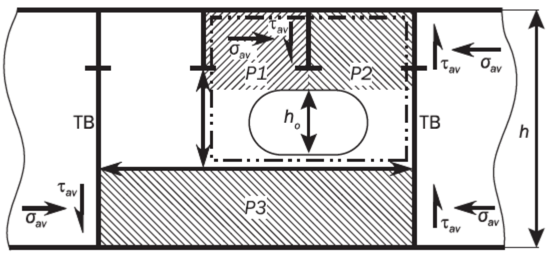


Fig. 3.26 Web plate idealisation

(IACS UR S35. Sec.5, Figure 3)

Table 3.15 Reduction factors κ_x, κ_y, and κ_τ

Configuration [1]	κ_x and κ_y	κ_τ **Opening modelled in PSM**	κ_τ **Opening not modelled in PSM**
(a) Without edge reinforcements [2]: 	Separate reduction factors are to be applied to areas P1 and P2 using load case 3 or case 6 in Table 3.12, with edge stress ratio ψ = 1,0	Separate reduction factors are to be applied to areas P1 and P2 using load case 18 or 19 in Table 3.12	- when load case 17 of Table 3.12 is applicable: A common reduction factor is to be applied to areas P1 and P2 using load case 17 in Table 3.12 with: $\tau_{av} = \tau_{av}\text{ (web)}$ - when load case 17 of Table 3.12 is not applicable: Separate reduction factors are to be applied to areas P1 and P2 using load case 18 or 19 in Table 3.12 with: $\tau_{av} = \dfrac{\tau_{av}(\text{web}) \cdot h}{h - h_0}$
(b) With edge reinforcements: 	Separate reduction factors are to be applied to areas P1 and P2 using, in Table 3.12 κ_x for load case 1 or κ_y for load case 2, with edge stress ratio ψ = 1,0	Separate reduction factors are to be applied to areas P1 and P2 using load case 15 in Table 3.12	Separate reduction factors are to be applied to areas P1 and P2 using load case 15 in Table 3.12, with: $\tau_{av} = \dfrac{\tau_{av}(\text{web}) \cdot h}{h - h_0}$
(c) Example of hole in web: 		Panels P1 and P2 are to be evaluated in accordance with configuration (a) Panel P3 is to be evaluated in accordance with configuration (b)	

where:

h : height [m], of the web of the primary supporting member in way of the opening
h_0 : height [m], of the opening measured in the depth of the web
τ_{av}(web) : weighted average shear stress [N/mm^2] over the web height h of the primary supporting member

(1) Web panels to be considered for buckling in way of openings are shown shaded and numbered P1, P2, etc.

(2) For a PSM web panel with opening and without edge reinforcements as shown in configuration (a), the applicable buckling assessment method depends on its specific boundary conditions. If one of the long edges along the face plate or along the attached plating is not subject to inline support, i.e. the edge is free to pull in, Method B should be applied. In other cases, typically such as when the short plate edge is attached to the plate flanges, Method A is applicable.

(IACS UR S35. Sec.5, Table 6)

5.2.5 Stiffened Panels with U-type Stiffeners

.1 Local plate buckling

For stiffened panels with U-type stiffeners, local plate buckling is to be checked for each of the plate panels EPP b_1, b_2, b_f and h_w (see Fig. 3.6) separately as follows:

- The attached plate panels EPP b_1 and b_2 are to be assessed using SP-A model, where in the calculation of buckling factors K as defined in Case 1 of Table 3.12, the correction factor F_{long} for U-type stiffeners as defined in Table 3.11 is to be used; and in the calculation of K as defined in Case 2 of Table 3.12, the F_{trans} for U-type stiffeners as defined in 5.2.2.3 is to be used.
- The face plate and web plate panels bf and hw are to be assessed using UP-B model with F_{long} = 1 and F_{trans} = 1.

(IACS UR S35. Sec.5, 2.5.1)

.2 Overall stiffened panel buckling and stiffener buckling

For a stiffened panel with U-type stiffeners, the overall buckling capacity and ultimate capacity of the stiffeners are to be checked with warping stress τ_w = 0, and with bending moment of inertia including effective width of attached plating being calculated based on the following assumptions:

- The two web panels of a U-type stiffener are to be taken as perpendicular to the attached plate with thickness equal to t_w and height equal to the distance between the attached plate and the face plate of the stiffener.
- Effective width of the attached plating, b_{eff} taken as the sum of the b_{eff} calculated for the EPP b_1 and b_2 respectively according to SP-A model.
- Effective width of the attached plating of a stiffener without shear lag effect, b_{eff1}, taken as the sum of the b_{eff1} calculated for the EPP b_1 and b_2 respectively.

(IACS UR S35. Sec.5, 2.5.2)

5.3 Buckling capacity of the other structures

5.3.1 Struts, pillars and cross ties

.1 Buckling utilisation factor

The buckling utilisation factor η, for axially compressed struts, pillars and cross ties, is to be taken as:

$$\eta = \frac{\sigma_{av}}{\sigma_{cr}}$$

where:

σ_{av}	=	average axial compressive stress in the member [N/mm^2]
σ_{cr}	=	minimum critical buckling stress [N/mm^2], taken as:
	=	σ_E [N/mm^2] for $\sigma_E \le 0,5\ R_{eHs}$
	=	$\left(1 - \dfrac{R_{eHs}}{4\ \sigma_E}\right) R_{eHs}$ [N/mm^2] for $\sigma_E > 0,5\ R_{eHs}$
σ_E	=	minimum elastic buckling stress [N/mm^2], according to 5.3.1.2 to 5.3.1.6, as applicable
R_{eHs}	=	specified minimum yield stress of the considered member [N/mm^2]. For built-up members, the lowest specified minimum yield stress is to be used

.2 Elastic column buckling stress

The elastic compressive column buckling stress σ_{EC} [N/mm^2], of members subject to axial compression is to be taken as:

$$\sigma_{EC} = \pi^2 \cdot E \cdot f_{end} \frac{I}{A\,\ell_{pill}^2}\, 10^{-4} \quad [N/mm^2]$$

where:

A	=	net cross-sectional area of the member [cm^2]
I	=	net moment of inertia about the weakest axis of the cross-section [cm^4]
ℓ_{pill}	=	length of the member [m]:

- for pillars and struts:
  ℓ_{pill} is the unsupported length of the member
- for cross ties:
  - in centre tanks: ℓ_{pill} is the distance between the flanges of longitudinal stiffeners on the starboard and port longitudinal bulkheads to which the cross tie's horizontal stringer is attached.
  - in wing tanks: ℓ_{pill} is the distance between the flanges of longitudinal stiffeners on the longitudinal bulkhead to which the cross tie's horizontal stringer is attached, and the inner hull plating.

f_{end} = end constraint factor, taken as:

- for pillars and struts:
  f_{end} = 1,0 where both ends are simply supported
  f_{end} = 2,0 where one end is simply supported and the other end is fixed
  f_{end} = 4,0 where both ends are fixed
- for cross ties:
  f_{end} = 2,0

A pillar end may be considered fixed when brackets of adequate size are fitted. Such brackets are to be supported by structural members with bending stiffness greater than the pillar.

(IACS UR S35. Sec.5, 3.1.1)

.3 Elastic torsional buckling stress of open-type cross-sections

The elastic torsional buckling stress σ_{ET} [N/mm^2], with respect to axial compression of members is to be taken as:

$$\sigma_{ET} = \frac{G\,I_{sv}}{I_{pol}} + \frac{\pi^2 \cdot f_{end} \cdot E \cdot c_{warp}}{I_{pol} \cdot \ell_{pill}^2}\, 10^{-4} \quad [N/mm^2]$$

where:

I_{sv}	=	net Saint Venant's moment of inertia [cm^4] (see Table 3.16 for examples of cross-sections)
I_{pol}	=	net polar moment of inertia about the shear centre of cross-section [cm^4], taken as:
	=	$I_y + I_z + A\,(y_0^2 + z_0^2)$ [cm^4]
c_{warp}	=	warping constant [cm^6] (see Table 3.16 for examples of cross-sections)
ℓ_{pill}	=	length of the member [m], as defined in 5.3.1.2

I_y	=	net moment of inertia about the y axis [cm^4]
I_z	=	net moment of inertia about the z axis [cm^4]
A	=	net cross-sectional area of the member [cm^2]
y_0	=	transverse position of shear centre relative to the cross-sectional centroid [cm] (see Table 3.16 for examples of cross sections)
z_0	=	vertical position of shear centre relative to the cross-sectional centroid, in cm (see Table 3.16 for examples of cross sections)

.4 Elastic torsional/column buckling stress of open-type cross-sections

For the cross-sections where the centroid and the shear centre do not coincide, the interaction between the torsional and column buckling modes is to be examined.

The elastic torsional/column buckling stress σ_{ETF} [N/mm^2], with respect to axial compression is to be taken as:

$$\sigma_{ETF} = \frac{1}{2\,\zeta}\left[(\sigma_{EC} + \sigma_{ET}) - \sqrt{(\sigma_{EC} + \sigma_{ET})^2 - 4\,\zeta\sigma_{EC} \cdot \sigma_{ET}}\right] \quad [N/mm^2]$$

where:

σ_{EC}	=	elastic compressive column buckling stress, as defined in 5.3.1.2
σ_{ET}	=	elastic torsional buckling stress, as defined in 5.3.1.3
ζ	=	coefficient taken as:
	=	$1 - \dfrac{(y_0^2 + z_0^2)\,A}{I_{pol}}$
A	=	net cross-sectional area of the member [cm^2]

y_0, z_0 and I_{pol} are defined in 5.3.1.3

.5 Elastic local buckling stress of open-type cross-sections

The elastic local buckling stress σ_{EL1} [N/mm^2], with respect to axial compression of open-type cross-sections is to be taken equal to the lesser of the values obtained from the following formulae:

$$\sigma_{EL1} = 78 \cdot \left(\frac{t_2}{b}\right)^2 10^4 \quad [N/mm^2]$$

$$\sigma_{EL1} = 32 \cdot \left(\frac{t_f}{b_f}\right)^2 10^4 \quad [N/mm^2]$$

.6 Elastic local buckling stress of hollow rectangular cross-sections

The elastic local buckling stress σ_{EL2} [N/mm^2], with respect to axial compression of hollow rectangular cross-sections is to be taken equal to the lesser of the values obtained from the following formulae:

$$\sigma_{EL2} = 78 \cdot \left(\frac{t_2}{b}\right)^2 10^4 \quad [N/mm^2]$$

$$\sigma_{EL2} = 78 \cdot \left(\frac{t_1}{b}\right)^2 10^4 \quad [N/mm^2]$$

where:

b	=	length [mm], of the shorter side of the cross-section
t_2	=	net web thickness [mm], of the shorter side of the cross-section
h	=	length [mm], of the longer side of the cross-section
t_1	=	net web thickness [mm], of the longer side of the cross-section

5.3.2 Corrugated bulkheads

The buckling utilisation factor of flange and web of corrugations of corrugated bulkheads is based on the combination of in-plane stresses and shear stress.

The interaction formulae of 5.2.2.1 are to be used considering the following coefficients:

- α = 2
- $\Psi = \Psi_y = 1$

Table 3.16 Cross-sectional properties

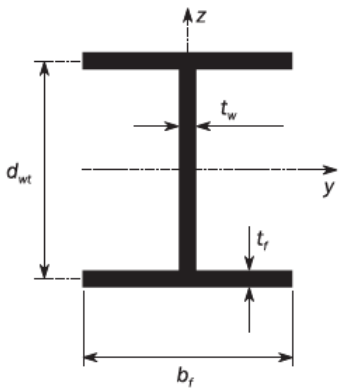
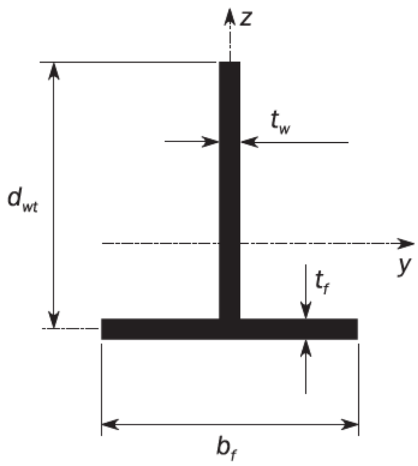
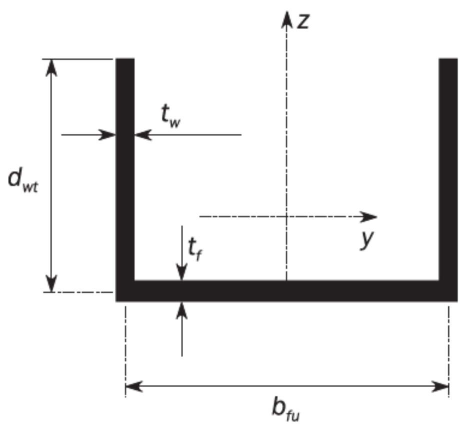
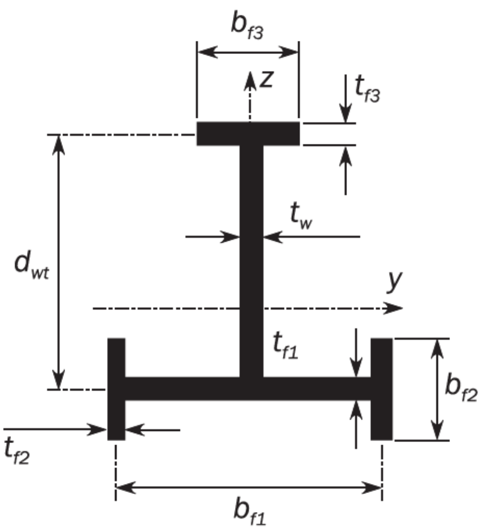
<table>
<tr><th>Typical cross-sections</th><th>Properties</th><th>Units</th></tr>
<tr><td rowspan="2">
</td><td>$I_{sv} = \frac{1}{3}\left(2\ b_f\ t_f^3 + d_{wt}\ t_w^3\right)\ 10^{-4}$</td><td>$cm^4$</td></tr>
<tr><td>$c_{warp} = \frac{d_{wt}^3\ b_f^3\ t_f}{24}\ 10^{-6}$</td><td>$cm^6$</td></tr>
<tr><td rowspan="4">
</td><td>$I_{sv} = \frac{1}{3}\left(b_f\ t_f^3 + d_{wt}\ t_w^3\right)\ 10^{-4}$</td><td>$cm^4$</td></tr>
<tr><td>$y_0 = 0$</td><td>cm</td></tr>
<tr><td>$z_0 = -0,5 \frac{d_{wt}^2\ t_w}{d_{wt}\ t_w + b_f\ t_f}\ 10^{-1}$</td><td>cm</td></tr>
<tr><td>$c_{warp} = \frac{b_f^3\ t_f^3 + 4\ d_{wt}^3\ t_w^3}{144}\ 10^{-6}$</td><td>$cm^6$</td></tr>
<tr><td rowspan="4">
</td><td>$I_{sv} = \frac{1}{3}\left(b_{fu}\ t_f^3 + 2 d_{wt}\ t_w^3\right)\ 10^{-4}$</td><td>$cm^4$</td></tr>
<tr><td>$y_0 = 0$</td><td>cm</td></tr>
<tr><td>$z_0 = \frac{d_{wt}^2\ t_w\ 10^{-1}}{2\ d_{wt}\ t_w + b_{fu}\ t_f} - \frac{0,5\ d_{wt}^2\ t_w\ 10^{-1}}{2\ d_{wt}\ t_w + b_{fu}\ t_f/6}$</td><td>cm</td></tr>
<tr><td>$c_{warp} = \frac{b_{fu}^3\ d_{wt}^3\ t_w\ (3\ d_{wt}\ t_w + 2\ b_{fu}\ t_f)}{12\ (6\ d_{wt}\ t_w + b_{fu}\ t_f)}\ 10^{-6}$</td><td>$cm^6$</td></tr>
</table>

Table 3.16 Cross-sectional properties *(continued)*

Typical cross-sections	Properties	Units
	$I_{sv} = \frac{1}{3}\left(b_{f1}\, t_{f1}^3 + 2 b_{f2}\, t_{f2}^3 + b_{f3}\, t_{f3}^3 + d_{wt}\, t_w^3\right) 10^{-4}$	cm^4
	$y_0 = 0$	cm
	$z_0 = z_s - \frac{\left(b_{f3}\, d_{wt}\, t_{f3} + 0,5\, d_{wt}^2\, t_w\right) 10^{-1}}{d_{wt}\, t_w + b_{f1}\, t_{f1} + 2\, b_{f2}\, t_{f2} + b_{f3}\, t_{f3}}$	cm
	$c_{warp} = \left[I_{f1}\, z_s^2 + \frac{I_{f2}\, b_{f1}^2}{200} + I_{f3}\left(\frac{d_{wt}}{10} - z_s\right)^2\right]$	cm^6
	$I_{f1} = \left[\frac{(b_{f1} - t_{f2})^3\, t_{f1}}{12} + \frac{b_{f2}\, t_{f2}\, b_{f1}^2}{2}\right] 10^{-4}$	cm^4
	$I_{f2} = \frac{b_{f2}^3\, t_{f2}}{12}\, 10^{-4}$	cm^4
	$I_{f3} = \frac{b_{f3}^3\, t_{f3}}{12}\, 10^{-4}$	cm^4
	$z_s = \frac{I_{f3}\, d_{wt}}{I_{f1} + I_{f3}}\, 10^{-4}$	cm

6. Reference Stresses for Direct Strength Analysis

Symbols

a	=	length [mm], of the longer side of the plate panel as defined in 5.
b	=	length [mm], of the shorter side of the plate panel as defined in 5.
A_i	=	area [mm^2], of the i-th plate element of the buckling panel
n	=	number of plate elements in the buckling panel
σ_x	=	actual stress [N/mm^2], at the centroid of the i-th plate element in x direction, applied along the shorter edge of the buckling panel
σ_y	=	actual stress [N/mm^2], at the centroid of the i-th plate element in y direction, applied along the longer edge of the buckling panel
Ψ	=	edge stress ratio as defined in 5.1.6
τ	=	actual membrane shear stress [N/mm^2], at the centroid of the i-th plate element of the buckling panel

(IACS UR S35. App.1, Symbols)

6.1 Stress Based Method

6.1.1 Introduction

.1 This Sub-Section provides a method to determine stress distribution along edges of the considered buckling panel by second-order polynomial curve, by linear distribution using least square method and by weighted average approach. This method is called Stress based Method. The reference stress is the stress components at centre of plate element transferred into the local system of the considered buckling panel.

(IACS UR S35. App.1, 1.1.1)

.2 Definition: A regular panel is a plate panel of rectangular shape. An irregular panel is plate panel which is not regular, as detailed in 4.2.3.1.

(IACS UR S35. App.1, 1.1.2)

6.1.2 Stress Application

.1 Regular panel

The reference stresses are to be taken as defined in 6.2.1 for a regular panel when the following conditions are satisfied:

— At least, one plate element centre is located in each third part of the long edge a of a regular panel and

— This element centre is located at a distance in the panel local x direction not less than a/4 to at least one of the element centres in the adjacent third part of the panel.

Otherwise, the reference stresses are to be taken as defined in 6.2.2 for an irregular panel.

(IACS UR S35. App.1, 1.2.1)

.2 Irregular panel and curved panel

The reference stresses of an irregular panel or of a curved panel are to be taken as defined in 6.2.2.

(IACS UR S35. App.1, 1.2.2)

6.2 Reference Stresses

6.2.1 Regular Panel

.1 Longitudinal stress

The longitudinal stress σ_x applied on the shorter edge of the buckling panel is to be calculated as follows:

— For plate buckling assessment, the distribution of $\sigma_x(X)$ is assumed as second order polynomial curve as:
$\sigma_x = Cx^2 + Dx + E$

The best fitting curve $\sigma_x(x)$ is to be obtained by minimising the square error Π considering the area of each element as a weighting factor.

$$\Pi = \sum_{i=1}^{n} A_i \left[\sigma_{xi} - \left(Cx_i^2 + Dxi + E\right)\right]^2$$

The unknown coefficients C, D and E must yield zero first derivatives, $\partial\Pi$ with respect to C, D and E, respectively.

$$\begin{cases} \frac{\partial\Pi}{\partial C} = 2\sum_{i=1}^{n} A_i x_i^2 \left[\sigma_{xi} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \\ \frac{\partial\Pi}{\partial D} = 2\sum_{i=1}^{n} A_i x_i \left[\sigma_{xi} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \\ \frac{\partial\Pi}{\partial E} = 2\sum_{i=1}^{n} A_i \left[\sigma_{xi} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \end{cases}$$

The unknown coefficients C, D and E can be obtained by solving the 3 above equations.

$$\sigma_{x1} = \frac{1}{b}\int_0^b \sigma_x(x)dx = \frac{b^2}{3}C + \frac{b}{2}D + E$$

$$\sigma_{x2} = \frac{1}{b}\int_{a-b}^0 \sigma_x(x)dx = \left(a^2 - ab + \frac{b^2}{3}\right)C + \left(a - \frac{b}{2}\right)D + E$$

If $-\frac{D}{2C} < \frac{b}{2}$ or $-\frac{D}{2C} > a - \frac{b}{2}$, σ_{x3} is to be ignored. Otherwise, σ_{x3} is taken as

$$\sigma_{x3} = \frac{1}{b}\int_{x_{min}}^{x_{max}} \sigma_x(x)dx = \frac{b^2}{12}C - \frac{D^2}{4C} + E$$

where:

$x_{min} = -\frac{b}{2} - \frac{D}{2C}$

$x_{max} = \frac{b}{2} - \frac{D}{2C}$

The longitudinal stress is to be taken as:

$\sigma_x = \text{Max}\,(\sigma_{x1}, \sigma_{x2}, \sigma_{x3})$

The edge stress ratio is to be taken as:

$\psi_x = 1$

— For overall stiffened panel buckling and stiffener buckling assessments, the longitudinal stress σ_x applied on the shorter edge of the attached plate is to be taken as:

$\sigma_x = \frac{\sum_{i=1}^{n} A_i\sigma_{xi}}{A_i}$

The edge stress ratio Ψ_x for the stress σ_x is equal to 1,0.

(IACS UR S35. App.1, 2.1.1)

.2 Transverse stress

The transverse stress σ_y applied along the longer edges of the buckling panel is to be calculated by extrapolation of the transverse stresses of all elements up to the shorter edges of the considered buckling panel.

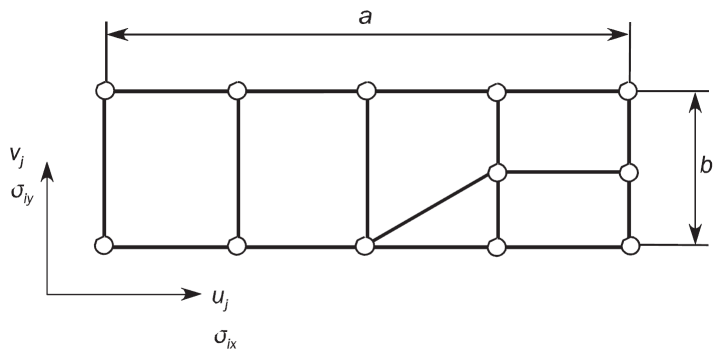


Fig. 3.27 Buckling panel

(IACS UR S35. App.1, Figure 1)

The distribution of $\sigma_y(x)$ is assumed as straight line. Therefore: $\sigma_y(x) = A + Bx$

The best fitting curve $\sigma_y(x)$is to be obtained by the least square method minimising the square error Π considering area of each element as a weighting factor.

$$\Pi = \sum_{i=1}^{n} A_i\left[\sigma_{yi} - (A + Bx_i)\right]^2$$

The unknown coefficients C and D must yield zero first partial derivatives, $\partial\Pi$ with respect to C and D, respectively.

$$\frac{\partial\Pi}{\partial A} = 2\sum_{i=1}^{n} A_i \left[\sigma_{yi} - (A + Bx_i)\right] = 0$$

$$\frac{\partial\Pi}{\partial A} = 2\sum_{i=1}^{n} A_i \left[\sigma_{yi} - (A + Bx_i)\right] = 0$$

The unknown coefficients A and B are obtained by solving the 2 above equations and are given as follow:

$$A = \frac{\left(\sum_{i=1}^{n} A_i\sigma_{yi}\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)\left(\sum_{i=1}^{n} A_i x_i \sigma_{yi}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)^2}$$

$$B = \frac{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i \sigma_{yi}\right) - \left(\sum_{i=1}^{n} A_i x_i\right)\left(\sum_{i=1}^{n} A_i\sigma_{yi}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)^2}$$

The transverse stress is to be taken as:

$$\sigma_y = \max\left[A; (A + Ba)\right]$$

The edge stress ratio is to be taken as:

$$\psi_y = \frac{\min[A; (A + Ba)]}{\max[A; (A + Ba)]} \quad \text{for } \sigma_y > 0$$

$$\sigma_y = 1 \quad \text{for } \sigma_y \le 0$$

(IACS UR S35. App.1, 2.1.2)

.3 Shear stress

The shear stress τ is to be calculated using a weighted average approach, and is to be taken as:

$$\tau = \frac{\sum_{i=1}^{n} A_i\tau_i}{A_i} \quad \text{for } \sigma_y > 0$$

(IACS UR S35. App.1, 2.1.3)

6.2.2 Irregular Panel and Curved Panel

.1 Reference stresses

The longitudinal, transverse and shear stresses are to be calculated using a weighted average approach. They are to be taken as:

$$\sigma_x = \frac{\sum_{i=1}^{n} A_i\sigma_{xi}}{A_i}$$

$$\sigma_y = \frac{\sum_{i=1}^{n} A_i\sigma_{yi}}{A_i}$$

$$\tau = \frac{\sum_{i=1}^{n} A_i\tau_i}{A_i}$$

The edge stress ratios are to be taken as:

$$\psi_x = 1$$

$$\psi_y = 1$$

(IACS UR S35. App.1, 2.2.1)

G. Rigidity of Transverses and Girders

The moment of inertia of deck transverses and girders, is not to be less than:

$$I = c \cdot W \cdot \ell \quad [\text{cm}^4]$$

c = 4,0 if both ends are simply supported
= 2,0 if one end is constrained
= 1,5 if both ends are constrained

W = section modulus of the structural member considered [cm^3]

ℓ = unsupported span of the structural member considered [m]

H. Structural Details

1. Continuity of structure

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)

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

2. Longitudinal members

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, C.1.

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 in this respect is to be paid to the construction of continuous longitudinal hatch coamings forming part of the longitudinal hull structure.

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

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

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

3. Transverses and girders

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

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

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.3.28.

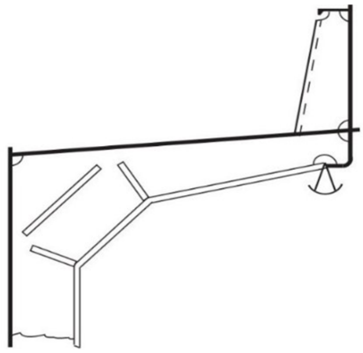


Fig. 3.28 Support of face plates of cantilevers

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

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

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

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

b_f = breadth of face plate [mm]

b_e = effective breadth of face plate :

= $t_w + n_1[t_f + c(b - t_f)]$ [mm]

t_w = web thickness [mm]

t_f = face plate thickness [mm]

b = coefficient, defined as:

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

c = $\frac{1}{\left[\frac{(b-t_f)^2}{(R \cdot t_t)}\right] - n_2} + \frac{n_3 \cdot t_f}{\alpha^2 \cdot R}$

c_{max} = 1

2α = knuckle angle [°], see Fig. 3.29

α_{max} = 45°

R = radius of rounded face plates [mm]

= t_f for knuckled face plates

n_1 = 1 for un-symmetrical face plates (face plate at one side only)

= 2 for symmetrical face plates

n_2 = 0 for face plate not supported by brackets

$= 0,9 \cdot \dfrac{(b - t_f)^2}{R \cdot t_f} \leq 1,0$ for face plates of multi-web girders

n_3 = 3 if no radial stiffener is fitted

= 3000 if two or more radial stiffeners are fitted or if one knuckle stiffener is fitted according to Fig. 3.29 (a).

$n_3 = \left(\dfrac{d}{t_f} - 8\right)^4$ if one stiffener is fitted according to Fig. 3.29 (b).

$3 \leq n_3 \leq 3000$

d = distance of the stiffener from the knuckle [mm]

For proof of fatigue strength of the weld seam in the knuckle, the stress concentration factor K_S (angle 2α according to Fig. 3.29 < 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 5 of Table 20.3:

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

n_4 = 7,143 for $\dfrac{d}{t_f} > 8$

$= \dfrac{d}{t_f} - 0,51 \cdot \sqrt[4]{\dfrac{d}{t_f}}$ for $8 \geq \dfrac{d}{t_f} > 1,35$

$= 0,5 \cdot \dfrac{d}{t_f} + 0 \cdot 125$ for $1,35 \geq \dfrac{d}{t_f} \geq -0,25$

The welding seam has to be shaped according to Fig. 3.30.

Scantlings of stiffeners (guidance):

thickness : $t_b = \dfrac{\sigma_a}{\sigma_p} \cdot t_f \cdot 2 \sin\alpha$ [mm]

height : $h = 1,5 \cdot b$ [mm]

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 shall not exceed $12 \cdot b_f$.

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

3.7 The location of lightening holes shall be such that the distance from hole edge to face plate is not less than 0,3 x web depth.

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

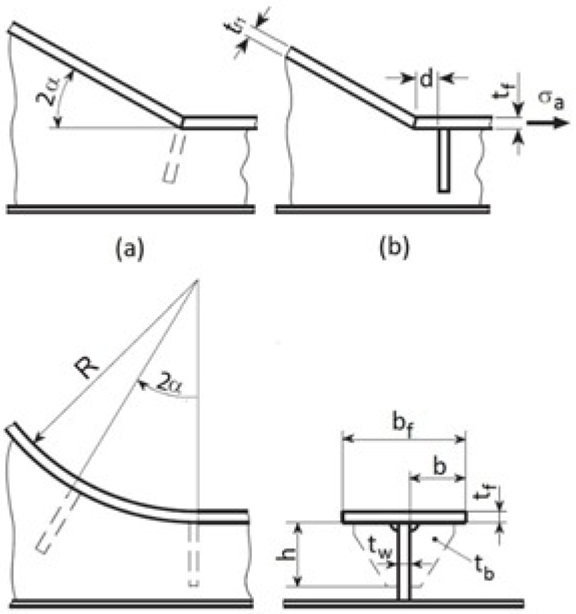


Fig. 3.29 Typical stiffeners of rounded of knuckled face plates

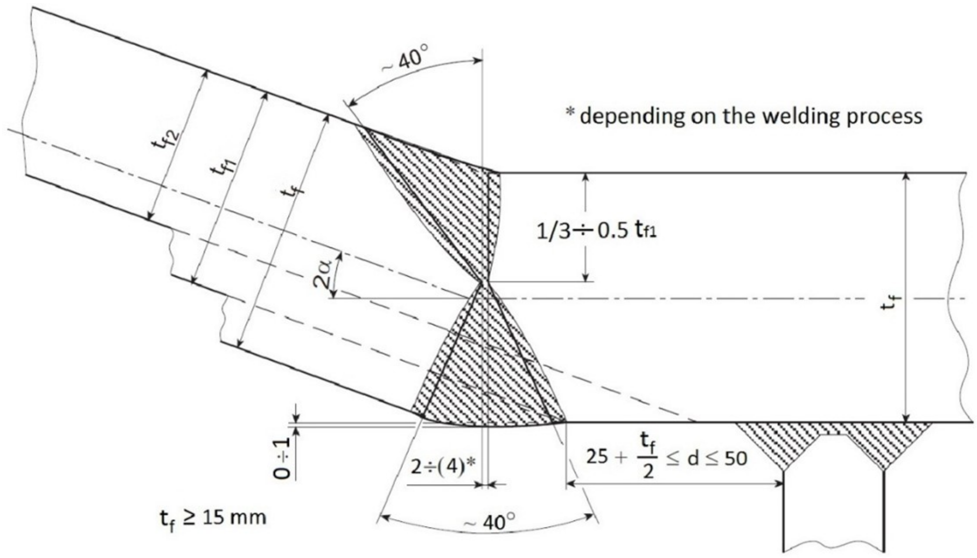


Fig. 3.30 Welding and supporting of knuckles

4. Knuckles (general)

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 at least:

$$d = 25 + \frac{t_f}{2}$$

but not more than 50 mm, see Fig. 3.30.

On bulk carriers at knuckles between inner bottom and tank side slopes in way of floors the welding cutouts have to be closed by collar plates or insert plates, see Fig. 3.31. In both cases a full penetration weld is required to inner bottom and bottom girder.

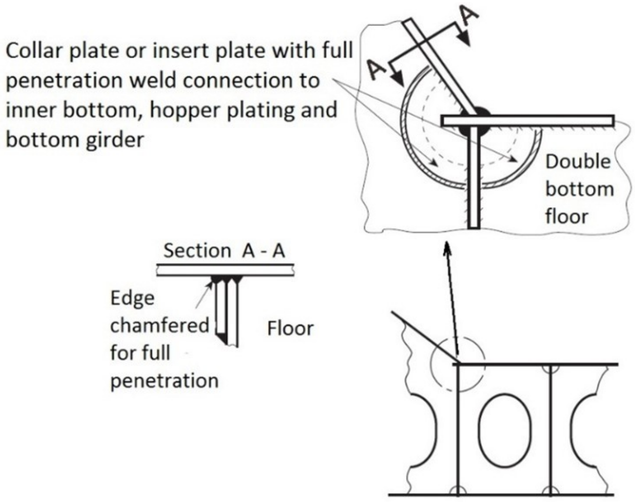


Fig. 3.31 Knuckles of the double bottom

J. Evaluation of Notch Stresses

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:

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

f	=	1,1	for normal strength hull structural steel
	=	0,9	for higher strength hull structural steel with R_{eH} = 315 N/mm^2
	=	0,8	for higher strength hull structural steel with R_{eH} = 355 N/mm^2
	=	0,73	for higher strength hull structural steel with R_{eH} = 390 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. 3.32 and Fig. 3.33

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

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

σ_{Kmax} = $+K_{tv} \cdot \sqrt{\sigma_1^2 + 3 \cdot \tau_1^2}$ For σ_1=tensile stress

= $-K_{tv} \cdot \sqrt{\sigma_1^2 + 3 \cdot \tau_1^2}$ For σ_1=compressive stress

K_{tv} = notch factor for equivalent stress

= $m\sqrt{\rho} + c$

m,c = parameters according to Fig. 3.34

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 (ℓ/r or a/r)
ρ_{min}	=	3

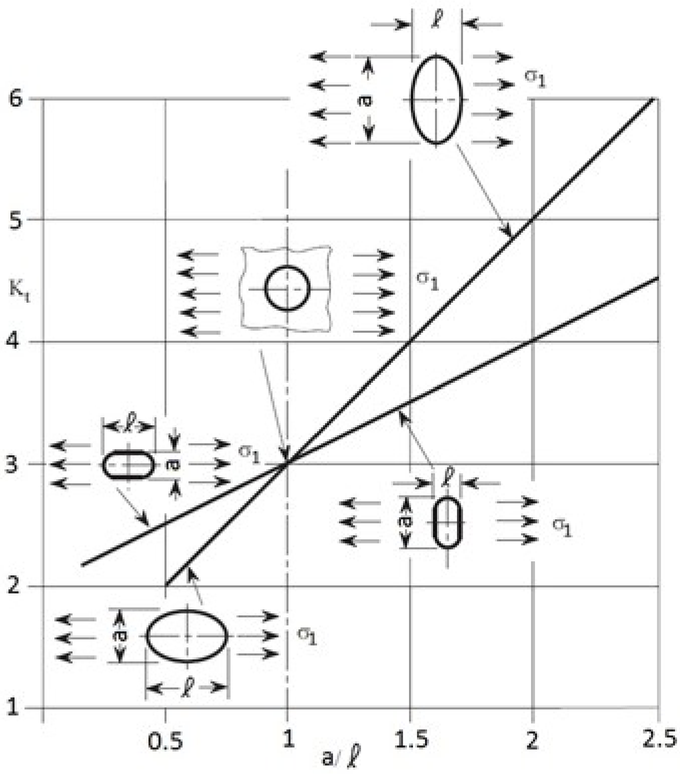


Fig. 3.32 Notch factor K_t for rounded openings

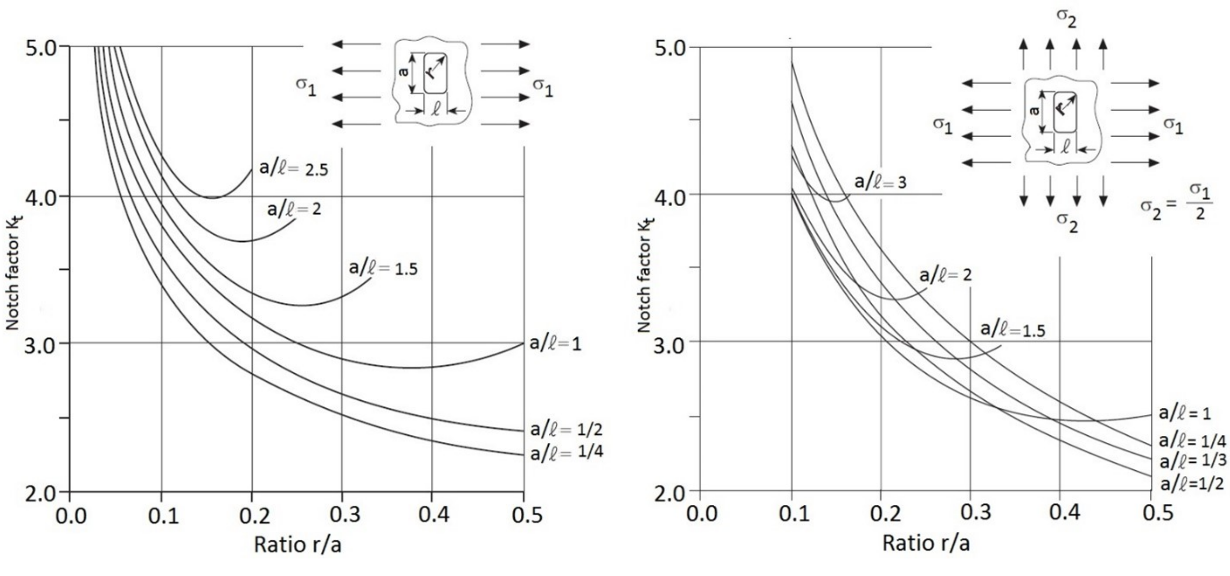


Fig. 3.33 Notch factor K_t for rectangular openings with rounded corners at uniaxial stress condition (left) and at biaxial stress condition (right)

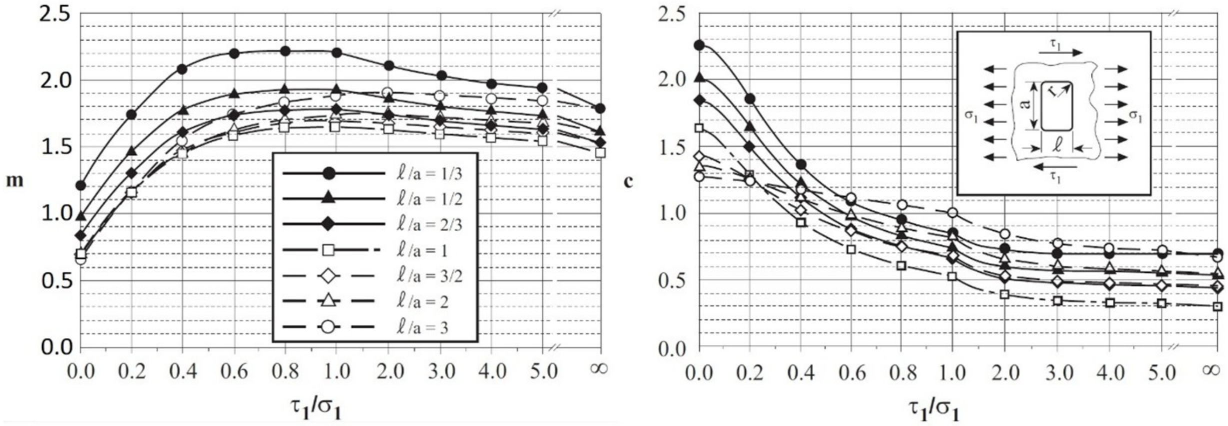


Fig. 3.34 Parameters m and c to determine the notch factors of rectangular openings loaded by superimposed longitudinal and shear stresses

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.

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 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.

K. Corrosion Additions

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

t_K	=	1,5 mm	for t'$\leq$10 mm
	=	$\frac{0,1.t'}{\sqrt{k}} + 0,5$ mm, max.$3,0$ mm	for t'> 10 mm

t' = required rule thickness excluding t_K [mm]

k = material factor according to Section 2, B.2

2. For structural elements in specified areas t_K is not to be less than given in Table 3.17. For corrosion protection see Section 38.

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

$$t_k = \frac{0,1.t'}{\sqrt{k}} \qquad \max.2,5 \text{ mm}$$

however, not less than 1,0 mm.

Table 3.17 Minimum corrosion addition

Area	t_{Kmin} [mm]
In ballast tanks where the weather deck forms the tank top, 1,5 m below tank top [1].	2,5
- In cargo oil tanks where the weather deck forms the tank top, 1,5 m below tank top. - 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_K = 2,5 mm for all structures within topside tanks of bulk carriers.	

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 the following formulae:

$$t_K = 1{,}0 \qquad [\text{mm}] \qquad \text{for } t' \leq 10 \text{ mm}$$

$$t_K = \frac{0{,}1 \cdot t'}{\sqrt{k}} + 0{,}5 \leq 3{,}0 \quad [\text{mm}] \qquad \text{for } t' \geq 10 \text{ mm}$$

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

L. Additional Stresses in Asymmetric Sections

1. Additional stresses for fatique strength analysis

The additional stress σ_h occurring in non-symmetric sections may be calculated by the following formulae:

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

Q	=	load on section parallel to its web within the unsupported span ℓ_f [kN]
	=	$p \cdot a \cdot \ell_f$ [kN] in case of uniformly distributed
ℓ_f	=	unsupported span of flange [m]
t_f, b_l, b_2	=	flange dimensions [mm] as shown Fig. 3.35. $b_1 \geq b_2$
W_y	=	Section modulus of section related to the y-y axis including the effective width of plating [cm^3]
W_z	=	section modulus of the partial section consisting of flange and half of web area related to the z-z axis [cm^3] (Bulb sections may be converted into a similar L-section)
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 of tankers.

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

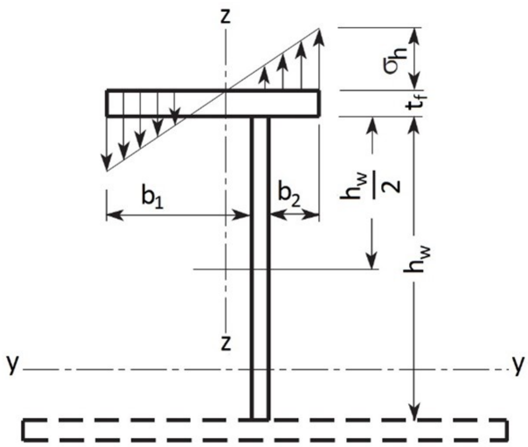


Fig. 3.35 Asymmetrical profile

2. Correction of section modulus

The required section modulus W_y according to A.2 is to be multiplied with the factor k_{sp} according to Table 3.18

Table 3.18 Increase factor k_{sp}

Type of Profile	k_{sp}
Flat bars and symmetric T-profiles	1,00
Bulb profiles	1,03
Asymmetric T profiles $\frac{b_2}{b_1} \approx 0.5$	1,05
Rolled angels (L-profiles)	1,15

M. Testing of Watertight and Weathertight Compartments

1. Tightness and structural testing of watertight and weathertight compartments has to be done in accordance with the Rules for Classification and Surveys (Pt. 1, Vol. I), Annex A.6.

Tank pressure heights according to Section 4, D.1 have to be observed.

2. For all tanks an operational test shall 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.

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, Definition

1. General

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 Volume.

2. Definitions

2.1 Load Centre

2.1.1 For plates:

- Vertical stiffening system:
  0,5 · stiffener spacing above the lower support of plate field, or lower edge of plate when the thickness changes within the plate field.

- Horizontal stiffening system:
  Midpoint of plate field.

2.1.2 For stiffeners and girders:

- Centre of span ℓ.

2.2 Definition of symbols

$\mathbf{v}_0$ = ship's speed according to Section 1, H.5

ρ_c = density of cargo as stowed $[\mathrm{t/m^3}]$

ρ = density of liquids $[\mathrm{t/m^3}]$

= 1,0 $\mathrm{t/m^3}$ for fresh water and sea water

z = vertical distance of the structure's load centre above base line [m]

x = distance from aft end of length **L** [m]

p_0 = basic external dynamic load

$= 2,1 \cdot (C_B + 0,7) \cdot c_0 \cdot c_L \cdot f \qquad [\mathrm{kN/m^2}]$

for wave directions with or against the ship's heading

p_{01} = $2,6 \cdot (\mathbf{C_B} + 0,7) \cdot c_0 \cdot c_L$ [kN/m^2]

for wave directions transverse the ship's heading

$\mathbf{C_B}$ = moulded block coefficient according to Section 1, H.4, where $\mathbf{C_B}$ is not to be taken less than 0,60

c_0 = wave coefficient

= $\left[\frac{\mathbf{L}}{25} + 4,1\right] \cdot c_{RW}$ for **L** < 90 m

= $\left[10,75 - \left[\frac{300 - \mathbf{L}}{100}\right]^{1,5}\right] \cdot c_{RW}$ for 90 $\le$ **L** $\le$ 300 m

= $10,75 \cdot c_{RW}$ for 300 < **L** < 350 m

= $\left[10,75 - \left[\frac{\mathbf{L} - 350}{100}\right]^{1,5}\right] \cdot c_{RW}$ for 350 $\le$ **L** $\le$ 500 m

c_L = length coefficient

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

= 1,0 for **L** $\ge$ 90 m

c_{RW} = service range coefficient

= 1,00 for unlimited service range

= 0,90 for service range **P**

= 0,75 for service range **L**

= 0,60 for service range **T**

f = probability factor

= 1,0 for plate panels of the outer hull (shell plating, weather decks)

= 0,75 for secondary stiffening members of the outer hull (frames, deck beams), but not less than f_Q according to Section 5, D.1

= 0,60 for girders and girder systems of the outer hull (web frames, stringers, grillage systems), but not less than f_Q/1,25

c_D, c_F = distribution factors according to Table 4.1.

B. External Sea Loads

1. Load on weather decks

The load on weather deck is to be determined according to the following formula:

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

P_{Dmin} = minimum load [kN/m^2] on weather decks, defined as

= $\max\,[16 \cdot f;\ 0,7 \cdot p_0]$ for strength decks which are to be treated as weather decks and for forecastle decks

	=	$P_L + P_Z$	where deck cargo is intended to be carried on the weather deck
P_L	=	load on cargo decks according to C.1 [kN/m²]	
P_Z	=	additional load $[\text{kN/m}^2]$ on cargo decks in case of small stowage heights, defined as:	
	=	$10 \cdot (1 - h_c)$	for $h_c \le 1$ m
	=	0	for $h_c > 1$ m
h_c	=	stowage height of the cargo [m]	

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

Range		Factor c_D	Factor c_F [1]
A	$0 \le \frac{x}{L} < 0,2$	$1,2 - \frac{x}{L}$	$1,0 + \frac{5}{C_B}\left(0,2 - \frac{x}{L}\right)$
M	$0,2 \le \frac{x}{L} < 0,7$	1,0	1,0
F	$0,7 \le \frac{x}{L} \le 1,0$	$1,0 + \frac{c}{3}\left(\frac{x}{L} - 0,7\right)$ $c = 0,15 \cdot L - 10$ where: $L_{min} = 100\text{m}$ $L_{max} = 250\text{m}$	$1,0 + \frac{20}{C_B}\left(\frac{x}{L} - 0,7\right)^2$

[1] Within the range A the ratio x/**L** need not be taken less than 0,1, within the range F the ratio x/**L** need not be taken greater than 0,93

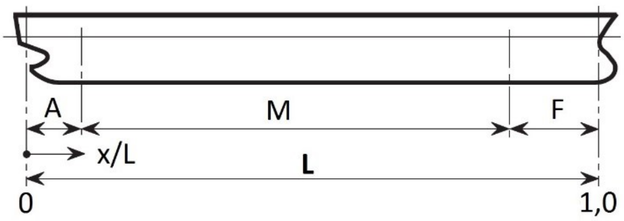


Fig. 4.1 Longitudinal sections A, M, and F according to Table 4.1

2. Load on ship's sides and of bow and stern structures

2.1 Load on ship's sides

The external load ps on the ship's sides is to be determined according to 2.1.1 and 2.1.2.

2.1.1 For elements the load centre of which is located below load waterline:

$$p_s = 10 \cdot (T - z) + p_0 \cdot c_F \left(1 + \frac{z}{T}\right) \qquad [\text{kN/m}^2]$$

for wave directions with or against the ship's heading.

$$p_{s1} = 10 \cdot (T - z) + p_{01} \cdot c_F \left[1 + \frac{z}{T}\left(2 - \frac{z}{T}\right)\right] \cdot 2\,\frac{|y|}{B} \qquad [\text{kN/m}^2]$$

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

y = horizontal distance between load centre and centreline [m]

2.1.2 For elements the load centre of which is located above the load waterline:

$$p_s = p_0 \cdot c_f \cdot \frac{20}{10 + z - \mathbf{T}} \qquad [\mathrm{kN/m^2}]$$

for wave directions with or against the ship's heading.

$$p_{s1} = p_{01} \cdot c_f \cdot \frac{20}{5 + z - \mathbf{T}} \cdot \frac{|y|}{\mathbf{B}} \qquad [\mathrm{kN/m^2}]$$

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

2.2 Load on bow structures

The design load for bow structures from forward to 0,1**L** behind **FP**. and above the ballast waterline in accordance with the draft T_b in 4. is to be determined according to the following formulae :

$$p_e = c\left[0,2 \cdot \mathbf{v}_0 + 0,6\sqrt{\mathbf{L}}\right]^2 \qquad [\mathrm{kN/m^2}]$$

with

$\mathbf{L}_{max}$ = 300 m

c = 0,8 in general

$= \dfrac{0,4}{(1,2 - 1,09 \cdot \sin\alpha)}$ for extremely flared sides where the flare angle α is larger than 40°

The flare angle α at the load centre is to be measured in the plane of frame between a vertical line and the tangent to the side shell plating.

For unusual bow shapes p_e can be specially considered.

p_e shall not be smaller than p_s according to 2.1.1 or 2.1.2 respectively.

Aft of 0,1**L** from **FP** up to 0,15**L** from **FP** the pressure between p_e and p_s is to be graded steadily.

The design load for bow doors is given in Section 6, H.3.

2.3 Load on stern structures

The design load for stern structures from the aft end to 0,1**L** forward of the aft end of **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 according to the following formulae:

$$p_e = c_a \cdot \mathbf{L} \qquad [\mathrm{kN/m^2}]$$

with

$\mathbf{L}_{max}$ = 300 m

c_A = $0,3 \cdot c \geq 0,36$

c = see 2.2

p_e = shall not be smaller than p_s according to 2.1.1 or 2.1.2 respectively

3. Load on the ship's bottom

The external load p_B of the ship's bottom is to be determined according to the greater of the following formulae:

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

For wave direction with or against the ship's heading.

$$p_{B1} = 10 \cdot \mathbf{T} + p_{01} \cdot 2\frac{|y|}{\mathbf{B}} \qquad [\mathrm{kN/m^2}]$$

For wave direction transverse to the ship's heading including quasi-static pressure increase due to heel.

4. Design bottom slamming pressure

The design bottom slamming pressure in the fore body may be determined by the following formulae:

$$p_{SL} = 162 \cdot \sqrt{\mathbf{L}} \cdot c_1 \cdot c_{SL} \cdot c_A \cdot c_S \qquad [\mathrm{kN/m^2}] \quad \text{for } \mathbf{L} \leq 150 \text{ m}$$

$$= 1984\,(1,3 - 0,002 \cdot \mathrm{L})\,c_1 \cdot c_{SL} \cdot c_A \cdot c_S \qquad [\mathrm{kN/m^2}] \quad \text{for } \mathbf{L} > 150 \text{ m}$$

c_1 = $3,6 - 6,5 \cdot \left[\frac{\mathbf{T_b}}{\mathbf{L}}\right]^{0,2}$ $\quad 0 \leq c_1 \leq 1,0$

$\mathbf{T_b}$ = smallest design ballast draught at **FP** for normal ballast conditions [m],according to which the strengthening of bottom forward, see Section 6,E, has to be done.

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

Where the sequential method for ballast water exchange is intended to be applied, $\mathbf{T_b}$ is to be considered for the sequence of exchange.

Note:

With respect to the observation of the smallest design ballast draught $\mathbf{T_b}$, 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.

C_{SL} = distribution factor, see also Fig.4.2

C_{SL} = 0 $\quad$ for $\frac{x}{L} \leq 0,5$

= $\frac{\frac{x}{L} - 0,5}{c_2}$ $\quad$ for $0,5 < \frac{x}{L} \leq 0,5 + c_2$

= 1,0 $\quad$ for $0,5 + c_2 < \frac{x}{L} \leq 0,65 + c_2$

= $0,5\left[1 + \frac{1 - \frac{x}{L}}{0,35 - c_2}\right]$ $\quad$ for $> 0,65 + c_2$

c_2 = $0,33 \cdot \mathbf{C_B} + \frac{\mathbf{L}}{2500}$

c_{2max} = 0,35

c_A = 10/A $\quad$ with $0,3 \leq c_A \leq 1,0$

= 1,0 $\quad$ for plate panels and stiffeners.

A = loaded area between the supports of the structure considered $[\mathrm{m^2}]$

$0,3 < c_A \leq 1,0$

c_S = $\frac{1 + c_{RW}}{2}$

c_{RW} = see A.2.2

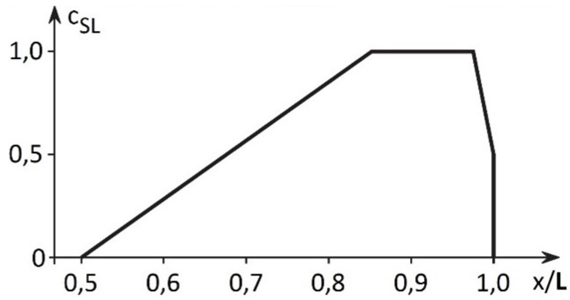


Fig. 4.2 Distribution factor c_{SL}

5. 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 5.1 and 5.2.

5.1 The load on exposed decks and parts of superstructure and deckhouse decks, which are not to be treated as strength deck, is to be determined as follows:

$$p_{DA} = p_D \cdot n \quad [\text{kN/m}^2] \qquad \text{for } \mathbf{L}>150 \text{ m}$$

p_D = load according 1.1

$n = 1 - \dfrac{z - \mathbf{H}}{10}$

= 1,0 for the forecastle deck

$n_{min} = 0,5$

For deckhouses the value so determined may be multiplied by the factor

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

b' = breadth of deckhouse

$\mathbf{B}'$ = largest breadth of ship at the position considered.

Except for the forecastle deck the minimum load is:

$$p_{DAmin} = 4,0 \quad [\text{kN/m}^2]$$

5.2 For exposed wheel house tops the load is not to be taken less than

$$p = 2,5 \quad [\text{kN/m}^2]$$

C. Cargo Loads, Load on Accommodation Decks

1. Load on cargo decks

1.1 The load on cargo decks is to be determined according to the following formulae:

$$p_L = p_c\,(1 + a_v) \quad [\text{kN/m}^2]$$

p_c = static cargo load [kN/m^2]

if no cargo load is given: $p_c = 7 \cdot h$ for. 'tween decks but not less than 15kN/m^2

h = mean 'tween deck height [m]

= In way of hatch casings the increased height of cargo is to be taken into account

a_v = acceleration factor as follows:

= F.m

F = $0{,}11 \dfrac{\mathbf{v_0}}{\sqrt{\mathbf{L}}}$

m = $m_0 - 5\,(m_0 - 1)\,\dfrac{\mathbf{x}}{\mathbf{L}}$ for $0 \le \dfrac{x}{L} \le 0{,}2$

= 1,0 for $0{,}2 < \dfrac{x}{L} \le 0{,}7$

= $1 + \dfrac{m_0 + 1}{0{,}3}\left[\dfrac{x}{L} - 0{,}7\right]$ for $0{,}7 < \dfrac{x}{L} \le 1{,}0$

m_0 = $(1{,}5 + F)$

$\mathbf{v_0}$ = see A.2.2 $\mathbf{v_0}$ is not to be taken less than $\sqrt{\mathbf{L}}$ [kn]

1.2 For timber and coke deck cargo the load on deck is to be determined by the following formulae:

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

h_s = stowing height of cargo [m]

1.3 The loads due to single forces P_E (e.g. in case of containers) are to be determined as follows:

$$P = P_E\,(1 + a_v) \quad [\text{kN}]$$

1.4 The cargo pressure of bulk cargoes is to be determined by the following formulae:

$$p_{bc} = p_c\,(1 + a_v) \quad [\text{kN/m}^2]$$

p_c = static bulk cargo load

= $9{,}81 \cdot \rho_c \cdot h \cdot n$ [kN/m^2]

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

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

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

γ = angle of repose of the cargo [°]

2. Load on inner bottom

2.1 The inner bottom cargo load is to be determined as follows:

$$p_i = 9{,}81\,\frac{G}{V}\,h\,(1 + a_v) \quad [\text{kN/m}^2]$$

G = stowing height of cargo [m]mass of cargo in the hold [t]

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

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

a_v = see 1.1

For calculating a_v the distance between the centre of gravity of the hold and the aft end of the length **L** is to be taken.

2.2 For inner bottom load in case of ore stowed in conical shape, see Section 23, B.3.

3. Loads on accommodation and machinery decks

3.1 The deck load in accommodation and service spaces is:

$$p = 3{,}5(1 + a_v) \quad [kN/m^2]$$

3.2 The deck load of machinery decks is:

$$p = 8{,}0(1 + a_v) \quad [kN/m^2]$$

3.3 Significant single forces are also to be considered, if necessary.

D. Load on Tank Structures

1. Design pressure for filled tanks

1.1 The design pressure for service conditions is the greater of the following values:

$$p_1 = 9{,}81 \cdot h_1 \cdot \rho(1 + a_v) + 100 \cdot p_v \quad [kN/m^2]$$

or

$$p_1 = 9{,}81 \cdot \rho \cdot h_p + 100 \cdot p_v \quad [kN/m^2]$$

For the calculation of p_1 the two highest points of the tank structures are to be identified for heeled condition to portside and to starboard side (see Fig.4.3). All distances and heights used in the calculation are to be measured in upright condition.

h_1 = distance from load centre to tank top [m]

h_p = pressure height [m] in heeled condition, defined as:

= $\max\left[\Delta y_p \cdot \sin\varphi + c_p \cdot \Delta z_p \cdot \cos\varphi; \Delta y_s \cdot \sin\varphi + c_s \cdot \Delta z_s \cdot \cos\varphi\right] - h_{ap}$

with $h_p \geq 0$

Δ_{yi} = transverse distances [m] between load centre and highest points, defined as:

Δ_{yp} distance between load centre and highest point for heel to portside

Δ_{ys} distance between load centre and highest point for heel to starboard side

Δ_{zi} = vertical distance [m] between load centre and highest points, defined as:

Δ_{zp} distance between load centre and highest point for heel to portside

Δ_{zs} distance between load centre and highest point for heel to starboard side

c_i = coefficients to take the relative position of the load centre to the highest points in upright condition into account, defined as:

c_P, c_S =1 if the position of the load centre is lower than the considered highest point

c_P, c_S =-1 if the position of the load centre is higher than the considered highest point

a_v = see C.1.1

φ = design heeling angle [°] for tanks

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

	$\geq$	20° for hatch covers of holds carrying liquids
f_{bk}	=	0,5 for ships with bilge keel
	=	0,6 for ships without bilge keel
b	=	upper breadth of tank [m]
h	=	maximum height [m] of tank
h_{ap}	=	height [m] of air pocket, defined as:
	=	0 in general
	=	$0,2\sqrt{\frac{b \cdot h}{\tan\varphi}} \cdot \sin\varphi$ for cargo tanks and cargo holds which are also used as ballast tanks
y	=	distance of load centre from the vertical longitudinal central plane of tank [m]
p_v	=	set pressure of pressure relief valve [bar], if a pressure relief valve is fitted
	=	working pressure during ballast water exchange [bar]
	=	$\frac{\Delta - 2,5}{10} + \Delta p_v$
Δ_z	=	distance from top of overflow to tank top [m]
Δ_v	=	pressure losses in the overflow line [bar]
Δp_{vmin}	=	0,1 bar
p_{vmin}	=	0,1 bar during ballast water exchange for both, the sequential method as well as the flow-through method
	=	0,2 bar (2,0 mWS) for cargo tanks of tankers Rules for Machinery Installations (Pt.1, Vol.III) Sec.15.

Smaller set pressures than 0,2 bar may be accepted in special cases. The actual set pressure will be entered into the Class Certificate.

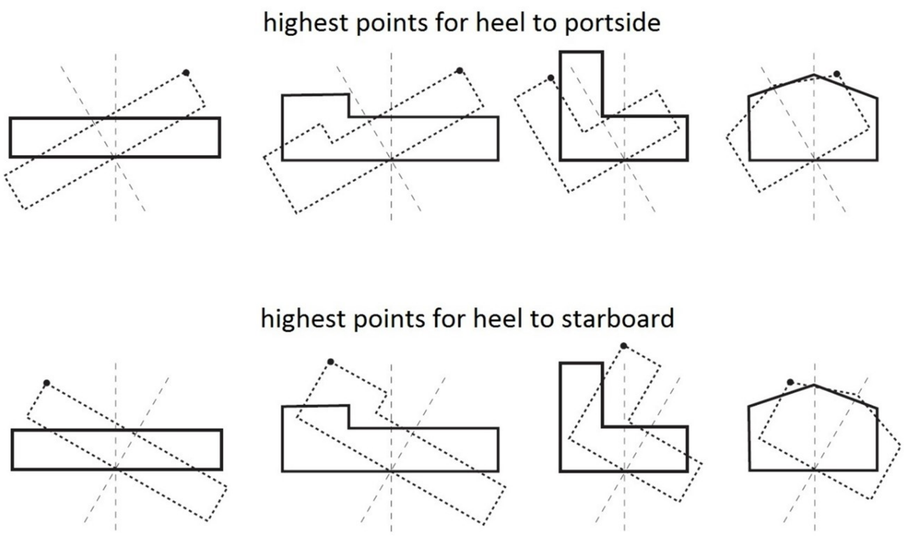


Fig. 4.3 Highest points for different tank shapes

1.2 The maximum static load p_2 on tank structures is to be determined by the following formula:

$$p_2 = 9,81.h_2 \quad [kN/m^2]$$

h_2 = load height [m], defined as:

= max $[h_{2,1}; h_{2,2}; h_{2,3}; h_{2,4}]$

$h_{2,1}$ = distance [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 [m] from load centre to a point 2,5 $\cdot$ ρ above tank top. Density of liquid intended to be carried is not to be taken less than 1 t/m^3.

$h_{2,3}$ = distance [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 Regulation for Construction, Equipment and Testing of Closed Fuel Oil Overflow Systems).

$h_{2,4}$ = distance [m] from load centre to a point $10 \cdot p_v[m]$ above tank top, if a pressure relief valve is fitted. Set pressure pv of pressure relief valve is not to be taken less than $0,25 \cdot \rho$ [bar]

2. Design pressure for partially filled tanks

2.1 For tanks which may be partially filled between 20% and 90% of their height, the design pressure is not to be taken less than given by the following formulae:

2.1.1 For structures located within 0,25ℓ_t from the bulkheads limiting the free liquid surface in the ship's longitudinal direction:

$$p_d = \left(4 - \frac{L}{150}\right) \ell_t \cdot \rho \cdot n_x \cdot + 100.p_v \quad [kN/m^2]$$

ℓ_t = distance [m] between transverse bulkheads or effective transverse wash bulkheads at the height where the structure is located.

n_x = distribution factor, defined as:

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

x_1 = distance [m] of structural element from the tank's ends in the ship's longitudinal direction

2.1.2 For structures located within 0,25 · bt from the bulkheads limiting the free liquid surface in the ship's transverse direction:

$$p_d = \left(5,5 - \frac{B}{20}\right) b_t \cdot \rho \cdot n_y \cdot + 100 \cdot p_v \quad [kN/m^2]$$

b_t = distance [m] between tank sides or effective longitudinal wash bulkhead at the height where the structure is located.

n_y = distribution factor, defined as:

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

y_1 = distance of structural element from the tank's sides in the ship's transverse direction [m]

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 pd may be required.

E. Design Values of Acceleration Components

1. Acceleration components

The following formulae may be taken for guidance when calculating the acceleration components owing to ship's motions. The accelerations ax, ay and az 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.

The acceleration components take account of the following components of motion:

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

$$a_y = \pm a_0 \sqrt{0,6 + 2,5\left[\frac{x}{\mathbf{L}} - 0,45\right]^2 + k\left[1 + 0,6 \cdot k\frac{z - \mathbf{T}}{\mathbf{B}}\right]}$$

Vertical acceleration (vertical to the base line) due to heave, and pitch.

$$a_z = \pm a_0 \sqrt{1 + \left[5,3 + \frac{4,5}{\mathbf{L}}\right]^2 + k\left[\frac{x}{\mathbf{L}} - 0,45\right]^2\left[\frac{0,6}{C_B}\right]^{1,5}}$$

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

$$a_x = \pm a_0 \sqrt{0,06 + A^2 - 0,25 \cdot A}$$

where:

A = coefficient, defined as:

$$= \left[0,7 - \frac{\mathbf{L}}{1200} + 5 \cdot \frac{z - \mathbf{T}}{\mathbf{L}}\right]\frac{0,6}{\mathbf{C_B}}$$

a_0 = basic acceleration, defined as:

$$= \left[0,2\frac{\mathbf{v_0}}{\sqrt{\mathbf{L_0}}} + \frac{3 - c_0 - c_L}{L_0}\right] f_0$$

L_0 = length of ship **L** [m], but for determination of a_0 the length $\mathbf{L_0}$ shall not be taken less than 100 m

k = $\dfrac{13 \cdot \overline{GM}}{\mathbf{B}}$

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

k_{min} = 1,0

f_Q = probability factor depending on probability level Q as outline in Table 4.2.

Table 4.2 Probability factor f_Q for a straightline spectrum of seaway-induced stress ranges

Q	f_Q
10^{-8}	1,000
10^{-7}	0,875
10^{-6}	0,750
10^{-5}	0,625
10^{-4}	0,500

2. Combined acceleration

The combined acceleration a may be determined by means of the "acceleration ellipse" according to Fig.4.4 (e.g. y-z plane).

φ = heeling angle
φ_{max} = maximum heeling angle

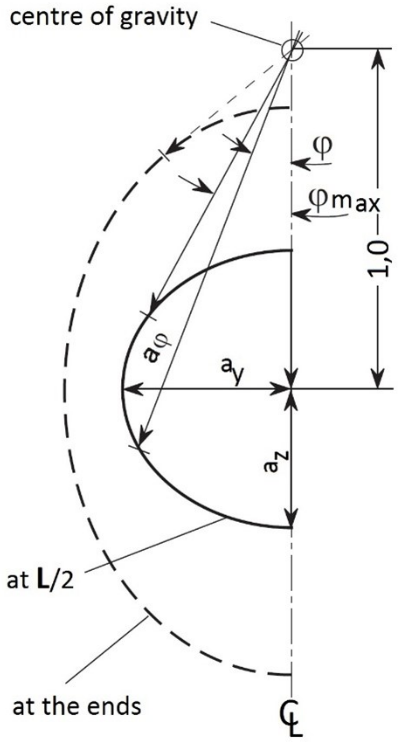


Fig. 4.4 Acceleration ellipse

Section 5 Longitudinal Strength

A. General

1. Scope and Reference

1.1 For ships of 65 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 m in length, the minimum midship section modulus according to C.2 is to be fulfilled.

1.2 The wave bending moments and shear forces specified under B.3 are design values which, in connection with the scantling formulae, correspond to a probability level Q = 10^{-8}. Reduced values may be used for the purpose of determining combined stresses as specified under D.1.

1.3 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.10

ICLL Annex 1, Ch. II, Reg. 10

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

For specific ship types reference is made to:

- for bulk carriers, ore carriers and combination carriers see Section 23, B.2
- for liquefied gas tankers see Rules for Ship Carrying Liquified Gas in Bulk (Pt.1, Vol.IX)

2. Calculation Particulars

The curves of the still water bending moments and still water shear forces for the envisaged loading and ballast conditions are to be calculated.

3. Assumptions for calculation, loading conditions

3.1 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 4.4.2, 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 transitory stage of the voyage are considered to result in a more severe loading condition, calculations for such transitory 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 transitory 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)

3.2 For other ship types than list in 4.4.2 and special ships, the calculation of bending moments and shear forces for other loading conditions according to the intended service may be required to be investigated, see also Section 23, B.2.

Where for ships of unusual design and form as well as for ships with large deck openings a complex stress analysis of the ship in the seaway becomes necessary, the analysis will normally be done by using computer programs approved by BKI and processing the data prepared by the yard.

4. Loading guidance information

4.1 General, definitions

4.1.1 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, Ch. II, Reg. 10 (1))

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 above, are to be carried on board at all times together with evidence that the information has been approved by the Administration.

(ICLL Annex 1, Ch. II, Reg. 10 (2))

Note:
Upon request, BKI will prepare the loading guidance information.

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, Ch. II, Reg. 10 (4))

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

In addition, 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, BKI may also require an approved loading instrument for ships of Category I less than 100 m in length.

Special requirements for bulk carriers, ore carriers and combination carriers are given in Section 23, B.10.

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 Guidelines for Certification of Loading Computer Systems (Pt.4, Vol.1) Sec.1.A.

4.1.3 The following definitions apply:

A loading manual is a document which describes:

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

(IACS UR S1.1.2)

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)

Loading computers have to be type tested and certified, see also 4.5. Type approved hardware may be waived, if redundancy is ensured by a second certified loading instrument.

Type approval is required if:

- the computers are installed on the bridge or in adjacent spaces
- interfaces to other systems of ship operation are provided.

For type approval the relevant rules and guidelines are to be observed.

Loading programs shall be approved and certified, see also 4.3.1 and 4.5.

Ship categories for the purpose of this Section are defined for all classed seagoing ships of 65 m in length and above which were contracted for construction on or after 1^{st} July 1998 as follows:

Category I Ships:

- Ships with large deck openings where, according to F., 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 more than 120 m in length, 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 exceptions given under Category I.

(IACS UR S1.1.1 and S1.1.2)

4.2 Conditions of approval of loading manuals

The approved loading manual is to be based on the final data of the ship. Manual should contain the design loading and ballast conditions, subdivided into departure and arrival conditions, and ballast exchange at sea conditions, where applicable, upon which the approval of the hull scantlings is based.

Subsection 4.4.2 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 new approved loading manual is to be issued. The loading manual shall 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)

4.3 Conditions of approval of loading instruments

4.3.1 The approval of the loading instrument is to include:

- verification of type approval, if required, see 4.1.3
- verification that the final data of the ship has been used,
- acceptance of number and position of read-out points,
- acceptance of relevant limits for all read-out points,
- checking of proper installation and operation of the instrument on board, in accordance with agreed test conditions, and availability of the approved operation manual.

4.3.2 Subsection 4.5 contains information on approval procedures for loading instruments.

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

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

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

(IACS UR S1.2.3)

The permissible limits for the still water bending moments and shear forces to be applied for the ballast water exchange at sea are to be determined in accordance with E., where B.3.1 is to be used for the wave bending moments and B.3.2 for the wave shear forces.

4.4 Design cargo and ballast loading conditions

4.4.1 For ballast water exchange see also the Guidelines on Ballast Water Exchange (G6-Res.MEPC.124(53)) BWM Convention.

.1 Partially filled ballast tanks in ballast loading condition

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

- design stress limits are not exceeded in all filling levels between empty and full.
- for bulk carriers, where applicable, the requirements of Section 23, B.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 4.3.2 any intermediate condition, the tanks intended to be partially filled are assumed to be:

— empty

— full

— partially filled at intended level

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

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

The trim conditions mentioned above are:

- trim by stern of 0,03**L**, or
- trim by bow of 0,015**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.

Guidance for partially filled ballast tanks in ballast loading conditions in according to Annex 1.

(IACS UR S11.2.1.3)

.2 Partially filled ballast tanks in combination with cargo loading conditions

In such cargo loading conditions, the requirements in 4.4.1.1 apply to the peak tanks only.

(IACS UR S11.2.1.4)

.3 Sequential ballast water exchange

Requirements of 4.4.1.1 and 4.4.1.2 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)

4.4.2 In particular the following loading conditions should be included:

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 condition afloat,

— loading and unloading transitory conditions, where applicable.

For oil tankers (see also Section 24, B) :

— homogeneous loading conditions (excluding dry and segregated ballast tanks) and ballast or part loaded conditions for both departure and arrival,

— any specified non-uniform distribution of loading,

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

— docking condition afloat,

— loading and unloading transitory conditions.

For chemical tankers :

— conditions as specified for oil tankers,

— conditions for high density or heated cargo, see also Section 12, A.6,

— 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 condition for which an increased vapour pressure has been approved Rules for Ships Carrying Liquefied Gas in Bulk (Pt.1, Vol.IX) Sec.4.4.2.6.4),

— docking condition 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)

4.5 Approval procedures of loading instruments

For approval of the loading instrument see Guidelines for Certification of Loading Computer Systems (Pt.4, Vol.1).

4.6 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 done in the presence of the Surveyor.

(IACS UR S1.1.3)

5. Definitions

k	=	material factor according to Section 2, B
$\mathbf{C_B}$	=	block coefficient as defined in Section 1, H.4, $\mathbf{C_B}$ is not to be taken less than 0,6
x	=	distance [m] between aft end of length **L** and the position considered
$\mathbf{v_0}$	=	speed of the ship [kn] according to Section 1, H.5
I_y	=	moment of inertia of the midship section $[m^4]$ around the horizontal axis at the position x/L
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_Z	=	vertical distance of the structural element considered from the horizontal neutral axis [m] (positive sign for above the neutral axis, negative sign for below)
W_B	=	section modulus of section $[m^3]$ related to base line
W_D	=	section modulus of section $[m^3]$ related to deck line at side
S	=	first moment of the sectional area considered $[m^3]$ related to the neutral axis
M_T	=	total bending moment in the seaway [kNm]
	=	$M_{SW,max} + M_{WV,hog}$ for the maximum vertical bending moment, or
	=	$M_{SW,min} + M_{WV,sag}$ for the minimum vertical bending moment
M_{SW}	=	permissible vertical still water bending moment [kNm] (positive sign for hogging, negative sign for sagging condition)
M_{WV}	=	vertical wave bending moment [kNm] (positive sign for hogging, M_{WVhog}, negative sign for sagging condition, M_{WVsag})
M_{WH}	=	horizontal wave bending moment [kNm] (positive sign for tension starboard side, negative for compression in starboard side)
M_{ST}	=	static torsional moment [kNm]
M_{WT}	=	wave induced torsional moment [kNm]
Q_T	=	total vertical shear force in the seaway [kN]
	=	$\max \begin{bmatrix} Q_{SW,max} + Q_{WV,max} \\ \lvert Q_{SW,min} + Q_{WV,min} \rvert \end{bmatrix}$
Q_{SW}	=	permissible vertical still water shear force [kN]
Q_{WV}	=	vertical wave shear force [kN]
Q_{WH}	=	horizontal wave shear force [kN]

Sign rule see Fig. 5.1.

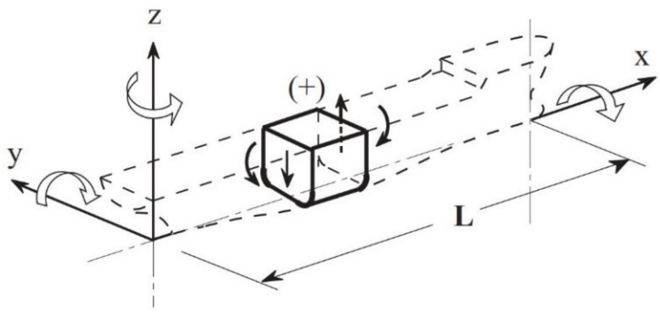


Fig. 5.1 Sign rule

B. Loads on the Ship's Hull

1. General

1.1 For ships having one or more of the following characteristics, BKI 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 Guidance for Design Wave Loads on Ship Structures (Pt.1, Vol. AA)). 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. **L/B** ≤ 5 , **B/H** ≥ 2,5 , **L** ≥ 500 m , $\mathbf{C}_B$ < 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 $\mathbf{v}_0$ ≥ 1,6 [kn]

(IACS UR S11.1)

1.2 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 Total vertical 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 see A.5.

2. Still Water Loads

2.1 General

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, B.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.

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)

Still water loads have to be superimposed with the wave-induced loads according to 3.

2.2 Guidance values for container ships with irregular loading

2.2.1 Still water bending moments

When determining the required section modulus of the midship section of containerships in the range:

$$\frac{x}{L} = 0,3 \text{ to } \frac{x}{L} = 0,55$$

it is recommended to use at least the following initial value for the hogging still water bending moment:

$$M_{SW,ini} = n_1 \cdot c_0 \cdot \mathbf{L}^2 \cdot \mathbf{B} \cdot (0,123 - 0,015 \cdot \mathbf{C}_B) \quad [\text{kNm}]$$

n_1 = $1,07\left[1 + 15\left(\frac{n}{10^5}\right)^2\right] \leq 1,2$

n = according to 2.2.2

$M_{SW,ini}$ shall be graduated regularly to ship's ends.

2.2.2 Static torsional moment

The maximum static torsional moment may be determined by:

$$M_{ST,max} = \pm 20 \cdot \mathbf{B} \cdot \sqrt{CC} \quad [\text{kNm}]$$

CC = maximum permissible cargo capacity of the ship [t]

= $n \cdot G$

n = maximum number of 20'-containers (TEU) of the mass G the ship can carry

G = mean mass of a single 20'-container [t]

For the purpose of a direct calculation the following envelope curve of the static torsional moment over the ship's length is to be taken:

$$M_{ST} = 0,568 \cdot M_{STmax}(|c_{TI}| + c_{T2}) \quad [\text{kNm}]$$

c_{T1}, c_{T2} = distribution factors, see also Fig. 5.2

c_{T1} = $\sin^{0,5}\left(2 \cdot \pi \cdot \frac{x}{\mathbf{L}}\right)$ for $0 \leq \frac{x}{\mathbf{L}} < 0,25$

= $\sin\left(2 \cdot \pi \cdot \frac{x}{\mathbf{L}}\right)$ for $0,25 \leq \frac{x}{\mathbf{L}} < 1,0$

c_{T2} = $\sin\left(\pi \cdot \frac{x}{\mathbf{L}}\right)$ for $0 \leq \frac{x}{\mathbf{L}} < 0,5$

= $\sin^2\left(\pi \cdot \frac{x}{\mathbf{L}}\right)$ for $0,5 \leq \frac{x}{\mathbf{L}} \leq 1,0$

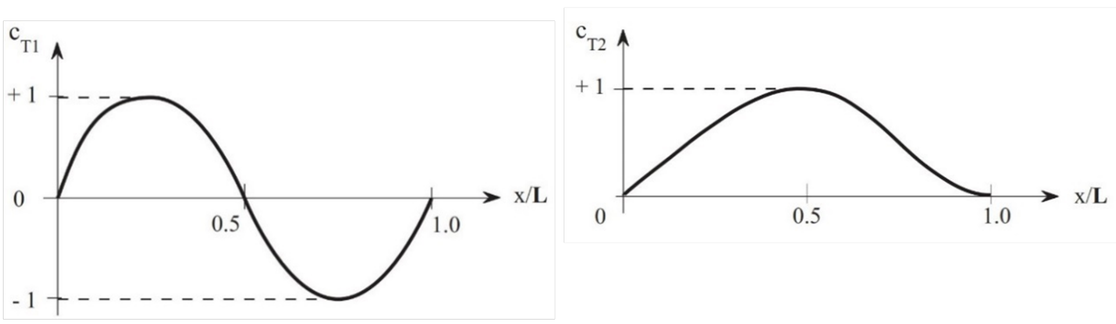


Fig. 5.2 Distribution factors c_{T1} and c_{T2} for torsional moments

3. Wave induced loads

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 according to the following formulae:

M_{WV} = $L^2 \cdot \mathbf{B} \cdot c_0 \cdot c_1 \cdot c_L \cdot c_M$ [kNm]

c_0, c_L = see Section 4, A.2.2

c_1 = hogging/sagging condition as follows:

c_{1H} = $0{,}19 \cdot \mathbf{C_B}$ for hogging condition

c_{1S} = $-0{,}11(\mathbf{C_B} + 0,7)$ for sagging condition

c_M = distribution factor, see also Fig. 5.3

c_{MH} = hogging condition

= $2,5 \cdot \frac{x}{L}$ for $0 \leq \frac{x}{L} < 0,4$

= 1,0 for $0,4 \leq \frac{x}{L} \leq 0,65$

= $\frac{1 - \frac{x}{L}}{0,35}$ for $0,65 < \frac{x}{L} \leq 1$

c_{MS} = sagging condition

= $2,5 \cdot c_v \cdot \frac{x}{L}$ for $0 \leq \frac{x}{L} < 0,4$

= c_v for $0,4 \leq \frac{x}{L} \leq 0,65 \cdot c_v$

= $c_v - \frac{\frac{x}{L} - 0,65 \cdot c_v}{1 - 0,65 \cdot c_v}$ for $0,65 \cdot c_v < \frac{x}{L} \leq 1$

c_v = influence with regard to speed v_0 of the vessel

= $\sqrt[3]{\frac{v_0}{1,4 \cdot \sqrt{\mathbf{L}}}} \geq 1{,}0$ for **L** the value need not be less than 100 m

= 1,0 for damaged condition

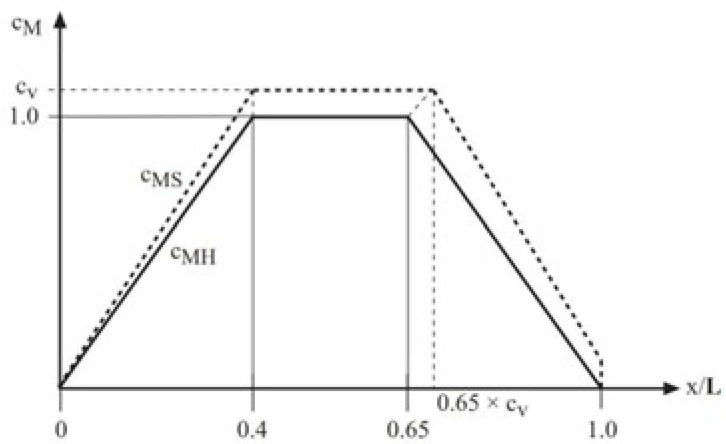


Fig. 5.3 Distribution factor c_M and influence factor c_v

3.2 Vertical wave shear forces

The vertical wave shear forces are to be determined by the following formulae:

$$Q_{WV} = c_D \cdot c_L \cdot \mathbf{L} \cdot \mathbf{B}\,(\mathbf{C_B} + 0,7) \qquad [\text{kN}]$$

c_0, c_L	=	see Section 4, A.2.2
c_Q	=	distribution factor according to Table 5.1, see also Fig. 5.4.
m	=	$-\frac{c_{1H}}{c_{1S}}$
c_{1H}, c_{1S}	=	see 3.1

Table 5.1 Distribution factor c_Q

Range	for positive shear forces	for negative shear forces
$0 \le \frac{x}{L} < 0,2$	$1,38.m\,\frac{x}{L}$	$-1,38\,\frac{x}{L}$
$0,2 \le \frac{x}{L} < 0,3$	$0,276 \cdot m$	$-0,276$
$0,3 \le \frac{x}{L} < 0,4$	$1,104\,m - 0,63 + (2,1 - 2,76\,m)\frac{x}{L}$	$-\left[0,474 - 0,66\,\frac{x}{L}\right]$
$0,4 \le \frac{x}{L} < 0,6$	$0,21$	$-0,21$
$0,6 \le \frac{x}{L} < 0,7$	$(3 \cdot c_v - 2,1)\left(\frac{x}{L} - 0,6\right) + 0,21$	$-\left[1,47 - 1,8 + 3(m - 0,7)\frac{x}{L}\right]$
$0,7 \le \frac{x}{L} < 0,85$	$0,3 \cdot c_v$	$-0,3\,m$
$0,85 \le \frac{x}{L} \le 1,0$	$\frac{1}{3}\left[c_v\left(14 \cdot \frac{x}{L} - 11\right) - 20 \cdot \frac{x}{L} + 17\right]$	$-2m\left[1 - \frac{x}{L}\right]$

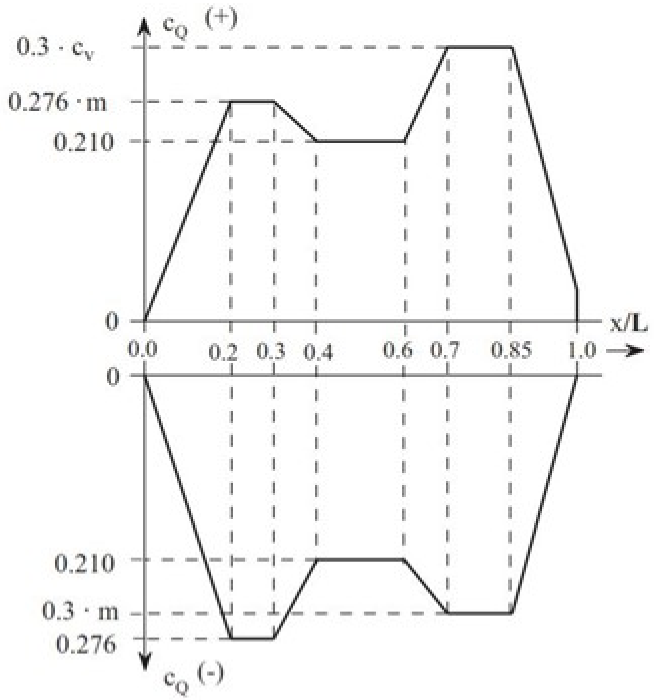


Fig. 5.4 Distribution factor c_Q

3.3 Horizontal bending moments

The horizontal bending moments M_{WH} over the ship's length are to be determined by the following formula:

$$M_{WH} = 0,32 \cdot \mathbf{L} \cdot Q_{WHmax} \cdot C_M \quad [\text{kNm}]$$

C_M = see 3.1, but for c_v = 1,0

Q_{WHmax} = see 3.4

3.4 Horizontal shear forces

The maximum horizontal shear force Q_{WH},max is to be determined by the following formula:

$$Q_{WHmax} = \pm C_N \cdot \sqrt{\mathbf{L} \cdot \mathbf{T}} \cdot \mathbf{B} \cdot \mathbf{C_B} \cdot c_0 \cdot c_L \quad [\text{kN}]$$

$$C_N = 1 + 0,15 \frac{\mathbf{L}}{\mathbf{B}}$$

C_{Nmin} = 2,0

The horizontal shear forces Q_{WH} over the ship's length are to be determined by the following formula:

$$Q_{WH} = Q_{WHmax} \cdot c_{QH}$$

c_{QH} = distribution factor according to Table 5.2, see also Fig. 5.5

Table 5.2, see also Fig. 5.5

Table 5.2 Distribution factor c_{QH}

Range	c_{QH}
$0 \leq \frac{x}{L} < 0,1$	$0,4 + 6.\frac{x}{L}$
$0,1 \leq \frac{x}{L} < 0,3$	1
$0,3 \leq \frac{x}{L} < 0,4$	$1,0 - 5.\left(\frac{x}{L} - 0,3\right)$
$0,4 \leq \frac{x}{L} < 0,6$	0,5
$0,6 \leq \frac{x}{L} < 0,7$	$0,5 + 5.\left(\frac{x}{L} - 0,6\right)$
$0,7 \leq \frac{x}{L} < 0,8$	1
$0,8 \leq \frac{x}{L} < 0,1$	$1,0 - 4,25.\left(\frac{x}{L} - 0,8\right)$

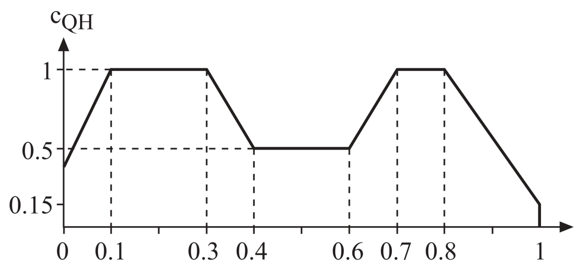


Fig. 5.5 Distribution factor c_{QH}

3.5 Torsional moments

The maximum wave induced torsional moment is to be determined as follows:

$$M_{WTmax} = \pm \mathbf{L} \cdot \mathbf{B^2} \cdot \mathbf{C_B} \cdot C_0 \cdot C_L \left[0,11 + \sqrt{a^2 + 0,012}\right] \quad [kNm]$$

a = $\sqrt{\frac{\mathbf{T}}{\mathbf{L}}} \cdot \frac{C_N \cdot z_Q}{\mathbf{B}}$

a_{min} = 0,1

C_N = see 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

When a direct calculation is performed, for the wave induced torsional moments the following envelope curve is to be taken:

$$M_{WT} = \pm \mathbf{L} \cdot \mathbf{B}^2 \cdot \mathbf{C_B} \cdot c_0 \cdot c_L \cdot c_{WT} \quad [kNm]$$

c_{WT} = distribution factor, see also Fig. 5.6

= $(a \cdot |c_T| + 0,22 \cdot c_{T2})(0,9 + 0,08 \cdot a)$

c_{T1}, c_{T2} = see 2.2.2

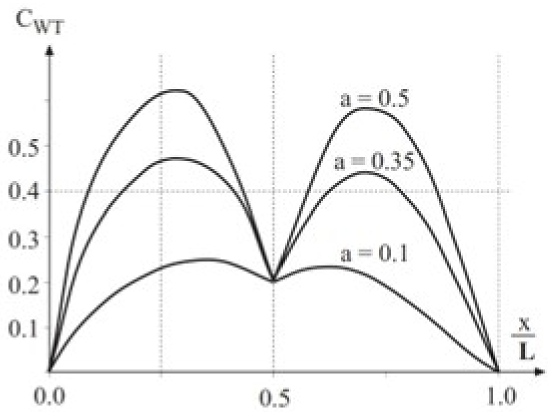


Fig. 5.6 Distribution factor c_{WT}

Note:

The envelope can be approximated by superposition of both distributions according to Fig. 5.2.

C. Section Moduli, Moments of Inertia, Shear and Buckling Strength

1. Section moduli as a function of the longitudinal bending moments

1.1 The section moduli related to deck W_D respectively $W_{D'}$ or bottom W_B are not to be less than:

W = $f_r \cdot \frac{|M_T|}{\sigma_P \cdot 10^3}$ $[m^3]$

f_r = factor to take the degree of deck opening into account, defined as:

= 1,0 in general

= according to F.2 for ships with large openings

σ_p = permissible longitudinal bending stress [N/mm^2]

= $c_s \cdot \sigma_{p0}$

σ_{p0} = $18,5 \frac{\sqrt{L}}{k}$ for **L**<90 m

= $\frac{175}{k}$ for **L**$\geq$90 m

c_s = $0,5 + \frac{5}{3} \cdot \frac{x}{L}$ for $0 \leq \frac{x}{L} < 0,30$

= $1,0$ for $0,30 \leq \frac{x}{L} \leq 0,70$

= $\frac{5}{3}\left[1,3 - \frac{x}{L}\right]$ for $0,70 < \frac{x}{L} \leq 1,0$

(IACS UR S11.3.1.1)

1.2 For the ranges outside 0,4**L** amidships the factor c_s may be increased up to c_s = 1,0, if this is justified under consideration of combined stresses due to longitudinal hull girder bending (including bending to impact loads), horizontal bending, torsion and local loads and under consideration of buckling strength.

1.3 The required section moduli have to be fulfilled inside and outside 0,4**L** amidships in general. Outside 0,4**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 container ships, locations at or near 0,25**L** and 0,75**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)

2. Minimum midship section modulus

2.1 The section modulus Wmin related to deck and bottom is not to be less than the following minimum value:

$$W_{min} = k \cdot c_0 \cdot L^2 \cdot B\,(C_B + 0,7)\,10^{-6} \quad [m^3]$$

c_0 according to Section 4, A.2.2 for unlimited service range.

(IACS UR S7.1)

For ships classed for a restricted range of service, the minimum section modulus may be reduced as follows:

- **P** (Restricted Ocean Service) : by 5%
- **L** (Coasting Service) : by 15%
- **T** (Sheltered Water Service) : by 25%

2.2 The scantlings of all continuous longitudinal members based on the minimum section modulus requirement are to be maintained within 0,4**L** amidships.

However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the end of the 0,4**L** part, bearing in mind the desire not inhabit the vessel's loading flexibility.

(IACS UR S7.2)

3. Midship section moment of inertia

The moment of inertia related to the horizontal axis is not to be less than :

$$I_y = 3 \cdot 10^{-2} \cdot W \cdot \frac{L}{k} \quad [m^4]$$

W see 1.1 and/or 2.1, the greater value is to be taken.

(IACS UR S11.3.2.1)

4. Calculation of section moduli

4.1 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 formulae:

$$W'_D = \frac{I_y}{e_D} \quad [m^3]$$

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

$$e'_D = z \cdot \left(0,9 + 0,2 \cdot \frac{y}{B}\right) \quad [m]$$

z = distance [m] from neutral axis of the cross section considered to top of continuous strength member

y = distance [m] from centre line to top of continuous strength member.

It is assumed that $e'_D > e_D$

(IACS UR S5)

For ships with multi-hatchways see 5.

4.2 When calculating the section modulus, the sectional area of all continuous longitudinal strength members shall 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. 5.7)

A deduction-free sum of smaller opening breadths in one transverse section in the bottom or deck area of 0,06 ($\mathbf{B} - \sum b$) (where **B** = breadth of ship at the considered transverse section, $\sum b$ = sum of breadth of openings) may be considered equivalent to the above reduction in section modulus by 3%.

The shadow area will be obtained by drawing two tangent lines with an opening angle of 30° (see Fig. 5.7).

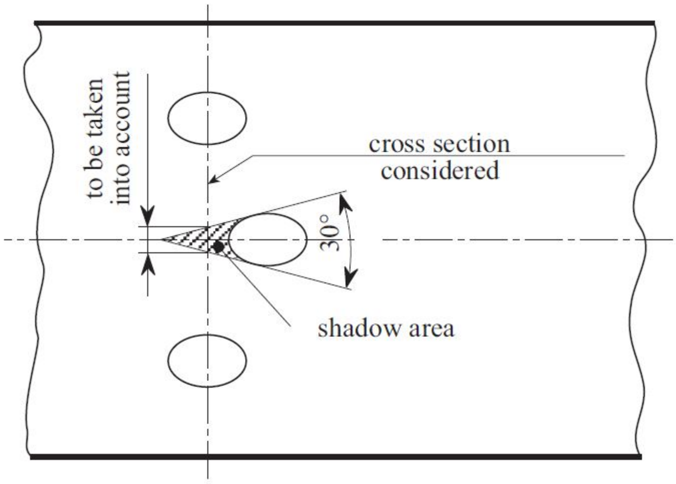


Fig. 5.7 Shadow area

(IACS UR S5)

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

(IACS UR S7.3)

Note:

In case of large openings local strengthenings may be required which will be considered in each individual case (see also Section 7, A.3.1).

5. Ships with multi-hatchways

5.1 For the determination of section moduli 100% effectivity of the longitudinal hatchway girders between the hatchways may be assumed, if an effective attachment of these girders is given.

5.2 An effective attachment of the longitudinal hatchway girder must fulfil the following condition:

The longitudinal displacement fL of the point of attachment due to action of a standard longitudinal force PL is not to exceed

$$f_L = \frac{\ell}{20} \quad [\mathrm{mm}]$$

$$P_L = 10 \cdot A_{LG} \quad [\mathrm{kN}]$$

ℓ = length of transverse hatchway girder according to Fig. 5.8 [m]

A_{LG} = entire cross sectional area of the longitudinal hatchway girder $[\mathrm{cm}^2]$

see also Fig. 5.8.

Where the longitudinal displacement exceeds $f_L = \ell/20$, special calculation of the effectivity of the longitudinal hatchway girders may be required.

Note:

Upon request BKI will carry out the relevant direct calculations.

5.3 For the permissible combined stress see Section 10, E.3.

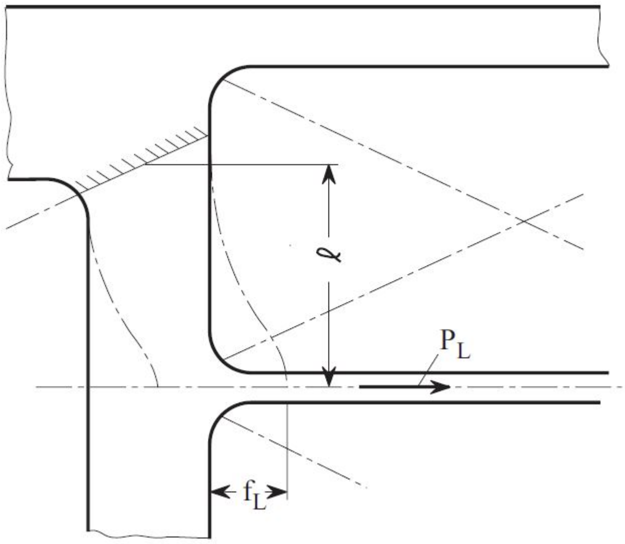


Fig. 5.8 Ship with multi-hatchways

6. Shear strength

The shear stress τ in longitudinal structures due to the vertical transverse forces Q_T acc. to E.2 and shall not exceed 110/ k [N/mm^2].

(IACS UR S11.4.1)

For ships with large deck openings and/or for ships with large static torsional moments, also the shear stresses due to M_{STmax} have to be considered adversely, i.e. increasing the stress level.

The shear stresses are to be determined according to D.3.

7. Proof of buckling strength

All longitudinal hull structural elements subjected to compressive stresses resulting from M_T according to E.1 and Q_T according to E.2 are to be examined for sufficient resistance to buckling according to Section 3, F. For this purpose the following load combinations are to be investigated:

— M_T and 0,7 Q_T

— 0,7 $\cdot$ M_T and Q_T

The stresses are to be determined according to D.

(IACS UR S11.3.2)

8. Ultimate load calculation of the ship's transverse sections

8.1 In extreme conditions, larger loads than referred to in B. may occur. Therefore, dimensioning of longitudinal structures is to be verified by proving the ultimate capacity according to 8.2 and 8.3. 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:

γ_R = 1,20

γ_{WV} = 1,20

8.2 Ultimate vertical bending moment

$$\left|M_{SW} + \frac{\gamma_{WV} \cdot M_{WV}}{c_S}\right| \le \left|\frac{M_U}{\gamma_R}\right|$$

c_S = stress factor according to 1.1

M_U = ultimate vertical bending moments of the ship's transverse section in the hogging ($M_{U,H}$) and sagging ($M_{U,S}$) conditions [kNm]. See 8.2.1

8.2.1 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. 5.9.

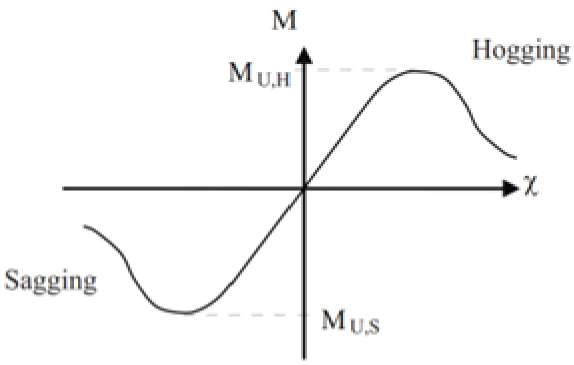


Fig. 5.9 Moment-curvature curve

The main steps to be used in the incremental-iterative approach are summarized as follows:

Step 1 The ship's transverse section is to be divided into plate-stiffener combinations (see 8.2.2.2.(a)) and hard corners (see 8.2.2.2.(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 8.2.2).

Step 3 The initial and incremental value of curvature $\Delta\chi$ is to be defined by the following formula:

$$\Delta\chi = \frac{0,05\frac{R_{eH}}{E}}{z_D - z_{NA,e}}$$

R_{eH} = minimum nominal yield point of structural elements in the strength deck [N/mm^2]

z_D = z co-ordinate of strength deck at side [m] (see also Fig. 5.1)

$z_{NA,e}$ = z co-ordinate of elastic neutral axis for the ship's transverse section [m]

Step 4 For the value of curvature, $\chi_j = \chi_{j-1} + \Delta_j$, the average strain, $\varepsilon_{Ei,j} = \chi_j z_i$ and corresponding average stress $\sigma_{i,j}$ is to be defined for each structural element i (see 8.2.2). For structural elements under tension, $\sigma_{i,j} = \sigma_{CR0}$ (see 8.2.2.1). For plate-stiffener combinations under compression, $\sigma_{i,j}$ = minimum$[\sigma_{CR1}, \sigma_{CR2}, \sigma_{CR3}]$ (see 8.2.2.2.(a)). For hard corners under compression, $\sigma_{i,j} = \sigma_{CR4}$ (see 8.2.2.2.(b)).

zi = z co-ordinate of ith structural element [m] relative to basis, see also Fig. 5.11

Step 5 For the value of curvature, $\chi_j = \chi_{j-1} + \Delta\chi$, the height of the neutral axis zNA,j is to be determined iteratively through force equilibrium over the ship's transverse section:

$$\sum_{i=1}^{m} A_i \sigma_{ij} = \sum_{i=1}^{n} A_i \sigma ij$$

m is the number of structural elements located above $z_{NA,j}$

n is the 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 :

$$M_{U,i} = \sum \sigma_{ij} \cdot A_i \left(z_{NA,j} - zi\right)$$

Steps 4 through 6 are to be repeated for increasing increments of curvature until the peaks in the M – χ 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 – χ curve.

8.2.2 Average stress - average strain curves

A typical average stress – average strain curve σ_{CRk} – ε for a structural element within a ship's transverse section is shown in Fig. 5.10, where the subscript k refers to the modes 0, 1, 2, 3 or 4, as applicable.

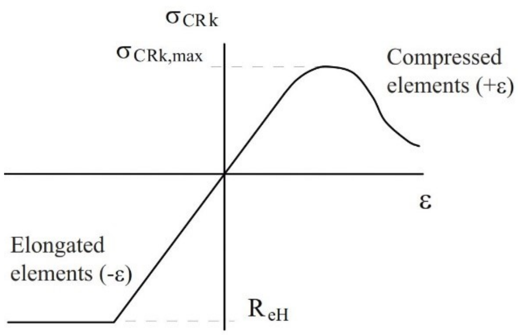


Fig. 5.10 Typical average stress - average strain curve

.1 Negative strain (σ_{CRO} – ε)

The portion of the curve corresponding to negative strain (i.e. tension) is in every case to be based on elasto-plastic behavior (i.e. material yielding) according to the following:

$$\sigma_{CR0} = \Phi \cdot R_{eH} \quad [N/m^2]$$

Φ = edge function

= -1 for ε <-1

= ε for $-1 \leq \varepsilon \leq 0$

ε = relative strain

= $\frac{\varepsilon_E}{\varepsilon_Y}$

ε_E = element strain

ε_Y = strain at yield stress in the element

= $\frac{R_{eH}}{E}$

.2 Positive strain

The portion of the curve corresponding to positive strain (i.e. compression) is to be based on some mode of collapse behavior (i.e. buckling) for two types of structural elements; (a) plate-stiffener combinations and (b) hard corners. See Fig. 5.11.

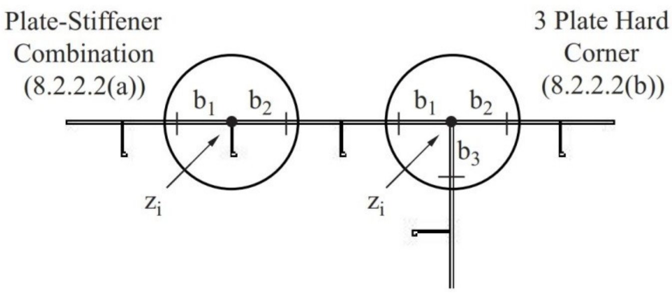


Fig. 5.11 Structural elements

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:

$$\sigma_{CR1} = \Phi\, R_{eH}\, \kappa_{BC} \frac{A_{Stif} + b_{m,1}\, t_1/2 + b_{m,2}\, t_2/2}{A_{Stif} + b_1\, t_1/2 + b_2\, t_2/2}$$

Φ = edge function

= ε for $0 \le \varepsilon \le 1$

= 1 for $\varepsilon > 1$

κ_{BC} = reduction factor

= 1 for $\lambda_K \le 0,2$

= $\dfrac{1}{k_D + \sqrt{k_D^2 - \lambda_k^2}}$ for $\lambda_K > 0,2$

λ_K = $\sqrt{\dfrac{\varepsilon_E \cdot a_2 \cdot A_x}{\varphi^2 \cdot I_x}} \cdot 10^{-4}$

k_D = $\left(1 + 0,21\,(\lambda_K - 0,2) + \lambda_K^2\right)/2$

a = length of stiffener [mm]

A_x = sectional area of stiffener with attached shell plating of breadth $(b_{m,1}/2 + b_{m,2}/2)$ [mm^2]

I_x = moment of inertia of stiffener with attached shell plating of breadth $(b_{m,1}/2 + b_{m,2}/2)$ [cm^4]

$b_{m,1}, b_{m,2}$ = effective breadths of single plate fields on sides 1 and 2 of stiffener [mm] according to Section 3, F.5.1.6 or F.5.2.3.5, in general based on Load Case 1 of Table 3.12, where the reference degree of slenderness is to be defined as:

λ = $\sqrt{\dfrac{\varepsilon_E}{0,9\left(\frac{t}{b}\right)^2 K}}$

b_1, b_2 = breadths of single plate fields on sides 1 and 2 of stiffener [mm], see also Fig. 5.11

t_1, t_2 = thicknesses of single plate fields on sides 1 and 2 of stiffener [mm]

A_{Stif} = sectional area of the stiffener without attached plating [mm^2]

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:

$$\sigma_{CR2} = \Phi\, R_{eH} \frac{A_{Stif}\, \kappa_T + b_{m1}\, t_1/2 + b_{m2}\, t_2/2}{A_{Stif} + b_1\, t_1/2 + b_2 t_2/2}$$

κ_T = reduction factor according to Section 3, F.5.2.2.1

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:

$h_{w,m}, b_{f,m}$ = effective width of web/flange plating [mm] according to Section 3, F.5.1.6 or F.5.2.3.5 (generally based on Load Case 3 of Table 3.12 for flat bars and flanges, otherwise Load Case 1) where the reference degree of slenderness is to be defined as

$$\sigma_{CR3} = \Phi\, R_{eH} \frac{h_{w,m}\, t_w + b_{f,m} t_f + b_{m,1} t_1/2 + b_{m,2} t_2/2}{h_w t_w + b_f t_f + b_1 t_1/2 + b_2 t_2/2}$$

h_w = web height [mm]

t_w = web thickness [mm]

b_f = flange breadth, where applicable [mm]

t_f = flange thickness, where applicable [mm]

b) Hard corners $(\sigma_{CR4}$ – $\varepsilon)$

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

$$\sigma_{CR4} = \Phi\, R_{eH} \frac{\sum_{i=1}^{n} b_{mj} \cdot t_i}{\sum_{i=1}^{n} b_i \cdot t_i} \quad [\mathrm{N/m^2}]$$

$b_{m,i}$ = effective breadths of single plate fields [mm] according to Section 3, F.5.1.6 or F.5.2.3.5, as applicable, in general based on applicable Load Cases in Table 3.12 and Table 3.13, where the reference degree of slenderness is to be defined as

λ = $\sqrt{\dfrac{\varepsilon_E}{0,9\left(\frac{t}{b}\right)^2 K}}$

b_i = breadth of single plate fields [mm], see also Fig. 5.11

t_i = thickness of single plate fields [mm]

n = number of plates comprising hard corner

8.3 Ultimate vertical shear force

$$\left|Q_{SW} + \frac{\gamma_{WV} \cdot Q_{WV}}{c_s}\right| \leq \left|\frac{Q_U}{\gamma_R}\right|$$

c_s = stress factor according to 1.1

Q_U = ultimate vertical shear force of the ship's transverse section [kN]

$= \dfrac{1}{1000 \cdot \sqrt{3}} \cdot \sum_{i=1}^{q} \kappa_{\tau i} \cdot b_i \cdot t_i \cdot R_{eH,i}$

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, F.5.2.2.1

b_i = breadth of the i^{th} plate field [mm]

t_i = thickness of the i^{th} plate field [mm]

$R_{eH,i}$ = minimum nominal yield point of the i^{th} plate field [N/mm^2]

D. Design Stresses

1. General

Design stresses for the purpose of this rule 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 σ_L in the plate level

The stresses σ_L and τ_L are to be considered in the formulas for dimensioning of plate thicknesses (Section 6, B.1 and C.1 and Section 12, B.2), longitudinals (Section 9, B.3) and grillage systems (Section 8, B.8.2 and Section 10, E.2).

The calculation of the stresses σ_L and τ_L can be carried out by an analysis of the complete hull. If no complete hull analysis is carried out, the most unfavourable values of the stress combinations according to Table 5.3 are to be taken for σ_L and τ_L respectively. The formulae in Table 5.3 contain $\sigma_{SW}, \sigma_{WV}, \sigma_{WH}, \sigma_{ST}$ and σ_{WT} according to 2. and $\tau_{SW}, \tau_{WV}, \tau_{WH}, \tau_{ST}$ and τ_{WT} according to 3. as well as:

f_F = weighting factor for the simultaneousness of global and local loads

= 0,8 for dimensioning of longitudinal structures according to Sections 3 and 6 to 12

$= 0,75 + \dfrac{x}{L}\left(1 - \dfrac{x}{L}\right)$ for fatigue strength calculations according to Section 20

f_Q = probability factor according to Table 4.2

f_{Qmin} = 0,75 for Q = 10^{-6}

Note:

f_Q is a function of the planned lifetime. For a lifetime of n > 20 years, f_Q may be determined by the following formulae for a straight-line spectrum of seaway induced stress ranges :

$$f_Q = -0,125 \cdot \log\left(\frac{2 \cdot 10^{-5}}{n}\right)$$

For greatest vertical wave bending moment:

$$\sigma_{WV} = (0,43 + C) \cdot \sigma_{WVhog}$$
$$\tau_{WV} = (0,43 + C) \cdot \tau_{WVhog}$$

For smallest vertical wave bending moment :

$$\sigma_{WV} = [0,43 + C \cdot (0,5 - C)] \cdot \sigma_{WVhog} + C \cdot (0,43 + C) \cdot \sigma_{WVsag}$$
$$\tau_{WV} = [0,43 + C \cdot (0,5 - C)] \cdot \tau_{WVhog} + C \cdot (0,43 + C) \cdot \tau_{WVsag}$$
$$C = \left(\frac{x}{L} - 0,5\right)^2$$

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.

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.

1.1 Buckling strength

For structures loaded by compression or shear forces, sufficient buckling strength according to Section 3, F is to be proved.

1.2 Permissible stresses

The equivalent stress from σ_L and τ_L is not to exceed the following value:

$$\sigma_v = \sqrt{\sigma_L^2 + 3 \cdot \tau_L^2} \leq \frac{190}{k} \quad [\text{N/mm}^2]$$

Table 5.3 Load cases and stress combinations

Load Case	Design stresses σ_L, 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}	$\sigma_{L2a} = \sigma_{SW} + \sigma_{ST} + f_Q \cdot (0,6 \cdot \sigma_{WV} + \sigma_{WH})$
	$\tau_{L2a} = 0,7.\tau_{SW} + \tau_{ST} + 0,7 \cdot f_Q \cdot (0,6 \cdot \tau_{WV} + \tau_{WH})$
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}	$\sigma_{L3a} = f_F \cdot \left[\sigma_{SW} + \sigma_{ST} + f_Q \cdot \left(\sigma'_{WV} + \sigma_{WH} + \sigma_{WT}\right)\right]$
	$\tau_{L3a} = f_F. \left\{0,7 \cdot \tau_{SW} \cdot \tau_{ST} + f_Q \cdot \left[0,7. \left(\tau'_{WV} + \tau_{WH}\right) + \tau_{WT}\right]\right\}$
L_{3b}	$\sigma_{L3a} = f_F \cdot \left\{0,7 \cdot \sigma_{SW}. \cdot \sigma_{ST} + f_Q \cdot \left[0,7 \cdot \left(\sigma'_{WV} + \sigma_{WH}\right) + \sigma_{WT}\right]\right\}$
	$\tau_{L3b} = f_F \cdot \left[\tau_{SW} + \tau_{ST} + f_Q \cdot \left(\tau'_{WV} + \tau_{WH} + \tau_{WT}\right)\right]$

$L_{1a,b}$ = Load caused by vertical bending and static torsional moment.
$L_{2a,b}$ = Load caused by vertical and horizontal bending moment as well as static torsional moment.
$L3_{a,b}$ = Load caused by vertical and horizontal bending moment as well as static and wave-induced torsional moment

1.3 Structural design

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

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

1.3.2 The required welding details and classifying of notches result from the fatigue strength analysis according to Section 20.

2. Normal stresses in the ship's longitudinal direction

2.1 Normal stresses from vertical bending moments

2.1.1 statical from M_{SW}:

$$\sigma_{SW} = \frac{M_{SW} \cdot e_z}{I_y \cdot 10^3} \quad [N/mm^2]$$

M_{SW} = still water bending moment according to A.5 at the position x/**L**

2.1.2 dynamical from M_{WV} :

$$\sigma_{WV} = \frac{M_{WV} \cdot e_z}{I_y \cdot 10^3} \quad [N/mm^2]$$

2.2 Normal stresses due to horizontal wave bending moments

dynamical from M_{WH} :

$$\sigma_{WH} = \frac{M_{WH} \cdot e_y}{I_z \cdot 10^3} \quad [N/mm^2]$$

M_{WH} = horizontal wave bending moment according to B.3.3 at the position x/**L**

I_z = moment of inertia $[m^4]$ of the transverse ship section considered around the vertical axis at the position x/**L**

e_y = horizontal distance of the structure considered from the vertical, neutral axis [m]
e_y is positive at the port side, negative at the starboard side

2.3 Normal stresses from torsion of the ship's hull

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.

2.3.1 statical from M_{STmax} :

For a distribution of the torsional moments according to B.2.2.2, the stresses can be calculated as follows:

$$\sigma_{ST} = \frac{0,65 \cdot C_{Tor} \cdot M_{STmax} \cdot \omega_i}{\lambda \cdot I_\omega \cdot 10^3} \cdot \left(1 - \frac{2}{e^a + 1}\right) \quad [N/mm^2]$$

M_{STmax} = max. static torsional moment according to B.2.2.2

$C_{Tor}, I_\omega, \omega_i, \lambda$, e, a, ℓ_c, C_c, x_A see 2.3.2.

For other distributions the stresses have to be determined by direct calculations.

2.3.2 dynamical from M_{WTmax}:

$$\sigma_{WT} = -\frac{C_{Tor} \cdot M_{WTmax} \cdot \omega_i}{\lambda . I_\omega \cdot 10^3} \cdot \left(1 - \frac{2}{e^a + 1}\right) \quad [N/mm^2]$$

M_{WTmax} = according to B.3.5

C_{Tor} = $4 \cdot \left(\sqrt{C_B} - 0,1\right) \cdot \frac{x}{L}$ for $0 \le \frac{x}{L} < 0,25$

= $\sqrt{C_B} - 0,1$ for $0,25 \le \frac{x}{L} < 0,25$

= $\frac{C_B - 0,1}{0,35} \cdot \left(1 - \frac{x}{L}\right)$ for $0,65 \le \frac{x}{L} \le 1$

I = sectorial inertia moment [m^6] of the ship's transverse section at the position x/**L**

ω_i = sectorial coordinate [m^2] of the structure considered

λ = warping value

= $\sqrt{\frac{I_T}{2,6 \cdot I_\omega}}$ [I/m]

I = torsional moment of inertia [m^4] of the ship's transverse section at the position x/**L**

e = Euler number (e = 2,718...)

a = $\lambda . \ell_c$

ℓ_c = characteristical torsion length [m]

= $0,5 \cdot \mathbf{L} \cdot C_c$ for $\frac{L}{B} < 6$

= $\left(1,22 - 0,12 \cdot \frac{L}{B}\right) \cdot \mathbf{L} \cdot C_c$ for $\frac{L}{B} \le 8,5$

= $0,2 \cdot \mathbf{L} \cdot C_c$ for $\frac{L}{B} > 8,5$

However, $\ell_c \leq \mathbf{L} - X_A$

C_c = $0,8 - \frac{x_A}{L} + \left(0,5 + 2,5 \cdot \frac{x_A}{L}\right) \cdot \frac{x}{L}$ for $0 \le \frac{x}{L} < 0,4$ and $0 \le \frac{x_A}{L} \le 0,4$

= $1,0$ for $0,4 \le \frac{x}{L} \le 0,55$

= $1 - \frac{1}{45} \cdot \left(\frac{x}{L} - 0,55\right)$ for $0,55 < \frac{x}{L} \le 1$

x_A = 0 for ships without cargo hatches

= distance [m] between the aft end of the length L and the aft edge of the hatch forward of the engine room front bulkhead on ships with cargo hatches, see also Table 5.4 and Table 5.5

3. Shear stresses

Shear stress distribution shall be calculated by calculation procedures approved by BKI. 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.

3.1 Shear stresses due to vertical shear forces

As a first approximation for ships without longitudinal bulkheads or with two longitudinal bulkheads, the distribution of the shear stress in the shell and in the longitudinal bulkheads can be calculated with the following formulae:

statical from Q_{SW} :

$$\tau_{SW} = \frac{Q_{SW} \cdot S_y(z)}{I_y \cdot t}(0,5 - \alpha) \qquad [N/mm^2]$$

dynamical from Q_{WV} :

$$\tau_{WV} = \frac{Q_{WV} \cdot S_y(z)}{I_y \cdot t}(0,5 - \alpha) \qquad [N/mm^2]$$

$S_y(z)$ = first moment of the sectional area considered $[m^3]$, above or below, respectively, the level z considered, and related to the horizontal, neutral axis

t = thickness of side shell or longitudinal bulkhead plating [mm] at the section considered

α = 0 for ships having no longitudinal bulkhead

If 2 (two) longitudinal bulkheads are arranged:

α = $0,16 + 0,08 \dfrac{A_s}{A_L}$ for the longitudinal bulkheads

= $0,34 + 0,08 \dfrac{A_s}{A_L}$ for the side shell

A_s = sectional area of side shell plating $[m^2]$ within the depth **H**

A_L = sectional area of longitudinal bulkhead plating $[m^2]$ within the depth **H**

For ships of normal shape and construction, the ratio S_y/I_y determined for the midship section can be used for all sections.

3.2 Shear stresses due to horizontal shear forces

Subsection 3. is to be applied to correspondingly.

3.3 Shear stresses due to torsional moments

statical from M_{STmax} :

For a distribution of torsional moments according to B.2.2.2, the stresses can be calculated as follows:

$$\tau_{ST} = 0,65 \cdot C_{Tor} \cdot M_{STmax} \cdot \frac{S_{\omega i}}{I_\omega \cdot t_i} \qquad [N/mm^2]$$

C_{Tor} = according to D.2.3.1

M_{STmax} = according to B.2.2.2

M_{WTmax} = according to B.3.5

I_ω = according to D.2.3.1

$S_{\omega i}$ = statical sector moment $[m^4]$ of the structure considered

t_i = thickness[mm] of the plate considered

For other distributions the stresses have to be determined by direct calculations.

dynamical from M_{WTmax}:

$$\tau_{WT} = C_{Tor} \cdot M_{WTmax} \cdot \frac{S_{\omega i}}{I_{\omega} \cdot t_i} \qquad [N/mm^2]$$

E. Permissible Still Water Loads

1. Vertical bending moments

The permissible still water bending moments $M_{SW,perm}$ over the ship's length **L** are to be determined by the following formulae:

$M_{SW,perm}$ = $M_T - M_{WV}$ [kNm]

$M_{T,perm}$ = permissible total bending moment [kNm]

$$= \min\left[\sigma_D \cdot W_{D(a)} \cdot \frac{10^3}{f_r}; \sigma_B \cdot W_{B(a)} \cdot \frac{10^3}{f_r}\right]$$

$W_{D(a)}, W_{B(a)}$ = actual section modulus in the deck or bottom, respectively

σ_D = longitudinal bending stress $[N/mm^2]$ for the ship's upper hull girder flange

= $\sigma_{SW} + \sigma_{WV}$

σ_B = longitudinal bending stress $[N/mm^2]$ for the ship's lower hull girder flange

= $\sigma_{SW} + \sigma_{WV}$

M_{WV} = vertical wave bending moment according to B.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

σ_{SW}, σ_{WV} longitudinal stress according to D.2.

f_r = correction factor, defined as:

= 1,0 (in general)

= according to F.2 for ships with large deck openings

In the range x/**L**= 0,3 to x/**L** = 0,7 the permissible still water bending moment should generally not exceed the value obtained for x/**L** = 0,5.

2. Vertical shear forces

The permissible still water shear forces $Q_{SW,perm}$ over the ship's length **L** are to be determined by the following formulae:

$Q_{SW,perm}$ = $Q_T - Q_{WV}$ [kN]

$Q_{T,perm}$ = permissible 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.

τ = permissible shear stress $[N/mm^2]$

Q_{WV} = according to B.3.2

For harbour and offshore terminal conditions, see 1.

2.1 Correction of still water shear force curve

In case with empty cargo hold, 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. 5.12.

2.2 The supporting forces of the bottom grillage at the transverse bulkheads may either be determined by direct calculation or by approximation, according to 2.3.

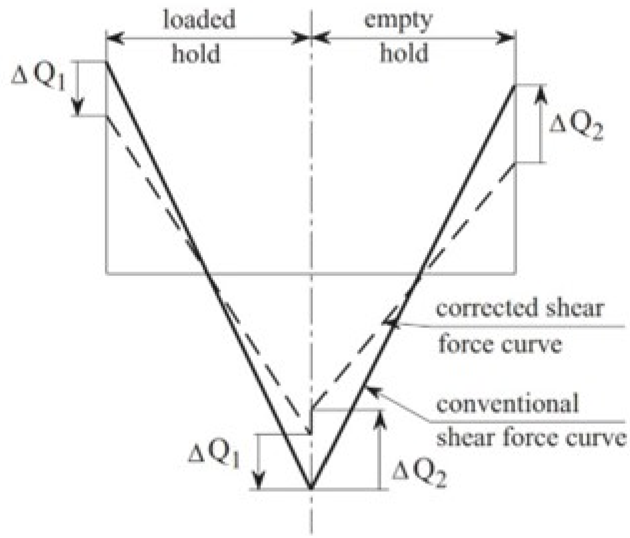


Fig. 5.12 Correction of the shear force curve

2.3 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:

$$\Delta Q = u \cdot P - v \cdot \mathbf{T^*} \quad [kN]$$

P = mass of cargo or ballast [t] in the hold considered, including any contents of bottom tanks within the flat part of the double bottom

T* = draught [m] at the centre of the hold

u, v = correction coefficients for cargo and buoyancy as follows:

$$u = \frac{10 \cdot \kappa \cdot \ell \cdot b \cdot h}{V} \quad [kN/t]$$

$$v = 10 \cdot \kappa \cdot \ell \cdot b \quad [kN/m]$$

$$\kappa = \frac{\mathbf{B}}{2,3\,(\mathbf{B} + \ell)}$$

ℓ = length of the flat part of the double bottom [m]

b = breadth of the flat part of the double bottom [m]

h = vertical distance between inner bottom and top of hatch coaming [m]

V = volume of cargo hold including volume enclosed by hatch coaming $[m^3]$.

3. Static torsional moments

The permissible static torsional moments have to be determined on the basis of the design stresses in Table 5.3 together with the formula in D.2.3.1.

3.1 For ships with torsional moments according to B.2 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.

3.2 Unless shown by a particular proof, during loading and unloading the static torsional moments shall not be higher than 75% of the wave induced torsional moment according to B.3.5.

F. Guidance Values for Large Deck Openings

1. General

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 BKI 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 2. and 3. are observed.

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, bL is the sum of the individual hatchway-breadths

ℓ_L = length of hatchway

B_M = breadth of deck measured at the mid 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.

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 C.1 and C.2.

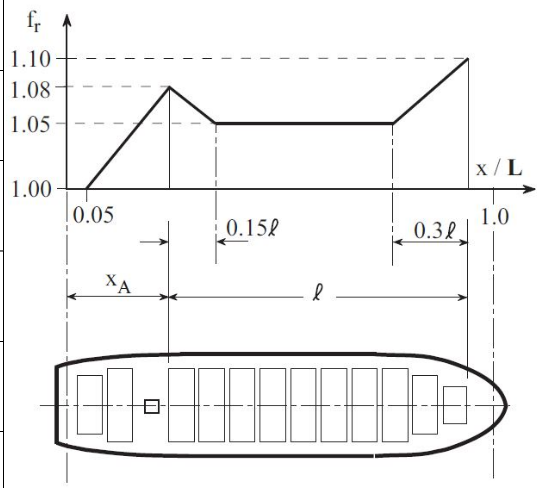
The factor f_r amounts to:

$$f_r = \frac{\sigma_{L1}}{\sigma_{SW} + 0,75 \cdot \sigma_{WV}}$$

σ_{L1}, σ_{SW}, σ_{WV} according to D. for the ship's upper respectively lower girder. The greater value is to be taken.

The calculation of the factor fr may be dispensed with, if f_r is selected according to Table 5.4.

Table 5.4 Correction factor f_r

Range	Value	Distribution over the ship's length
$\frac{x}{L} \le 0,05$	1,00	
$0,05 < \frac{x}{L} \le \frac{x_A}{L}$	$1,00 + 0,08 \cdot \frac{x - 0,05 \cdot L}{x_A - 0,05. \cdot L}$	
$\frac{x_A}{L} < \frac{x}{L} \le \frac{x_A + 0,15 \cdot \ell}{L}$	$1,08 + 0,2 \cdot \frac{x_A - x}{\ell}$	
$\frac{x_A + 0,15 \cdot \ell}{L} < \frac{x}{L} \le \frac{x_A + 0,70 \cdot \ell}{L}$	1,05	
$\frac{x_A + 0,70 \cdot \ell}{L} < \frac{x}{L} \le \frac{x_A + \ell}{L}$	$1,10 + \frac{x - x_A - \ell}{6 \cdot \ell}$	
$\frac{x_A + \ell}{L} < \frac{x}{L}$	1,00	

3. Guidance values for the design of transverse box girders of container ships

The scantlings of the 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 shall not be less than obtained from the following formulae (see also Fig. 5.13):

$$t_1 = \sqrt{L} \quad [mm] \quad \text{or} \quad t_1 = 0,5\, t_0 \quad [mm]$$

$$t_2 = 0{,}85 \quad [mm] \quad \text{or} \quad t_2 = 12 \cdot a \quad [mm]$$

t_0 = thickness of longitudinal hatch coaming or of the uppermost strake of the longitudinal bulkhead [mm]

a = spacing of stiffeners [m].

The larger of the values t_1 or t_2 is to be taken. **L** need not be taken greater than 200 m.

For coamings on the open deck see also Section 17, B.1.

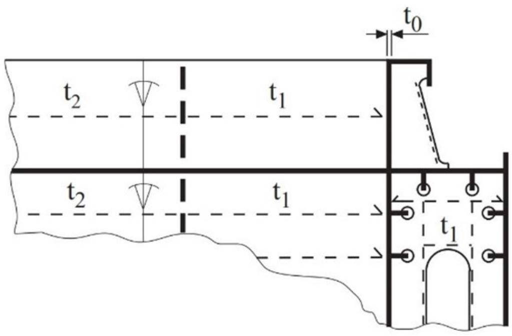


Fig. 5.13 Plate thickness of the transverse box girder

4. Guidance values for the displacements of the upper girder of the ship

In general, the relative displacement Δ_u 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:

$$\Delta_u = 6 \cdot 10^{-5}\,(M_{STmax} + M_{WTmax}) \cdot \left(1 - \frac{\mathbf{L}}{450}\right) \cdot \left[4 + 0,1\left(\frac{\mathbf{L}}{\mathbf{B}}\right)^2\right] \cdot c_u + 20 \qquad [\text{mm}]$$

M_{STmax}, M_{WTmax} according to B.2.2.2 or B.3.5, respectively

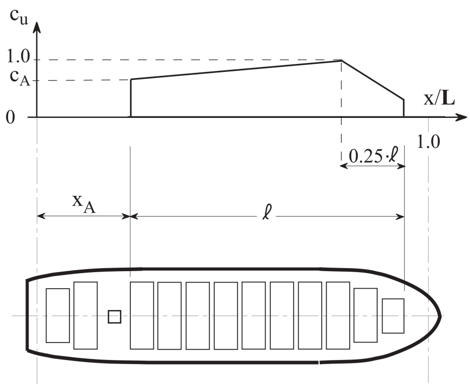
c_u = distribution factor according to Table 5.5

c_A = value for cu at the aft part of the open region, see also Table 5.5

$= \left(1,25 - \frac{\mathbf{L}}{400}\right) \cdot \left(1,6 - \frac{3 \cdot x_A}{\mathbf{L}}\right) \leq 1,0$

x_A = according to D.2.3.1; for x_A no smaller value than 0,15**L** and no greater value than 0,3**L** is to be taken.

Table 5.5 Distribution factor c_u

Range	Value	Distribution over the ship's length
$\frac{x}{\mathbf{L}} < \frac{x_A}{\mathbf{L}}$	0	
$\frac{x_A}{\mathbf{L}} \leq \frac{x}{\mathbf{L}} < \frac{x_A + 0,75 \cdot \ell}{\mathbf{L}}$	$\frac{1 - c_A}{0,75} \cdot \frac{x - x_A}{\ell} + c_A$	
$\frac{x_A + 0,75 \cdot \ell}{\mathbf{L}} \leq \frac{x}{\mathbf{L}} < \frac{x_A + \ell}{\mathbf{L}}$	$\frac{\mathbf{L} - x}{\mathbf{L} - x_A - 0,75 \cdot \ell}$	
$\frac{x_A + \ell}{\mathbf{L}} < \frac{x}{\mathbf{L}}$	0	

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Section 6 Shell Plating

A. General, Definitions

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.

1. General

1.1 The application of the design formulae given in B.1.2 and C.1.2 to ships of less than 90 m in length may be accepted when a proof of longitudinal strength has been carried out.

1.2 The plate thicknesses are to be tapered gradually, if different. Gradual taper is also to be effected between the thicknesses required for strengthening of the bottom forward as per E.2 and the adjacent thicknesses.

2. Definitions

c_{RW}	=	service range coefficient according to Section 4, A.2
k	=	material factor according to Section 2, B
ℓ	=	unsupported span [m] of longitudinal or transverse, respectively
p_B, p_{B1}	=	load on bottom [kN/m^2] according to Section 4, B.3
p_s, p_{s1}	=	load on sides [kN/m^2] according to Section 4, B.2.1
p_e	=	design pressure for the bow area [kN/m^2] according to Section 4, B.2.2 or according to Section 4, B.2.3 for the stern area as the case may be
p_{SL}	=	design slamming pressure [kN/m^2] according to Section 4, B.4
n_f	=	1,0 for transverse framing
	=	0,83 for longitudinal framing
σ_L	=	maximum design hull girder bending stress according to Section 5, D.1
τ_L	=	maximum design shear stress due to longitudinal hull girder bending [N/mm^2], according to Section 5, D.1

σ_{perm} = permissible design stress [N/mm^2]

$= \left(0,8 + \frac{\mathbf{L}}{450}\right)\frac{230}{k}$ [N/mm^2] for **L** < 90 m

$= \frac{230}{k}$ [N/mm^2] for **L** ≥ 90 m

t_K = corrosion addition according to Section 3, K

B. Bottom Plating

1. Plate thickness based on load stress criteria

1.1 Ships with lengths L < 90 m

The thickness of the bottom shell plating within 0,4**L** amidships is not to be less than :

$$t_{B1} = 1,9 \cdot n_f \cdot \mathbf{a}\sqrt{p_B \cdot k} + t_k \qquad [mm]$$

Within 0,1**L** forward of the aft end of the length **L** and within 0,05**L** aft of **FP** the thickness is not to be less than t_{B2} according to 1.2.

1.2 Ships with length L ≥ 90 m

The thickness of the bottom plating is not to be less than the greater of the two following values:

$$t_{B1} = 18,3 \cdot n_f \cdot \mathbf{a} \cdot \sqrt{\frac{p_B}{\sigma_{p\ell}}} + t_k \qquad [mm]$$

$$t_{B2} = 1,21 \cdot \mathbf{a}\sqrt{p_B \cdot k} + t_k \qquad [mm]$$

$$\sigma_{p\ell} = \sqrt{\sigma_{perm}^2 - 3 \cdot \tau_L^2} - 0,89 \cdot \sigma_{LB} \qquad [N/mm^2]$$

Note:

As a first approximation σ_{LB} and τ_L may be taken as follows:.

$\sigma_{LB} = \frac{12,6\sqrt{\mathbf{L}}}{k}$ [N/mm^2] *for **L** < 90 m*

$= \frac{120}{k}$ [N/mm^2] *for **L** ≥ 90 m*

$\tau_L = 0$

2. Critical plate thickness, buckling strength

2.1 Guidance values for critical plate thickness

For ships, for which proof of longitudinal strength is required or carried out respectively, the following guidance values for the critical plate thickness are recommended:

for $\sigma_{LB} \leq 0,6 \cdot R_{eH}$:

$$t_{crit} = c \cdot 2,23 \cdot \mathbf{a}\sqrt{\sigma_{LB}} + t_k \qquad [mm]$$

for $\sigma_{LB} > 0,6 \cdot R_{eH}$:

$$t_{crit} = c \cdot 1,57 \cdot \mathbf{a}\frac{\sqrt{R_{eH}}}{1,474 - \frac{\sigma_{LB}}{R_{eH}}} + t_k \qquad [mm]$$

c = 0,5 for longitudinal framing

= $\frac{1}{(1+\alpha^2)\sqrt{F_{tran}}}$ for transverse framing

α = aspect ratio a/b of plate panel considered (see Section 3, F.5.1.6)

σ_{LB} = largest compressive stress in the bottom due to longitudinal hull girder bending

F_{tran} = see Section 3, F.5.2.2.3 (Table 3.12)

= 1,0 for longitudinal framing

2.2 Buckling strength

The guidance values obtained from 2.1 are to be verified according to Section 3, F and Section 5, C.7 applies where solely longitudinal hull girder bending stress need to be considered. Section 8, B.8.3 applies where the combined action of longitudinal hull girder bending and local loads has to be considered.

3. Minimum thickness

At no point the thickness of the bottom shell plating shall be less than:

t_{min} = $(1,5 - 0,01 \cdot \mathbf{L})\sqrt{\mathbf{L} \cdot k}$ [mm] for $\mathbf{L} < 50$ m

= $\sqrt{\mathbf{L} \cdot k}$ [mm] for $\mathbf{L} \geq 50$ m

t_{max} = 16 mm in general

or bulk carriers see Section 23, B.5.3, for tankers see Section 24, A.12.

4. Bilge strake

4.1 The thickness of the bilge strake is to be determined as required for the bottom plating according to 1. The thickness so determined is to be verified for sufficient buckling strength according to the requirements of Section 5, C.7 and Section 3, F, see Table 3.12, load cases 1a, 1b, 2 and 4.

If this verification shows that a smaller thickness than that of the bottom plating is possible, such smaller thickness may be permitted.

4.2 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:

$b = 800 + 5 \cdot \mathbf{L}$ [mm]

4.3 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, F is to be shown for the plane plate fields ($a_L \cdot \mathbf{a}$) between the bilge strake and the longitudinal stiffeners. For the proof of buckling strength the longitudinal stresses according to Section 5, C.7 and the transverse compression stresses σ_q are to be taken into account.

$$\sigma_q = \frac{p \cdot R}{t \cdot 10^3} \quad [\text{N/mm}^2]$$

The thickness of these plate fields shall not be less than the thickness derived from 1. to 3. and C.1 respectively.

For the frame spacing **a** and the field length ℓ, a_L and b_L + R/4 are to be taken accordingly, see Fig. 6.1.

a_L = spacing of the floors or transverse stiffeners respectively [mm]

b_L = distance of the longitudinal stiffener from the end of corner radius [mm]

R = bilge radius [mm]

p = p_s, p_{s1} or p_{B1} at the end of corner radius or p_{SL} according to Section 4, B.4 as the case may be [kN/m^2]

t = plate thickness [mm]

If the derived thickness for the plane plate field is larger than that for the curved bilge strake according to 4.1 the reinforcement is to be expanded by a minimum of R/6 into the radius.

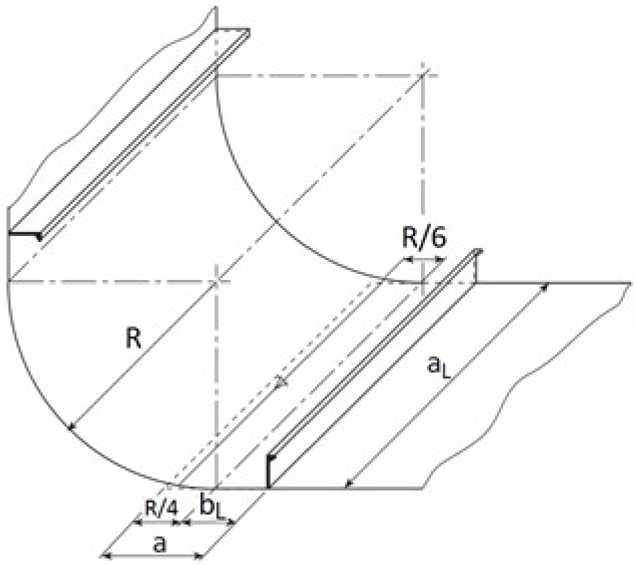

Fig. 6.1 Bilge strake

5. Flat plate keel and garboard strake

5.1 The width of the flat plate keel is not to be less than:

$$b = 800 + 5 \cdot \mathbf{L} \quad [\text{mm}]$$

The thickness of the flat plate keel is not to be less than:

t_{FK} = $t_B + 2{,}0$ [mm] within 0,7**L** amidships and in way of the engine seating

= t_B [mm] otherwise

t_B = thickness of the bottom plating [mm] according to 1. – 3.

5.2 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 approx. 500 mm from centre line. The sectional area of one longitudinal stiffener should not be less than 0,2**L** [cm^2].

5.3 Where a bar keel is arranged, the adjacent garboard strake is to have the scantlings of a flat plate keel.

C. Side Shell Plating

1. Plate thickness based on load stress criteria

1.1 Ships with lengths L < 90 m

The thickness of the side shell plating within 0,4**L** amidship is not to be less than:

$$t_{S1} = 1{,}9 \cdot n_f \cdot \mathbf{a}\sqrt{p_s \cdot k} + t_K \quad [mm]$$

Within 0,1**L** forward of the aft end of the length **L** and within 0,05**L** aft of **FP** the thickness is not to be less than t_{S2} according to 1.2.

1.2 Ships with lengths L ≥ 90 m

The thickness of the side shell plating is not to be less than the greater of the following values:

$$t_{S1} = 18{,}3 \cdot n_f \cdot \mathbf{a}\sqrt{\frac{p_s}{\sigma_{p\ell}}} + t_k \quad [mm]$$

$$t_{S2} = 1{,}21 \cdot \mathbf{a}\sqrt{p \cdot k} + t_k \quad [mm]$$

$$t_{S3} = 18{,}3 \cdot n_f \cdot \mathbf{a} \cdot \sqrt{\frac{p_{s1}}{\sigma_{p\ell max}}} + t_k \quad [mm]$$

$$\sigma_{p\ell} = \sqrt{\sigma_{perm}^2 - 3 \cdot \tau_L^2} - 0{,}89 \cdot \sigma_{LS} \quad [N/mm^2]$$

$$\sigma_{p\ell max} = \sqrt{\left(\frac{230}{k}\right)^2 - 3 \cdot \tau_L^2} - 0{,}89 \cdot \sigma_{LS} \quad [N/mm^2]$$

p = p_s or p_e as the case may be

Note:

As a first approximation σ_{LS} and τ_L may be taken as follows:

$$\sigma_{LS} = 0{,}76 \cdot \sigma_{LB} \quad [N/mm^2]$$

$$\tau_L = \frac{55}{k} \quad [N/mm^2]$$

σ_{LB} = *see B.1.2*

1.1 In way of large shear forces, the shear stresses are to be checked in accordance with Section 5, D.

2. Minimum thickness

For the minimum thickness of the side shell plating B.3 applies accordingly. Above a level **T** + $c_0/2$ above base line smaller thicknesses than t_{min} may be accepted if the stress level permits such reduction.

For c_0 see Section 4, A.2.2.

3. Sheer strake

3.1 The width of the sheer strake is not to be less than:

b = 800 + 5 · **L** [mm]

b_{max} = 1800 [mm]

3.2 The thickness of the sheer strake shall, in general, not be less than the greater of the following two values:

t = 0,5 $(t_D + t_S)$ [mm]

= t_S [mm]

t_D = required thickness of strength deck

t_S = required thickness of side shell

3.3 Where the connection of the deck stringer with the sheer strake is rounded, the radius is to be at least 15 times the plate thickness.

3.4 Welds on upper edge of sheer strake are subject to special approval.

Regarding welding between sheer strake and deck stringer see Section 7, A.2.

Holes for scuppers and other openings are to be carefully rounded, any notches shall be avoided.

4. Buckling strength

For ship for which proof of longitudinal strength is required or carried out proof of buckling strength of the side shell is to be provided in accordance with the requirements of Section 5, C.7 and Section 3, F.

5. Strengthenings for harbour and tug manoeuvres

5.1 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 5.2. 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 shall 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 shall not be less than approximately 5,0 m. The height of the strengthened areas shall extend from about 0,5 m above ballast waterline to about 4,0 m above scantling draught.

Where the side shell thickness so determined exceeds the thickness required by 1. – 3. it is recommended to specially mark these areas.

5.2 The plate thickness in the strengthened areas is to be determined by the following formulae:

$$t = 0,65\sqrt{P_{f\ell} \cdot k} + t_k \quad [mm]$$

$P_{f\ell}$ = local design impact force [kN]

= D/100 [kN] with a minimum of 200 kN and a maximum of 1000 kN

D = displacement of the ship [t]

Any reductions in thickness for restricted service are not permissible.

5.3 In the strengthened areas the section modulus of side longitudinals is not to be less than:

$$W = 0,35 \cdot P_{f\ell} \cdot \ell \cdot k \quad [cm^3]$$

ℓ = unsupported span of longitudinal [m]

5.4 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. Side Plating of Superstructures

1. The side plating of effective superstructures is to be determined according to C.

2. The side plating of non-effective superstructures is to be determined according to Section 16.

3. For the definition of effective and non-effective superstructures see Section 16, A.1. For strengthening at ends of superstructures see Section 16, A.3.

E. Strengthening of Bottom Forward

1. Arrangement of floors and girders

1.1 For the purpose of arranging floors and girders the following areas are defined:

– forward of $\frac{x}{\mathbf{L}}$ = 0,7 for **L** ≤ 100 m

– forward of $\frac{x}{\mathbf{L}}$ = 0,6 + 0,001 · **L** for 100 < **L** ≤ 150 m

– forward of $\frac{x}{\mathbf{L}}$ = 0,7 for **L** > 150 m

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.

1.3 In case of transverse framing, the spacing of side girders is not to exceed **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.

1.4 Distances deviating from those defined in 1.2 and 1.3 may be accepted on the basis of direct calculations.

1.5 Within the areas defined in 1.1 any scalloping is to be restricted to holes for welding and for limbers

2. Bottom plating forward of $\frac{x}{\mathbf{L}} = 0{,}5$

2.1 The thickness of the bottom plating of the flat part of the ship's bottom up to a height of 0,05 · $\mathbf{T_b}$ or 0,3 m above baseline, whichever is the smaller value, is not to be less than:

$$t = 0{,}9 \cdot f_2 \cdot \mathbf{a}\sqrt{p_{SL} \cdot k} + t_K \quad \text{[mm]}$$

T_b = smallest design ballast draft at the forward perpendicular [m].

f_2 = see Section 3, A.3

2.2 Above 0,05 $\mathbf{T_b}$ or 0,3 m above baseline 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 shall at least extend to the bilge curvature.

3. Stiffeners forward of x/L = 0,5

3.1 The section modulus of transverse or longitudinal stiffeners is not to be less than:

$$W = 0{,}155 \cdot p_{SL} \cdot \mathbf{a} \cdot \ell^2 \cdot k \quad \text{[cm}^3\text{]}$$

3.2 The shear area of the stiffeners is not to be less than:

$$A = 0{,}028 \cdot p_{SL} \cdot \mathbf{a}(\ell - 0{,}5 \cdot \mathbf{a})\, k \quad \text{[cm}^2\text{]}$$

The area of the welded connection has to be at least twice this value.

F. Strengthenings in Way of Propellers and Propeller Shaft Brackets, Bilge Keels

1. Strengthenings in way of propellers and propeller brackets

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 8, A.1.2.3 and Section 12, A.8). 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***

	$\alpha \geq 0{,}3$			$\alpha < 0{,}3$	
	$0 < d_r \leq 1$	$1 < d_r \leq 2$	$2 < d_r \leq 3$	$0 < d_r \leq 1$	$1 < d_r \leq 3$
$f_{plate} >$	$4{,}40 \cdot f_{blade}$	$3{,}45 \cdot f_{blade}$	$2{,}40 \cdot f_{blade}$	$3{,}45 \cdot f_{blade}$	$2{,}40 \cdot f_{blade}$
$f_{stiff} >$	$4{,}40 \cdot f_{blade}$	$3{,}45 \cdot f_{blade}$	$2{,}40 \cdot f_{blade}$	$3{,}45 \cdot f_{blade}$	$2{,}40 \cdot f_{blade}$

a = *ratio, defined as:*

$= \dfrac{P}{\Delta}$

P = *nominal main engine output [kW]*

Δ = *ship's design displacement [t]*

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]*

d_r = *ratio* $\dfrac{r}{d_p} \geq 1,0$

r = *distance of plate field or stiffener to 12 o'clock propeller blade tip position [m]*

d_p = *propeller diameter [m]*

f_{blade} = *propeller blade passage excitation frequency at n [Hz]*

$= \dfrac{1}{60} \cdot n \cdot z \quad [Hz]$

n = *maximum propeller shaft revolution rate [1/min]*

z = *number of propeller blades*

1.2 In way of propeller shaft brackets, Section 19, B.4.3 has to be observed

1.3 Where propeller revolutions are exceeding 300 rpm (approx.), particularly in case of flat bottoms intercostal carlings are to be fitted above or forward of the propeller in order to reduce the size of the bottom plate panels (see also Section 8, A.1.2.3).

2. Bilge keels

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.

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 shall terminate above an internal stiffening element.

2.3 Any scallops or cut-outs in the bilge keels are to be avoided.

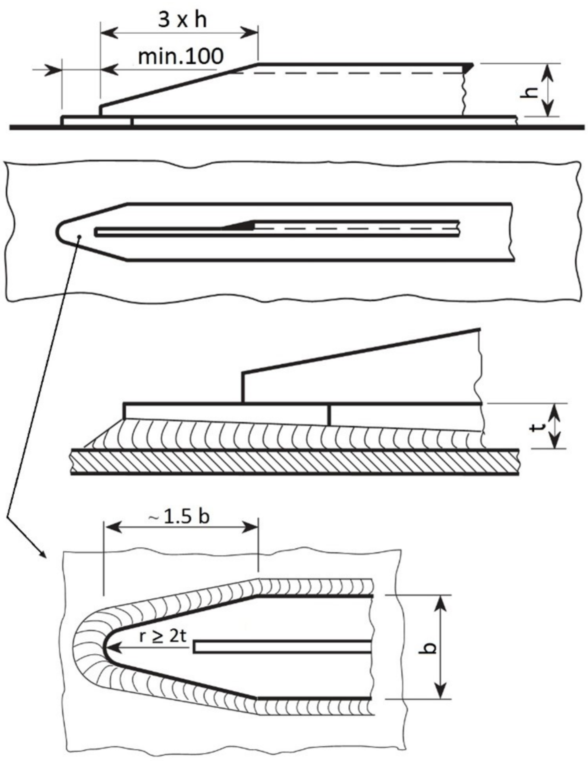

Fig. 6.2 Soft transition zones at the ends of bilge keels

G. Openings in the Shell Plating

1. General

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.

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 J. Special strengthening is required in the range of openings at ends of superstructures.

1.3 The shell plating in way of the hawse pipes is to be reinforced.

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.

H. Bow Doors and Inner Doors

1. General, definitions

1.1 Applicability

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 superstructures, or to a long non-enclosed superstructure, where fitted to attain minimum bow height equivalence.

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

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

(IACS UR S8.1.1a)

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 door will be specially considered in association with the applicable requirements of these Rules.

(IACS UR S8.1.1b)

1.2 Arrangement

1.2.1 Bow doors are to be situated above the free-board 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)

1.2.2 An inner door is to be provided. 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, A.2.1 for the position of the collision bulkhead. A vehicle ramp may be arranged for this purpose, provided its position complies with Section 11, A.2.1. If this is not possible, a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

(IACS UR S8.1.2b)

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)

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 1.2.2.

(IACS UR S8.1.2d)

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)

1.3 Definitions

Securing device	is a device used to keep the door closed by preventing it from rotating about its hinges.
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	is a device that locks a securing device in the closed position.

(IACS UR S8.1.3 and IACS UR S9.1.3)

2. Strength criteria

2.1 Primary structure and securing and supporting devices

2.1.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be so designed that under the design loads defined in 3. the following stresses are not exceeded:

bending stress:

$$\sigma \leq \frac{120}{k} \qquad [N/mm^2]$$

shear stress:

$$\tau \leq \frac{80}{k} \qquad [N/mm^2]$$

equivalent stress:

$$\sigma_v \leq \sqrt{\sigma^2 + 3\tau^2} = \frac{150}{k} \qquad [N/mm^2]$$

where k is the material factor as given in Section 2, B, but is not to be taken less than 0,72 unless a fatigue analysis is carried out according to Section 20.

(IACS UR S8.2.1a and IACS UR S.9.2.1a)

2.1.2 The buckling strength of primary members is to be verified according to Section 3, F.

(IACS UR S8.2.1b and IACS UR S.9.2.1b)

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 stress 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)

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 according to 2.1.1.

(IACS UR S8.2.1d and IACS UR S.9.2.1d)

3. Design loads

3.1 Bow doors

3.1.1 The design external pressure to be considered for the scantlings of primary members of bow doors is not to be less than the pressure specified in Section 4, B.2, but is not to be taken less than :

$$p_e = 2,75\left(\frac{1+c_{RW}}{2}\right) \cdot c_H \cdot (0,22 + 0,15 \cdot \tan\alpha) \cdot \left(0,4 \cdot v_0 \cdot \sin\beta + 0,6\sqrt{L}\right)^2 \quad [kN/m^2]$$

v_0 = ship's speed [kn] as defined in Section 1, H.5

L = ship's length [m], **L** need not to be taken greater than 200 m

c_{RW} = service range coefficient according to Section 4, A.2.2

c_H = coefficient, defined as:

= $0{,}0125 \cdot \mathbf{L}$ for $\mathbf{L} < 80$ m

= 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

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

See also Fig. 6.3

(IACS UR S8.3.1a)

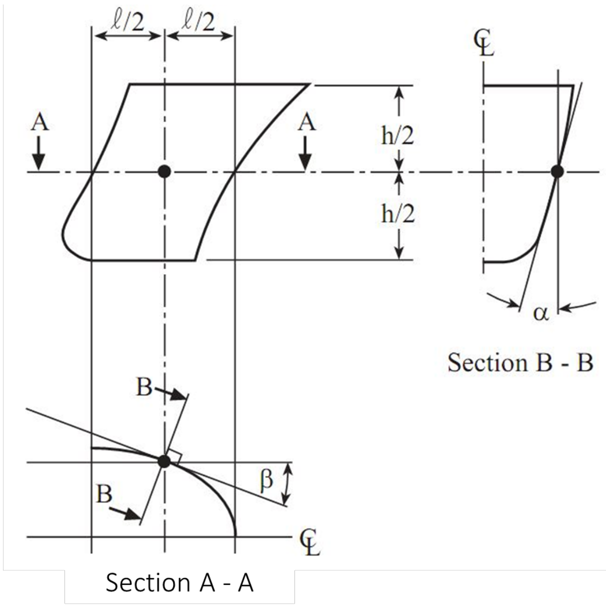

Fig. 6.3 Definition angles α and β

3.1.2 The design external forces for determining scantlings of securing and supporting devices of bow doors are not to be less than:

$$F_x = p_e \cdot A_x \text{ [kN]}$$

$$F_y = p_e \cdot A_y \text{ [kN]}$$

$$F_z = p_e \cdot A_z \text{ [kN]}$$

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,

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,

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,

for A_x , A_y and A_z see also Fig. 6.4.

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,

ℓ = length [m] of the door at a height h/2 above the bottom of the door,

p_e = external design pressure [kN/m^2] as given in 3.1.1 with angles α and β defined as follows:

α = flare angle measured at the point on the bow door, $\ell/2$ aft of the stem line on the plane h/2 above the bottom of the door, as shown in Fig. 6.3.

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

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

(IACS UR S8.3.1b)

3.1.3 For visor doors the closing moment M_y under external loads is to be taken as:

$$M_y = F_x \cdot a + 10 \cdot W \cdot c - F_z \cdot b \qquad [kN\,m]$$

F_x, F_z = design external forces according to 3.1.2

W = mass of the visor door [t]

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 Az of the visor door, as shown in Fig. 6.4

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)

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)

3.2 Inner doors

3.2.1 The design external pressure pe considered for the scantlings of primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of the following:

– $p_e = 0{,}45 \cdot \mathbf{L}$ $[\mathrm{kN/m^2}]$ or

- hydrostatic pressure $p_h = 10 \cdot h$ $[\mathrm{kN/m^2}]$ where h is the distance [m] from the load point to the top of the cargo space

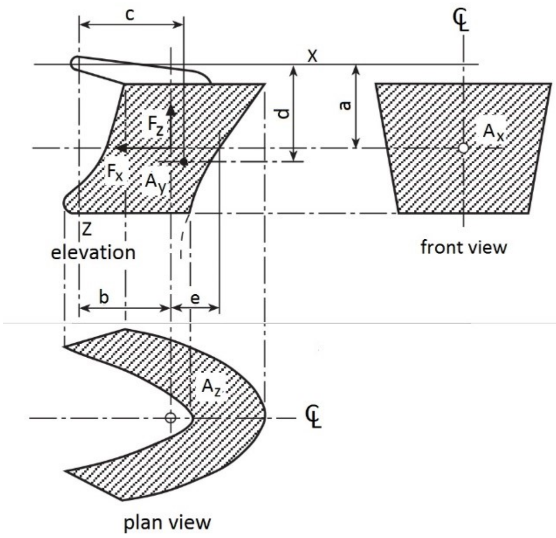

Fig. 6.4 Bow door of visor type

Where **L** is the ship's length, as defined in 3.1.1.

(IACS UR S8.3.2a)

3.2.2 The design internal pressure pi considered for the scantlings of securing devices of inner doors is not to be less than:

$p_i = 25$ $[\mathrm{kN/m^2}]$

(IACS UR S8.3.2b)

4. Scantlings of bow doors

4.1 General

4.1.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

((IACS UR S8.4.1a)

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)

4.2 Plating and secondary stiffeners

4.2.1 The thickness t of the bow door plating is to be determined by the following formula:

$t = t_{S2}$ with $t \geq t_{min}$

t_{S2} = shell thickness according to C.1.2, using bow door stiffener spacing and $\sigma_{p\ell} \leq 230/k$

t_{min} = minimum shell thickness according to C.2

(IACS UR S8.4.2a)

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)

4.2.3 The stiffener webs are to have a net sectional area not less than:

$$A_W = \frac{Q \cdot k}{10} \quad [cm^2]$$

Q = shear force [kN] in the stiffener calculated by using uniformly distributed external design pressure p_e as given in 3.1.1

(IACS UR S8.4.2c)

4.3 Primary structure

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

(IACS UR S8.4.3b)

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)

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 3.1.1 and permissible stresses given in 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)

5. Scantlings of inner doors

5.1 General

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 4.3.3 and permissible stresses given in 2.1.1. Normally, formulae for simple beam theory may be applied.

(IACS UR S8.5.1a)

5.1.2 Where inner doors also serve as vehicle ramps, the scantlings are not to be less than those required for vehicle decks as per Section 7, B.2.

(IACS UR S8.5.1b)

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)

6. Securing and supporting of bow doors

6.1 General

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 3,0 mm.

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

(IACS UR S8.6.1a)

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 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 6.2.6 and 6.2.7 and the available space for adequate support in the hull structure.

(IACS UR S8.6.1b)

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 My > 0. Moreover, the closing moment My as given in 3.1.3 is to be not less than:

$$M_{y0} = 10 \cdot W \cdot c + 0,1\sqrt{a^2 + b^2} \cdot \sqrt{F_x^2 + F_z^2} \quad [\text{kNm}]$$

F_x, F_z = design external forces according to 3.1.2

W = mass [t] of the visor door

a, b, c = distances according to 3.1.3

A_x, A_z = areas according to 3.1.2

(IACS UR S8.6.1c)

6.2 Scantlings

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 2.1.1.

(IACS UR S8.6.2a)

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 $0{,}7 \cdot F_z$.

The forces F_x, F_y and F_z are to be determined as indicated in 3.1.2 and applied at the centroid of the projected areas.

(IACS UR S8.6.2b)

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 3.1.2 applied at the centroid of the projected areas

(IACS UR S8.6.2c)

6.2.4 The support forces as determined according to 6.2.2 and 6.2.3 shall generally 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)

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)

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% the permissible stresses as given in 2.1.1.

(IACS UR S8.6.2f)

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 2.1.1. The opening moment M0 to be balanced by this reaction force, is not to be taken less than the greater of the following values:

$$M_{01} = F_H \cdot d + 5 \cdot A_x \cdot a \quad [\mathrm{kNm}]$$

$$M_{02} = \Delta_x \cdot \sqrt{F_x^2 + F_z^2} \quad [\mathrm{kNm}]$$

F_H = horizontal design force [kN], acting forward in the centre of gravity, $F_H = 10 \cdot W$

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 3.1.2

Δ_x	=	lever
	=	0,25 · e [m]
e	=	distance[m] as defined in Fig. 6.4
a	=	distance[m] as defined in 3.1.3
F_x, F_z	=	design external forces according to 3.1.2

(IACS UR S8.6.2g)

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 2.1.1.

F_Z	=	design external force according to 3.1.2
W	=	mass [t] of the visor door

(IACS UR S8.6.2h)

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)

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)

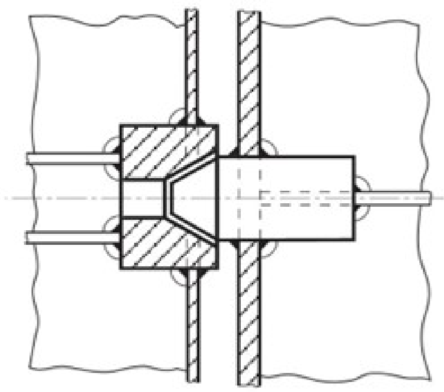

Fig. 6.5 Thrust bearing

7. Arrangement of securing and locking devices

7.1 Systems for operation

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)

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)

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)

7.2 Systems for indication/monitoring

The requirements according to 7.2.3 – 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.

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)

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)

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)

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)

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 shall 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)

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 acoustic 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)

7.2.7 For indication and monitoring systems see also Rules for Electrical Installations (Pt.1, Vol.IV) Sec.16.E.

8. Operating and maintenance manual

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

- main particulars and design drawings, special safety precautions, details of vessel, equipment and design loading (for ramps), key plan of equipment (doors and ramps), manufacturer's recommended testing for equipment, description of equipment for :
  - bow doors
  - inner bow doors
  - bow ramp/doors
  - side doors
  - stern doors
  - central power pack
  - bridge panel
  - engine control room panel
- service conditions
  - limiting heel and trim of ship for loading/unloading
  - limiting heel and trim for door operations
  - doors/ramps operating instructions
  - doors/ramps emergency operating instructions
- maintenance
  - schedule and extent of maintenance
  - trouble shooting and acceptable clearances

  - manufacturer’s maintenance procedures

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

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

Note:

It is recommended that recorded inspections of the door supporting and securing devices be carried out by the ship’s staff at monthly intervals and/or following incidents that could result in damage, including heavy weather and/or contact in the region of the shell doors.

Any damages recorded during such inspections are to be reported to BKI.

(IACS UR S8.8.1)

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)

9. Retrospective Application of Bow Doors and Inner Doors to existing Ro-Ro Passenger Ships

9.1 The following requirements are to be complied with by all existing ro-ro passenger ships with the date of building before the 30th June 1996:

- The location and arrangement of inner doors are to comply with the applicable requirements of the SOLAS Convention and with 1.2.4.

- Ships with visor door are to comply with 6.2.7 requiring redundant provision of securing devices preventing the upward opening of the bow door. In addition, where the visor door is not self-closing under external loads (i.e. the closing moment M_y calculated in accordance with 3.1.3 is less than zero) then the opening moment M_o is not to be taken less than M_y. If drainage arrangements in the space between the inner and bow doors are not fitted, the value of M_o is to be specially considered.

  Where available space above the tank top does not enable the full application of 6.2.7, equivalent measures are to be taken to ensure that the door has positive means for being kept closed during seagoing operation.

- Ships with visor door are to comply with 6.2.8 requiring securing and supporting devices excluding hinges to be capable of bearing the vertical design force (F_z – 10 · W) without exceeding the permissible stresses given in 2.1.1.

- For side-opening doors, the structural arrangements for supporting vertical loads, including securing devices, supporting devices and, where applicable, hull structure above the door, are to be re-assessed in accordance with the applicable requirements of 6. and modified accordingly

- The securing device and locking arrangement of bow doors and inner doors which may lead to the flooding of a special category space or ro-ro space as defined in 1.3 are to be arranged and verified in according to Rules for Classification and Surveys (Pt.1, Vol.I) Sec. 4.II.C.4

9.2 The requirements of 8. concerning operating procedures of the bow door and inner door are to be complied with.

(IACS UR S16)

J. Side Shell Doors and Stern Doors

1. General

1.1 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)

1.2 For the definition of securing, supporting and locking devices see H.1.3.

2. Arrangement

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)

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)

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)

2.4 Doors should preferably open outwards.

(IACS UR S9.1.2d)

2.5 In case of ice strengthening see Section 15.

3. Strength criteria

The requirements of H.2 apply.

(IACS UR S9.2)

4. Design loads

4.1 The design forces 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 following values:

4.1.1 Design forces for securing or supporting devices of doors opening inwards:

— external force : $F_e = A \cdot p_e + F_p$ [kN]

— internal force : $F_i = F_0 + 10 \cdot W$ [kN]

4.1.2 Design forces for securing or supporting devices of doors opening outwards:

— external force : $F_e = A \cdot p_e$ [kN]

— internal force : $F_i = F_0 + 10 \cdot W + F_p$ [kN]

4.1.3 Design forces for primary members:

- external force : $F_e = A \cdot p_e$ [kN]
- internal force : $F_i = F_0 + 10 \cdot W$ [kN]

A	=	area of the door opening [m^2]
W	=	mass of the door [t]
F_p	=	total packing force[kN], where the packing line pressure is normally not to be taken less than 5,0 N/mm
F_0	=	the greater of F_c or $5 \cdot A$ [kN]
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
p_e	=	external design pressure determined at the centre of gravity of the door opening and not taken less than:
	=	p_s according to Section 4, B.2.1 or:
p_e	=	$10\,(\mathbf{T} - z_G) + 25$ [kN/m^2] for $z_G < \mathbf{T}$
	=	25 [kN/m^2] for $z_G > \mathbf{T}$

Moreover, for stern doors of ships fitted also with bow doors, $p_{e,min}$ is to be determined by the following formula:

$$p_e = 0,6\left(\frac{1 + C_{RW}}{2}\right) \cdot C_H \left(0,8 + 0,6\sqrt{\mathbf{L}}\right)^2 \quad [kN/m^2]$$

z_G = height of centre of area of door above base line [m].

(IACS UR S9.3.1)

5. Scantlings

5.1 General

The requirements of H.4.1 apply analogously with the following additions:

- The strength of side shell doors and stern doors is to be commensurate with that of the surrounding structure.
- Side shell doors and stern doors are to be adequately stiffened and means are to be provided to prevent any lateral or vertical movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship's structure.
- 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)

5.2 Plating and secondary stiffeners

The requirements of H.4.2.1 and H.4.2.2 apply analogously with the following additions:

Where doors serve as vehicle ramps, plate thickness and stiffener scantlings are to comply with the requirements of Section 7, B.2.

(IACS UR S9.4.2a)

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

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

(IACS UR S9.4.2b)

5.3 Primary structure

The requirements of H.4.3 apply analogously taking into account the design loads specified in 4.

Where doors serve as vehicle ramps, plate thickness and stiffener scantlings are to comply with the requirements of Section 7, B.2.

(IACS UR S9.4.3)

6. Securing and supporting of side shell and stern doors

6.1 General

The requirements of H.6.1.1 and H.6.1.2 apply analogously.

(IACS UR S9.5.1)

6.2 Scantlings

The requirements of H.6.2.1, H.6.2.5, H.6.2.6 and H.6.2.9 apply analogously taking into account the design loads specified in 4.

(IACS UR S9.5.2)

7. Arrangement of securing and locking devices

7.1 Systems for operation

7.1.1 The requirements of H.7.1.1 apply.

(IACS UR S9.6.1a)

7.1.2 Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6,0 m^2 are to be provided with an arrangement for remote control, from a position above the freeboard deck according to H.7.1.2.

(IACS UR S9.6.1b)

7.1.3 The requirements of H.7.1.3 apply.

(IACS UR S9.6.1c)

7.2 Systems for indication/monitoring

7.2.1 The requirements of H.7.2.1, H.7.2.2 and H.7.2.3 apply analogously 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.

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.

8. Operating and maintenance manual

The requirements of H.8 apply analogously as well as the IACS UR S9.

(IACS UR S9.7)

9. Retrospective Application of Side Shell Doors and Stern Doors to existing Ro-Ro Passenger Ships

9.1 The following requirements are to be complied with by all existing ro-ro passenger ships with the date of building before the 30th June 1996:

— The structural arrangement of securing devices and supporting devices of inwards opening doors in way of these securing devices and, where applicable, of the surrounding hull structure is to be reassessed in accordance with the applicable requirements of 6. and modified accordingly.

— The securing device and locking arrangement of side shell doors and stern doors which may lead to the flooding of a special category space or ro-ro space as defined in H.1.3 are to be arranged and verified in according to Rules for Classification and Surveys (Pt.1, Vol.I) Sec. 4.II.C.4

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

(IACS UR S15)

K. Bulwarks

1. The thickness of bulwark plating is not to be less than :

$$t = \left[0,75 - \frac{\mathbf{L}}{1000}\right]\sqrt{\mathbf{L}} \quad [\text{mm}] \quad \text{for} \quad \mathbf{L} \leq 100 \text{ m}$$

$$= 0,65\sqrt{\mathbf{L}} \quad [\text{mm}] \quad \text{for} \quad \mathbf{L} > 100 \text{ m}$$

L need not be taken greater than 200 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, B.1.

In way of superstructures above the freeboard deck abaft 0,25**L** from **FP** the thickness of the bulwark plating may be reduced by 0,5 mm.

2. The bulwark height or height of guard rail is not to be less than 1,0 m, the lesser height may be approved if adequate protection is provided.

3. Plate bulwarks are to be stiffened at the upper edge by a bulwark rail section.

4. The bulwark is to be supported by bulwark stays fitted at every alternate frame. Where the stays are designed as per Fig. 6.6, the section modulus of their cross section effectively attached to the deck is not to be less than:

$$W = 4 \cdot p \cdot e \cdot \ell^2 \ [cm^3]$$

p = p_s or p_e as the case may be

p_{min} = 15 kN/m^2

e = spacing of stays [m]

ℓ = length of stay [m]

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, E.3.

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.

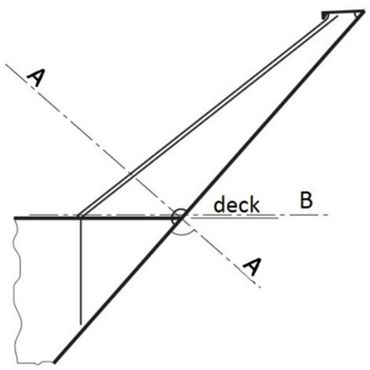

Fig. 6.6 Bulwark stay

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:

bending stress:

$$\sigma_b = \frac{120}{\mathbf{k}} \quad [N/mm^2]$$

shear stress:

$$\tau = \frac{80}{\mathbf{k}} \quad [N/mm^2]$$

For loads caused by containers and by stow and lashing arrangements. See also Section 21, J.

7. An adequate number of expansion joints is to be provided in the bulwark. In longitudinal direction the stays adjacent to the expansion joints shall be as flexible as practicable.

The number of expansion joints for ships exceeding 60 m in length should not be less than:

$$n = \frac{L}{40}$$, but need not be greater than n = 5

8. Openings in the bulwarks shall have sufficient distance from the end bulkheads of superstructures. For avoiding cracks the connection of bulwarks to deckhouse supports is to be carefully designed.

9. For the connection of bulwarks with the sheer strake C.3.4 is to be observed.

10. Bulwarks are to be provided with freeing ports of sufficient size. See also Section 21, E.2 and **ICLL**.

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Section 7 Decks

A. Strength Deck

1. General, Definition

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 or the deck of a sunk superstructure which extends into 0,4**L** amidships.

At the option of the designer the deck below superstructure deck may be taken as strength deck.

1.1 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.

The thicknesses of a strength deck plating 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, A.3.

1.2 If the strength deck is protected by sheathing a smaller corrosion addition t_K than required by Section 3, K 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.

1.3 For ships with a speed $\mathbf{v}_0 > 1{,}6 \cdot \sqrt{\mathbf{L}}$ [kn], additional strengthening of the strength deck and the sheer strake may be required.

1.4 The following definitions apply throughout this Section:

k	=	material factor according to Section 2, B
p	=	loads on accommodation and machinery decks according to Section 4, C.3
p_D	=	load according to Section 4, B.1
p_L	=	load according to Section 4, C.1
t_K	=	corrosion addition according to Section 3, K

2. Connection between strength deck and sheer strake

2.1 The welded connection between strength deck and sheer strake may be effected by fillet welds according to Table 19.4. Where the plate thickness exceeds approximately 25 mm, a double bevel weld connection according to Section 19, B.3.2, shall 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 mm.

2.2 Where the connection of deck stringer to sheer strake is rounded, the requirements of Section 6, C.3.3 are to be observed.

3. Openings in the strength deck

3.1 All openings in the strength deck are to have well rounded corners circular openings are to be edge-reinforced.

The sectional area of the face bar is not to be less than:

$$A_f = 0,25 \cdot d \cdot t \quad [cm^2]$$

d = diameter of openings [cm]

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 x 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.

3.2 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**L** amidships, the thickness of the strengthened plate is to be equal to the deck thickness abreast the hatchway plus the deck thickness between the hatchways. Outside 0,5**L** amidships the thickness of the strengthened plated need not 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.

3.3 The hatchway corner radius is not to be less than:

$$r = n \cdot b \left(1 - \frac{b}{\mathbf{B}}\right)$$

r_{min} = 0,1 m

$n = \dfrac{\ell}{200}$

n_{min} = 0,1

n_{max} = 0,25

ℓ = length of hatchway [m]

b = breadth [m], of hatchway or total breadth of hatchways in case of more than one hatchway. b/**B** need not be taken smaller than 0,4. For ships with large hatch openings see 3.6.

3.4 Where the hatchway corners are elliptic or parabolic, strengthening according to 3.2 is not required. The dimensions of the elliptical and parabolical corners shall be as shown in Fig. 7.1:

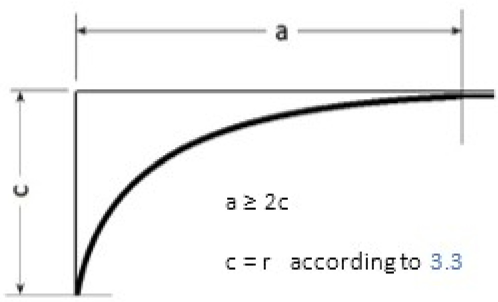


Fig. 7.1 Elliptic or parabolic hatch corner

Where smaller values are taken for a and c, reinforced insert plates are required which will be considered in each individual case.

3.5 At the corners of the engine room casings, strengthenings according to 3.2 may also be required, depending on the position and the dimensions of the casing.

3.6 Ships with large deck openings

3.6.1 For ships with large deck openings according to Section 5, F 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:

$$r \geq c_1 \cdot c_2$$

r_{min}	=	0,15 m	for hatchway corners in the strength deck
	=	0,1 m	in all other locations
c_1	=	coefficient, defined as:	
	=	$\left(f_D + \frac{\ell}{750}\right) \cdot b_L$	for hatchway corners at deck girders alongside the hatchway, adjacent to a closed deck area, see HC1 in Fig. 7.2.
	=	$0{,}4 \cdot b_Q$	for hatchway corners at cross deck strips between hatchways adjacent to a closed deck area, see HC2 in Fig. 7.2.
	=	$\left(f_D + \frac{\ell}{750}\right) \cdot \sqrt{\frac{b_L^2 \cdot b_Q^2}{b_L^2 + b_Q^2}}$	for hatchway corners adjacent to a cross deck strip, see HC3 in Fig. 7.2.
f_D	=	coefficient for deck configuration, defined as:	
	=	$0{,}25 + \frac{\mathbf{L}}{2000}$	for hatchway corners of the strength deck and for decks and coamings above the strength deck
	=	$0{,}2 + \frac{\mathbf{L}}{1800}$	for the strength deck, decks and coamings above the strength deck and for decks within the distance of maximum bL 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 of large deck openings [m] forward and/or aft of the superstructure	
$\mathbf{L}_{min}$	=	100 m	
$\mathbf{L}_{max}$	=	300 m	
b_L	=	breadth of deck girder alongside the hatchway [m]	
b_Q	=	breadth of cross deck strip between hatchways [m]	
		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.	
c_2	=	coefficient, defined as:	
	=	$\frac{\lvert M_T (z_D - z_0) \rvert}{I_y \cdot 175 \cdot 10^3 \cdot c_s} \cdot \frac{t_D}{t_i} \cdot \sqrt[4]{k_i}$	

t_D = plate thickness of the longitudinal structural member [mm]

t_i = thickness of the hatchway corner plate [mm]

$1 \geq \frac{t_D}{t_i} \geq 0,625$

M_T = total longitudinal bending moment [kNm], according to Section 5, A.5 at the forward or aft edge of the relevant cross deck strip or the relevant closed deck area

I_y = moment of inertia [m^4] of the section according to Section 5, A.5 in the hatchway corner without inserted strengthened plate

c_s = distribution factor, defined as:

= according to Section 5, C.1.1 for the strength deck

= 1,0 for the lower decks

z_0 = distance of neutral axis of the hull section from the baseline [m]

z_D = distance of the relevant hatchway corner from the baseline [m]

k_i = material factor according to Section 2, B of the relevant hatchway corner

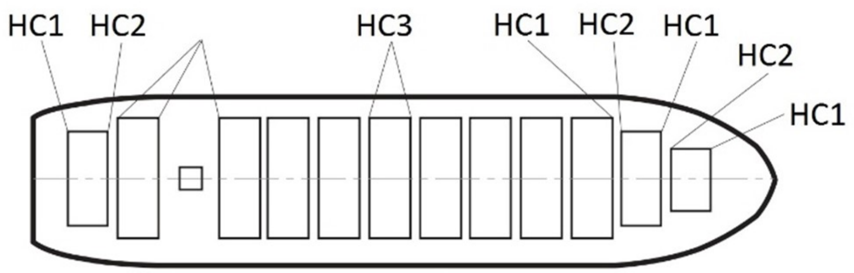


Fig. 7.2 Positions of hatch corners

3.6.2 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

$a = 3\ (t_i - t) + 300$ [mm]

$a_{min} = 350$ mm

$b = r + 3\ (t_i - t) + 125$ [mm]

3.6.3 Openings in way of hatchway corners are not to be located within the following minimum distances (see Fig. 7.3)

a) Opening outside of insert plate

c = distance of opening from butt seam
= $2 \cdot t + h + 50$ [mm] for strength deck
= $2 \cdot t + h/2 + 50$ [mm] for lower decks

b) Opening inside of insert plate

e = distance of opening from longitudinal bulkhead
= $2 \cdot r + h/2$ [mm] for strength deck
= $1,5 \cdot r + h/2$ [mm] for lower decks

t_i = thickness of the hatchway corner plate according to 3.6.1

t = thickness [mm] of the deck plate

r = radius of the hatchway corner according to 3.6.1

h = diameter of opening [mm]

On the basis of direct calculations, other minimum distances for specific cases may be accepted. Outside 0,5**L** amidships the thickness of the strengthened plate shall not exceed 1,6 times the thickness of the deck plating abreast the hatchway.

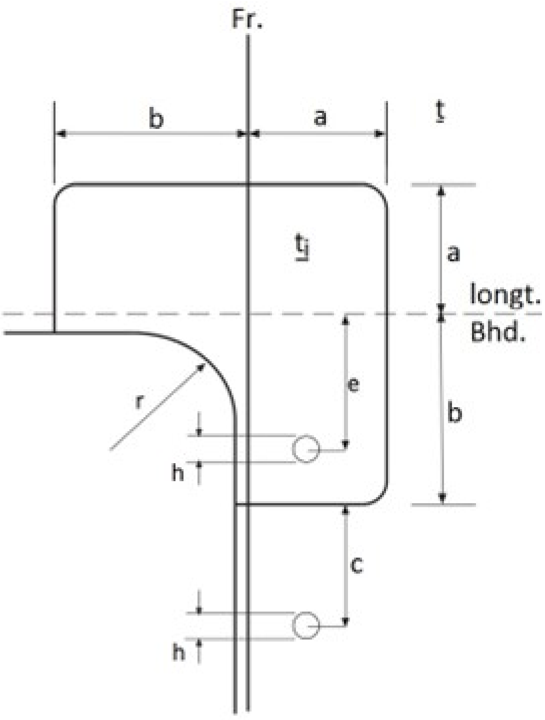


Fig. 7.3 Strengthening of hatchway corners

3.7 Stresses due to lateral loads

$$\sigma_Q = \frac{M_Q}{W_1 \cdot 10^3} \quad [N/mm^2]$$

M_Q = bending moment around the z-axis due to the action of the external water pressure according to Section 4, B.2 and/or cargo loads [kNm], stressing the girder consisting of deck strip, longitudinal hatch coaming and effective parts of longitudinal bulkhead and side shell plating.

W_1 = section modulus [m³] of the girder specified above abreast hatchway around the vertical axis. Longitudinal hatch coamings can only be included, if carried sufficiently beyond the hatchway ends.

For container ships with hatchway lengths not exceeding approximately 14 m and with transverse box girders of approximately equal rigidity, σ_Q may be determined by the following formulae:

$$\sigma_Q = \frac{\left(\frac{\mathbf{T}^3}{\mathbf{H}} + 0,25 \cdot \mathbf{H} \cdot p_0\right) \cdot \ell_L^2}{7,2.W_1 \cdot 10^3} \quad [N/mm^2]$$

p_0 = see Section 4, A.2.2

In the hatch corners of ships with large deck openings according to Section 5, F, the following equation must be complied with:

$$\sigma_L + \sigma_Q \leq \sigma_V$$

σ_V = see Section 5, D.1.2

σ_L = see Section 5, D.1

4. Scantlings of strength deck of ships up to 65 m in length

The scantlings of the strength deck for ships, for which proof of longitudinal strength is not required, i.e. in general for ships with length **L** ≤ 65 m, the sectional area of the strength deck within 0,4**L** amidships is to be determined such that the requirements for the minimum amidships section modulus according to Sectionn 5, C.2 are complied with.

The thickness within 0,4**L** amidships is not to be less than the minimum thickness according to 6.

For the range 0,1**L** from ends, the requirement of 7.1 apply.

5. Scantlings of strength deck of ships of more than 65 m in length

5.1 Deck sectional area

The deck sectional area abreast the hatchways, if any, is to be so determined that the section modulii of the cross section is in accordance with the requirements of Section 5, C.

5.2 Critical plate thickness, buckling strength

5.2.1 The critical plate thickness is to be determined according to Section 6, B.2 analogously.

5.2.2 Reductions from the critical plate thickness on account of restricted service are not admissible.

5.2.3 In regard to buckling strength the requirements of Section 6, B.2.2 apply analogously.

5.3 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 sheer strake and the thickness of the side shell plating.

6. Minimum thickness

6.1 The thickness of deck plating for 0,4**L** amidships outside line of hatchways, is not to be less than the greater of the two following values:

$$t_{min} = (4,5 + 0,05 \cdot \mathbf{L}) \cdot \sqrt{k} \quad \text{[mm]}$$

or

t_E = according to 7.1,

L need not be taken greater than 200 m.

6.2 When the deck is located above a level of **T** + c_0 above basis a smaller thickness than t_{min} may be accepted if the stress level permits such reduction. c_0 see Section 4, A.2.2.

7. End thickness, thickness inside line of hatchways

7.1 The thickness of strength deck plating for 0,1**L** from the ends and between hatchways is not to be less than:

$$t_{E1} = 1,21 \cdot \mathbf{a}\sqrt{p_D \cdot k} + t_K \quad [mm]$$

$$t_{E2} = 1,1 \cdot \mathbf{a}\sqrt{p_L \cdot k} + t_K \quad [mm]$$

$$t_{Emin} = (5,5 + 0,02 \cdot \mathbf{L})\sqrt{k} \quad [mm]$$

L need not be taken greater than 200 m.

7.2 Between the amidships thickness and the end thickness, the thicknesses are to be tapered gradually.

7.3 The strength of deck structure between hatch openings has to withstand compressive transversely acting loads.

Proof of buckling strength is to be provided according to Section 3, F.

B. Lower Decks

1. Thickness of decks for cargo loads

1.1 The plate thickness is not to be less than:

$$t = 1,21 \cdot \mathbf{a}\sqrt{p_L \cdot k} + t_K \quad [mm]$$

$$t_{min} = (5,5 + 0,02 \cdot \mathbf{L})\sqrt{k} \quad [mm] \quad \text{for the } 2^{nd} \text{ deck}$$

$$= 6,0 \quad mm \quad \text{for other lower decks}$$

L need not be taken greater than 200 m.

1.2 For the critical deck thickness see A.5.2.

2. Thickness of decks for wheel loading

2.1 The thickness of deck plating for wheel loading is to be determined by the following formulae:

$$t = c\sqrt{P \cdot k} + t_K \quad [mm]$$

P = load [kN] of one wheel or group of wheels on a plate panel a · b considering the aceleration factor a_v.

$= \frac{Q}{N}(1 + a_v)$

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 = according to Section 4, C.1.1 for general

= 0 for harbour conditions

c = factor according to Table 7.1

Table 7.1 Coefficient c

Ratio of area of wheel print and area of plate panel	b/a = 1,0	b/a ≥ 2,5
$0 < \frac{f}{F} < 0,3$	$c = 1,87 - \sqrt{\frac{f}{F}\left[3,4 - 4,4\frac{f}{F}\right]}$	$c = 2,00 - \sqrt{\frac{f}{F}\left[5,2 - 7,2\frac{f}{F}\right]}$
$0,3 \le \frac{f}{F} \le 1,0$	$c = 1,20 - 0,40\frac{f}{F}$	$c = 1,20 - 0,517\frac{f}{F}$
for intermediate values of b/a the factor c is to be obtained by direct interpolation		

f = print area of wheel or group of wheels.

F = area of plate panel a · b according to Fig. 7.4

a = width of smaller side of plate panel (in general beam spacing)

b = width of larger side of plate panel

F need not be taken greater than 2,5 a^2.

In case of narrowly spaced wheels these may be grouped together to one wheel print area.

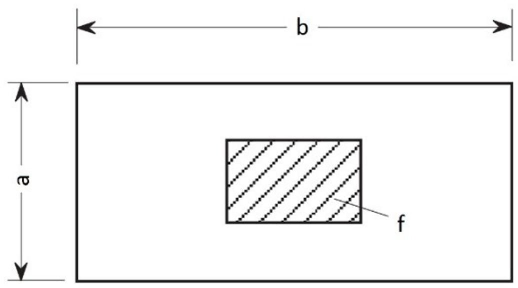


Fig. 7.4 Footprint of wheel

2.2 Where the wheel print area is not known, it may approximately be determined as follows:

$$f = \frac{P}{p} \cdot 10^2 \qquad [cm^2]$$

p = specific wheel pressure according to Table 7.2.

2.3 In deck beams and girders, the stress is not to exceed 165/k [N/mm^2].

Table 7.2 Specific wheel pressure

Type of vehicle	Specific wheel pressure p [bar]	
	Pneumatic tyres	Solid rubber tyres
private cars	2	-
trucks	8	-
trailers	8	15
fork lift trucks	6	15

3. Machinery decks and accommodation decks

The scantlings of machinery decks and other accommodation decks have to be based on the loads given in Coefficient Section 4, C.3.

The thickness of the plates is not to be less than:

$$t = 1,11 \cdot a\sqrt{p \cdot k} + t_K \quad [mm]$$

$$t_{min} = 5,0 \quad mm$$

3.1 At the corners of the engine room casings, strengthenings according to A.3.2 may also be required depending on the position and the dimensions of the casing.

C. Helidecks and Helicopter Landing Areas

1. General, Definition

Helideck is a purpose-built helicopter landing platform or other deck area including all structure, firefighting 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 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.

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.

1.2 The starting/landing zone is to be dimensioned for the largest helicopter type expected to use the helicopter deck.

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.

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 2. maybe used as a basis.

1.4 Requirements regarding structural fire protection see Section 22.

1.5 The following provisions in principle apply to starting/landing zones on special pillar-supported landing decks or on decks of superstructures and deckhouses.

Depending of the flag state relevant national or international standards and regulations have to be fulfilled besides of these BKI Rules. The following examples are given as reference:

— Guide to Helicopter/Ship Operations, published by the International Chamber of Shipping (ICS).

— ffshore 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.

— Guidance for The Class Notation Helicopter Deck and Facilities (Pt.7, Vol.A).

2. Design Load

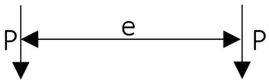
The following load cases **(LC)** are to be considered:

2.1 LC 1

Helicopter lashed on deck, with the following vertical forces acting simultaneously:

1) 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 = $0,5 \cdot G(1 + a_v)$ [kN]



G = maximum permissible take-off weight [kN]

a_v = see Section 4, C.1.1

P = evenly distributed force over the contact area f = 30 x 30 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

2) Force due to weight of helicopter deck M_e as follows :

$M_e(1 + a_v)$ [kN]

3) Load p = 2,0 kN/m^2 evenly distributed over the entire landing deck for taking into account snow or other environmental load

2.2 LC 2

Helicopter lashed on deck, with the following horizontal and vertical forces acting simultaneously:

1) 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 [kN]

2) vertical force on supports of the deck due to weight of helicopter deck:

M_e [kN]

3) load p = 2,0 kN/m^2 evenly distributed over the entire landing deck for taking into account snow or other environmental loads

4) horizontal forces on the lashing points of the helicopter:

H = 0,6 $\cdot$ G + W_{He} [Kn]

W_{He} = wind load [kN] on the helicopter at the lashing points related to a wind velocity of; wind velocity v_w = 50 m/s.

5) horizontal force on supports of the deck due to weight and structure of helicopter deck:

H = 0,6 $\cdot$ G + W_{St} [Kn]

W_{St} = wind load [kN] on the structure of the helicopter deck related to a wind velocity of v_w = 50 m/s.

2.3 LC 3

Normal landing impact, with the following forces acting simultaneously:

1) 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 · G [kN]

2) Load p = 0,5 kN/m^2 evenly distributed over the entire landing deck for taking into account snow or other environmental loads

3) Weight of the helicopter deck M_e as follows:

   M_e [kN]

4) Wind load in accordance with the wind velocity admitted for helicopter operation (vw), where no data are available, vw = 25 m/s may be used.

   W_{St} [kN]

2.4 LC 4

Emergency/crash landing impact with following vertical forces:

1) 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 · G [kN]

2) forces due to weight of helicopter deck, evenly distributed loads and wind loads according to LC 3 are to be considered.

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:

$$W = 0,5 \cdot \rho \cdot v_w^2 \cdot A \cdot 10^{-3} \text{ [kN]}$$

ρ = air density [kg/m3], defined as:

= 1,2 for an air temperature of 20° C

v_w = wind velocity [m/s]

A = area [m^2] exposed to wind

3. Scantlings of structural members

3.1 Stresses and forces in the supporting structure are to be evaluated by means of direct calculations.

3.2 Permissible stresses for stiffeners, girders and substructure:

$$\sigma_{perm} = \frac{235}{k \cdot \gamma_f}$$

γ_f = Safety factors according to Table 7.3.

Table 7.3 Safety factor γ_f

Structural element	γ_f		
	LC 1, LC 2	**LC 3**	**LC 4**
Stiffeners (deck beam)	1,25	1,1	1,00
main girders (deck girder)	1,45	1,45	1,10
load-bearing structure (pillar system)	1,70	2,00	1,20

3.3 The thickness of the plating is to be determined according to B.2 where the coefficient c may be reduced by 5%.

3.4 Proof of sufficient buckling strength is to be carried out in accordance with Section 3, F for structures subjected to compressive stresses.

4. Helicopter deck equipment

Requirement regarding Helicopter deck equipment, see rules for Guidance for The Class Notation Hellicopter Deck and Facilities (Pt.7, Vol.A) Sec.2.C.

Section 8 Bottom Structures

A. Single Bottom

1. Floor plates

1.1 General

1.1.1 Floor plates are to be fitted at every frame. For the connection with the frames, see Section 19, B.4.2.

1.1.2 Deep floors, particularly in the after peak, are to be provided with buckling stiffeners.

1.1.3 The floor plates are to be provided with limbers to permit the water to reach the pump suctions.

1.2 Scantlings

1.2.1 Floor plates in the cargo hold area

On ships without double bottom or outside any double bottom, the scantlings of floor plates fitted between after peak bulkhead and collision bulkhead are to be determined according to the following formulae.

The section modulus is not to be less than:

$$W = c \cdot \mathbf{T} \cdot e \cdot \ell^2 \quad [\mathrm{cm}^3]$$

e	=	spacing of plate floor [m]	
ℓ	=	unsupported span [m], generally measured on upper edge of floor from side shell to side shell	
ℓ_{min}	=	$0{,}7 \cdot \mathbf{B}$	if the floors are not supported at longitudinal bulkheads
c	=	7,5	for spaces which may be empty at full draught, e.g. machinery spaces, storerooms, etc.
	=	4,5	elsewhere

The depth of the floor plates is not to be less than :

$$h = 55 \cdot \mathbf{B} - 45 \quad [\mathrm{mm}]$$

$$h_{min} = 180 \text{ mm}$$

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 shall not 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 is not to be less than:

$$t = \frac{h}{100} + 3,0 \quad [mm]$$

The web sectional area is to be determined according to B.6.2.2 analogously.

1.2.2 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.

1.2.3 Floor plates in the peaks

The thickness of the floor plates in the peaks is not to be less than:

$$t = 0{,}035 \cdot \mathbf{L} + 5{,}0 \quad [mm]$$

The thickness, however, need not be greater than required by B.6.2.1.

The floor plate height in the fore peak above top of keel or stem shoe is not to be less than:

$$h = 0{,}06 \cdot \mathbf{H} + 0{,}7 \quad [m]$$

For small ship deviation from this requirement may be considered.

The floor plates in the after peak are to extend over the stern tube (see also Section 13, C.1.4).

Where propeller revolutions are exceeding 300 rpm (approx.) the peak floors above the propeller are to be strengthened.

Particularly in case of flat bottoms additional longitudinal stiffeners are to be fitted above or forward of the propeller.

2. Longitudinal girders

2.1 General

2.1.1 All single bottom ships are to have a centre girder. Where the breadth measured on top of floors does not exceed 9,0 m one additional side girder is to be fitted, and two side girders where the breadth exceeds 9,0 m. Side girders are not required where the breadth does not exceed 6,0 m.

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, E.1.

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.

2.2 Scantlings

2.2.1 Centre girder

The web thickness tw and the sectional area of the face plate Af within 0,7**L** amidships is not to be less than:

$$t_w = 0{,}07 \cdot \mathbf{L} + 5{,}5 \quad [mm]$$

$$A_f = 0{,}7 \cdot \mathbf{L} + 12 \quad [cm^2]$$

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.

2.2.2 Side girder

The web thickness t_w and the sectional area of the face plate A_f within 0,7**L** amidships is not to be less than:

$$t_w = 0{,}04 \cdot \mathbf{L} + 5 \quad [\text{mm}]$$

$$A_f = 0{,}2 \cdot \mathbf{L} + 6 \quad [\text{cm}^2]$$

Towards the ends, the thickness of the web plate and the sectional area of the face plate may be reduced by 10%.

B. Double Bottom

1. General

1.1 On all passenger ships and cargo ships of 500 GT and more other than tankers a double bottom shall 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. For oil tankers see Section 24.

1.2 The arrangement shall comply with Chapter II-1 of SOLAS as amended. See also Section 36, D.

1.3 Where a double bottom is required to be fitted the inner bottom shall 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:

$$h = \frac{\mathbf{B}}{20}$$

However, in no case is the value of h to be less than 760 mm, and need not be taken as more than 2000 mm.

(SOLAS II-1, 9.2)

1.4 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)

1.5 In fore- and after peak a double bottom need not be arranged.

1.6 The centre girder should be watertight at least for 0,5**L** amidships, unless the double bottom is subdivided by watertight side girders. On ships which are assigned the load line permissible for timber deck load, the double bottom is to be subdivided watertight by the centre girder or side girders as required by the ICLL 66.

((ICLL Annex 1, Ch. IV, Reg. 43 (3))

1.7 For the double bottom structures of bulk carriers, see Section 23, B.4.

1.8 For bottom strengthening forward see Section 6, E.

1.9 For the material factor k see Section 2, B. For the corrosion addition t_K see Section 3, K.

1.10 For buckling strength of the double bottom structures see 8.3.

1.11 Where a duct keel is arranged, the centre girder may be replaced by two girders spaced no more than 3 m apart. Spacing wider than 3 m will be specially considered.

1.12 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 3.1.

When the longitudinal framing system is adopted, the longitudinal girder system according to 7.5 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.1 to B.5.

2. Centre girder

2.1 Lightening holes

Lightening holes in the centre girder are generally permitted only outside 0,75**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 lightening holes in the centre girder are to be reduced to minimum.

2.2 Scantlings

2.2.1 The depth of the centre girder is not to be less than:

$$h = 350 + 45 \cdot \ell \quad [\text{mm}]$$

$$h_{min} = 600 \text{ mm}$$

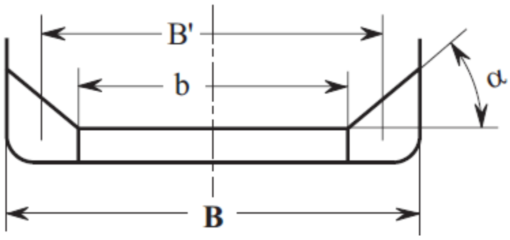
ℓ = unsupported span of floor plate [m]

ℓ = **B** In general

ℓ = 0,8 · **B** In case longitudinal side bulkheads, the distance between the bulkheads can be used as unsupport span

ℓ = **B'** In case of double bottoms with hopper tanks (e.g. on bulk carriers) the fictitious breadth **B'** according to Fig. 8.1 can be used as unsupported span

However, $\ell \geq 0{,}8\mathbf{B}$ in case of additional longitudinal bulkheads, the unsupported span can be shortened accordingly.



$$B' = \frac{1}{3}(2 \cdot \mathbf{B} + b) \quad \text{for } \alpha \geq 35°$$

$$B' = \mathbf{B} \quad \text{for } \alpha < 35°$$

Fig. 8.1 Fictitious breadth B'

2.2.2 The thickness of the centre girder is not to be less than:

$$t_m = \frac{h}{h_a}\left(\frac{h}{100}+1,0\right)\sqrt{k} \quad [mm] \quad \text{for } h \le 1200\ [mm]$$

$$t_m = \frac{h}{h_a}\left(\frac{h}{120}+3,0\right)\sqrt{k} \quad [mm] \quad \text{for } h > 1200\ [mm]$$

h = depth of the center girder according to 2.2.1

h_a = depth of centre girder as built [mm]

t_m = shall not be less than t according to 7.5

3. Side girders

3.1 Arrangement

At least one side girder shall be fitted in the engine room and in way of 0,25**L** aft of **FP**. In the other parts of the double bottom, one side girder shall be fitted where the horizontal distance between ship's side and centre girder exceeds 4,5 m.

Two side girders shall be fitted where the distance exceeds 8,0 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 shall not be greater than:

— 1,8 m in the engine room within the breadth of 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.

3.2 Scantlings

The thickness of the side girders is not to be less than:

$$t = \frac{h^2}{120 \cdot h_a}\sqrt{k} \quad [mm]$$

h = depth of the centre girder [mm] according to 2.2

h_a = as built depth of side girders [mm], h_a need not be taken less than h to calculate t

t = shall not be less than t according to 7.5

For strengthenings under the engine seating, see C.2.3.

4. Inner bottom

4.1 The thickness of the inner bottom plating is not to be less than:

$$t = 1,1 \cdot \mathbf{a}\sqrt{p \cdot k} + t_k \quad [mm]$$

p = design pressure [kN/m^2], p is the greater of the following values:

p_1 = 10 (**T**-h_{DB})

p_2 = 10 · h, where the inner bottom forms a tank boundary

p_3 = p_i according to Section 4, C.2

h = distance from top of overflow pipe to inner bottom [m]

h_{DB} = double bottom height [m]

4.2 If no ceiling according to Section 21, C.1 is fitted on the inner bottom, the thickness determined in accordance with 4.1 for p_1 or p_2 is to be increased by 2,0 mm. This increase is required for ships with the Notation **"GENERAL DRY CARGO SHIP"** and **"MULTI-PURPOSE DRY CARGO SHIP"**.

4.3 For strengthening of inner bottom in machinery spaces, see C.2.4.

5. Double bottom tanks

5.1 Scantlings

Structures forming boundaries of double bottom tanks are to comply with the requirements of Section 12.

5.2 Fuel and lubricating oil tanks

5.2.1 In double bottom tanks, oil fuel may be carried, the flash point (closed cup test) of which exceeds $60°$ C.

5.2.2 Where practicable, lubricating oil discharge tanks or circulating tanks shall be separated from the shell.

The lubricating oil circulating tanks are to be separated from the shell by at least 500 mm.

5.2.3 For the separation of oil fuel tanks from tanks for other liquids, see Section 12, A.5.

5.2.4 For air, overflow and sounding pipes, see Section 21, F as well as Rules for Machinery Installations (Pt.1, Vol.III) Sec.11.

5.2.5 Manholes for access to oil fuel double bottom tanks situated under cargo oil tanks are not permitted in cargo oil tanks nor in the engine room (see also Section 21, O.6 and Section 24, A.3.1.2).

5.2.6 The thickness of structures is not to be less than the minimum thickness according to Section 12, A.7.

5.2.7 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 shall be designed with a soft taper at the end of each arm. The thickness of the vertical brackets shall correspond to the thickness of the floor plates according to C.2.2, the thickness of the horizontal brackets shall correspond to the tank top thickness of the circulating tank.

The brackets shall be connected to the ship structure by double-bevel welds according to Section 19, B.3.2.2.

5.3 Bilge wells

Bilge wells shall 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 Section 21, F as well as Rules for Machinery Installations (Pt.1, Vol.III) Sec.11. Bilge wells are to be separated from the shell.Section 29-I, F.5 shall be applied analogously.

5.4 Sea chests

5.4.1 The plate thickness of sea chests is not to be less than:

$$t = 12 \cdot a\sqrt{p \cdot k} + t_k \quad [mm]$$

a = spacing of stiffeners [m]

p = blow out pressure at the safety valve [bar]. p is not to be less than 2 bar (see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.11)

5.4.2 The section modulus of sea chest stiffeners is not to be less than:

$$W = 56 \cdot \mathbf{a} \cdot p \cdot \ell^2 \cdot k \quad [cm^3]$$

a and p see 5.4.1

ℓ = unsupported span of stiffeners [m]

5.4.3 The sea-water inlet openings in the shell are to be protected by gratings.

5.4.4 A cathodic corrosion protection with galvanic anodes made of zinc or aluminium is to be provided in sea chests with chest coolers. For the suitably coated plates a current density of 30 $\mu A/m^2$ is to be provided and for the cooling area a current density of 180 $\mu A/m^2$.

6. Double bottom, transverse framing system

6.1 Plate floors

6.1.1 It is recommended to fit plate floors at every frame in the double bottom if transverse framing is adopted.

6.1.2 Plate floors are to be fitted at every frame:

— in way of strengthening of the bottom forward according to Section 6, E

— in the engine room

— under boiler seatings

6.1.3 Plate floors are to be fitted:

— below bulkheads

— below corrugated bulkheads, see also Section 3, D.4 and Section 23, B.4.3

6.1.4 For the remaining part of the double bottom, the spacing of plate floors shall not exceed approximately 3,0 m.

6.2 Scantlings

6.2.1 The thickness of plate floors is not to be less than:

$$t_{pf} = (t_m - 2,0)\sqrt{k} \quad [mm]$$

t_m = thickness of centre girder according to 2.2.2

The thickness need not exceed 16 mm.

6.2.2 The web sectional area of the plate floors is not to be less than:

$$A_W = \varepsilon \cdot \mathbf{T} \cdot \ell \cdot e \left(1 - \frac{2 \cdot y}{\ell}\right) \cdot k \quad [cm^2]$$

e = spacing of plate floors [m]

ℓ = span between longitudinal bulkheads, if any [m]

= **B** if longitudinal bulkheads are not fitted

y = distance between supporting point of the plate floor (ship's side, longitudinal bulkhead) and the section considered [m]. The distance y is not to be taken greater than 0,4 ℓ

ε = 0,5 for spaces which may be empty at full draught, e.g. machinery spaces, store rooms, etc.

= 0,3 elsewhere

6.2.3 Where in small ships side girders are not required (see 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.

6.2.4 In way of strengthening of bottom forward according to Section 6, E, the plate floors are to be connected to the shell plating and inner bottom by continuous fillet welding.

6.2.5 For strengthening of floors in machinery spaces, see C.2.2.

6.3 Watertight floors

6.3.1 The thickness of watertight floors is not to be less than that required for tank bulkheads according to Section 12, B.2. In no case their thickness is to be less than required for plate floors according to 6.2.

6.3.2 The scantlings of stiffeners at watertight floors are to be determined according to Section 12, B.3.

6.4 Bracket floors

6.4.1 Where plate floors are not required according to 6.1 bracket floors may be fitted.

6.4.2 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.

6.4.3 The section modulus of bottom and inner bottom frames is not to be less than:

$$W = n \cdot c \cdot \mathbf{a} \cdot \ell^2 \cdot p \cdot k \quad [\mathrm{cm}^3]$$

p = design load, as applicable [kN/m^2] as follows :

for bottom frames

p = p_B according to Section 4, B.3

for inner bottom frames

p = p_i according to Section 4, C.2
= p_1 or p_2 according to Section 4, D.1
= $10\,(\mathbf{T} - h_{DB})$

The greater value is to be used.

h_{DB} = double bottom height [m]

n = 0,44 if $p = p_2$
= 0,55 if $p = p_i$ or p_1
= 0,70 if $p = p_B$

c = 0,60 where struts according to 6.6 are provided at $\ell/2$, otherwise c = 1,0

ℓ = unsupported span [m] disregarding struts, if any.

6.5 Brackets

6.5.1 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 as per 2.2. The brackets are to be flanged at their free edges, where the unsupported span of bottom frames exceeds 1,0 m or where the depth of floors exceeds 750 mm.

6.5.2 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.

6.6 Struts

The cross sectional area of the struts is to be determined according to Section 10, C.2 analogously. The design force is to be taken as the following value:

$$P = 0{,}5 \cdot p \cdot \mathbf{a} \cdot \ell \quad [\text{kN}]$$

p = load according to 6.4.3

ℓ = unsupported span according to 6.4.3

7. Double bottom, longitudinal framing system

7.1 General

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

7.2 Bottom and inner bottom longitudinals

7.2.1 The section moduli are to be calculated according to Section 9, B.

7.2.2 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, B. The scantlings of the struts are be determined in accordance with 6.6.

7.3 Plate floors

7.3.1 The floor spacing shall, in general, not exceed 5 times the mean longitudinal frame spacing.

7.3.2 Floors are to be fitted at every frame as defined in 6.1.3 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.

7.3.3 Regarding floors in way of the strengthening of the bottom forward, Section 6, E is to be observed. For ships intended for carrying heavy cargo, see Section 23.

7.3.4 The scantlings of floors are to be determined according to 6.2.

7.3.5 The plate floors should be stiffened in general at every longitudinal by a vertical stiffener having scantlings which fulfil the requirements in Section 9, B.4.

7.4 Brackets

7.4.1 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.

7.4.2 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 m apart. Where the floor spacing is greater, two brackets are should be fitted.

7.5 Longitudinal girder system

7.5.1 Where longitudinal girders are fitted instead of bottom longitudinals, the spacing of floors may be greater than permitted by 7.3.1, provided that adequate strength of the structure is proved.

7.5.2 The plate thickness of the longitudinal girders is not to be less than:

$$t = (5{,}0 + 0{,}03 \cdot \mathbf{L}) \cdot \sqrt{k} \quad [mm]$$

$$t_{min} = 6{,}0 \cdot \sqrt{k} \quad [mm]$$

7.5.3 The longitudinal girders are to be examined for sufficient safety against buckling according to Section 3, F.

8. Direct calculation of bottom structures

8.1 General, Definitions

8.1.1 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.

Definitions

p_i = load on inner bottom according to Section 4, C.2 [kN/m^2] or Section 4, C.1 [kN/m^2], (where applicable) Where high density ore cargo is intended to be carried in the holds in a conical shape, in agreement with BKI a corresponding load distribution pi on the inner bottom is to be used for the calculation

p'_a = $10 \cdot \mathbf{T} + p_0 \cdot c_F$ [kN/m^2] (hogging condition)

= $10 \cdot \mathbf{T} - p_0 \cdot c_F$ [kN/m^2] (sagging condition)

p_0, c_F , see Section 4, A.2.2

σ_L = design hull girder bending stress [N/mm^2] according to Section 5, D.1 (hogging or sagging, whichever condition is examined)

σ_ℓ = bending stress [N/mm^2] in longitudinal direction, due to the load p, in longitudinal girders

σ_q = bending stress [N/mm^2] in transverse direction, due to the load p, in transverse girders

τ = shear stress in the longitudinal girders or transverse girders due to the load p [N/mm^2]

8.1.2 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.

8.2 Design loads, permissible stresses

8.2.1 Design loads

$p = p_i - p_a$ [kN/m^2] for loaded holds

$= p_a$ [kN/m^2] for empty holds

Where the grillage system of the double bottom is subjected to single loads caused by containers, the stresses in the bottom structure are to be calculated for these single loads as well as for the bottom load p'_a as per 8.1.1. The permissible stresses specified there in are to be observed.

8.2.2 Permissible stresses

.1 Permissible equivalent stress σ_v

The equivalent stress is not to exceed the following value :

$\sigma_v \quad \leq \frac{230}{k}$ [N/mm^2]

$= \sqrt{\sigma_x^2 + \sigma^2 \sigma_x \cdot \sigma_y + 3\tau^2}$ [N/mm^2]

σ_x = stress [N/mm^2] in the ship's longitudinal direction, defined as :

= $\sigma_L + \sigma_\ell$ in general

= 0 for webs of transverse girders

σ_y = stress [N/mm^2] in the ship's transverse direction

= σ_q in general

= 0 ' for webs of longitudinal girders

Note:
Where grillage computer programs are used the following stress definitions apply:

$$\sigma_x = \sigma_L + \sigma_\ell + 0,3 \cdot \sigma_q$$

$$\sigma_y = \sigma_q + 0,3\,(\sigma_L + \sigma_\ell)$$

.2 Permissible max. values for σ_ℓ, σ_q and τ

The bending stresses σ_ℓ in longitudinal girder, the bending stress σ_q in transverse girder and the shear stress τ in both longitudinal and transverse girder are not to exceed the following values:

$$\sigma_\ell, \sigma_q \leq \frac{150}{k} \quad [\text{N/mm}^2]$$

$$\tau \leq \frac{100}{k} \quad [\text{N/mm}^2]$$

8.3 Buckling strength

The buckling strength of the double bottom structures is to be examined according to Section 3, F. For this purpose the design stresses according to Section 5, D.1 and the stresses due to local loads are to be considered.

9. Testing for tightness

Each compartment or tank of a double bottom is to be tested for tightness as specified in Section 12, A.4.5.

C. Bottom Structure in Machinery Spaces in Way of the Main Propulsion Plant

1. Single bottom

1.1 The scantlings of floors are to be determined according to A.1.2.1 for the greatest span measured in the engine room.

1.2 The web depth of the plate floors in way of the engine foundation should be as large as possible. The depth of plate floors connected to web frames shall be similar to the depth of the longitudinal foundation girders. In way of the crank case, the depth shall not be less than 0,5h.

The web thickness is not to be less than:

$$t = \frac{h}{100} + 4,0 \quad [\text{mm}]$$

h depth of the floor plate according to A.1.2.1.

1.3 The thickness of the longitudinal foundation girders is to be determined according to 3.2.1.

1.4 No centre girder need be fitted in way of longitudinal foundation girders. Intercostal docking profiles are to be fitted instead. The sectional area of the docking profiles is not to be less than:

$$A_W = 10 + 0{,}2 \cdot \mathbf{L} \quad [cm^2]$$

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.

2. Double bottom

2.1 General

2.1.1 Lightening holes 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 lightening holes are to be strengthened by means of face bars or the plate panels are to be stiffened.

2.1.2 Local strengthenings are to be provided beside the following minimum requirements, according to the construction and the local conditions.

2.2 Plate floors

Plate floors are to be fitted at every frame. The floor thickness according to B.6.2 is to be increased as follows:

$$3,6 + \frac{P}{500} \; [\%]$$

minimum 5%, maximum 15%

P = single engine output [kW]

The thickness of the plate floors below web frames is 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, A.6.2.1.

2.3 Side girders

2.3.1 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 3.2.1.

2.3.2 Side girders with the thickness of longitudinal girders according to 3.2 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 3000 kW.

2.3.3 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 shall be two to four frame spacings if practicable.

2.3.4 No centre girder is required in way of the engine seating (see 1.4).

2.4 Inner bottom

Between the foundation girders, the thickness of the inner bottom plating required according to B.4.1 is to be increased by 2,0 mm. The strengthened plate is to be extended beyond the engine seating by three to five frame spacings.

3. Engine seating

3.1 General

3.1.1 The following rules apply to low speed engines. Seating for medium and high speed engines as well as for turbines will be specially considered.

3.1.2 The rigidity of the engine seating and the surrounding bottom structure must 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 motorseatings 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 $\Delta_f = f_u + f_o$ shall not be greater than:*

Δ_f = $0,2 \cdot \ell_M$ *[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 shall not be greater than:.

$f_{u\ max}, f_{o\ max} = 0,7 \times \Delta f$ *[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 shall not exceed 50% of the above values.*

3.1.3 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, A.7.

3.1.4 The foundation bolts for fastening the engine at the seating shall 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

3.1.5 In the whole speed range of main propulsion installations for continuous service resonance vibrations with inadmissible vibration amplitudes must not 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. BKI may require a vibration analysis and, if deemed necessary, vibration measurement.

3.2 Longitudinal girders

3.2.1 The thickness of the longitudinal girders above the inner bottom is not to be less than:

$$t = \sqrt{\frac{P}{15}} + 6,0 \quad [mm] \quad \text{for} \quad P < 1500\ kW$$

$$t = \frac{P}{750} + 14 \quad [mm] \quad \text{for} \quad 1500 \le P < 7500\ kW$$

$$t = \frac{P}{1875} + 20 \quad [mm] \quad \text{for} \quad P \ge 7500\ kW$$

P see 2.2.

3.2.2 Where two longitudinal girders are fitted on either side of the engine, their thickness required according to 3.2.1 may be reduced by 4,0 mm.

3.2.3 The sizes of the top plate (width and thickness) shall 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 shall approximately be equal to the diameter of the fitted-in bolts. The cross sectional area of the top plate is not to be less than:

$$A_T = \frac{P}{15} + 30 \quad [cm^2] \qquad \text{for} \quad P \leq 750\ kW$$

$$= \frac{P}{75} + 70 \quad [cm^2] \qquad \text{for} \quad P > 750\ kW$$

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.

3.2.4 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, A.6.

3.2.5 Top plates are preferably 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).

D. Transverse Thrusters

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 BKI.

2. Structural principles

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:

$$t = \sqrt{\mathbf{L} \cdot k + 5,0} \quad [mm]$$

2.2 Thrust element housing structures as holding fixtures for propulsion units are to be effectively connected to the tunnel structure.

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.

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 Fig. 19.8). In certain circumstances HV- or DHV-welds with defined incomplete root penetration according to Section 19, B (see also Fig. 19.9) may be used for lightly loaded structural elements for which the risk of damage is low.

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:

$$R = 3 + 0{,}7 \cdot t_s \cdot \cos\left(A_W - 45°\right) \quad [mm]$$

t_s = thickness [mm] of the gear housing support bracket

A_W = angle [°] between tunnel and gear housing support bracket

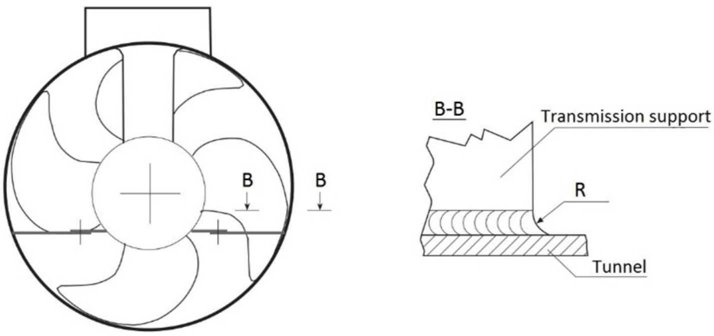


Fig. 8.2 Connection between gear housing support bracket and thruster tunnel

3. Special designs

If suction or draining ducts are arranged in the ship's bottom the design bottom slamming pressure pSL according to Section 4, B.4 is to be considered.

4. Thruster grids

For ships with ice class notation see also Section 15, B.10 and for ships with class notation I_W see also Section 37, B.8.

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:

$$f_{plate} > 1,2 \cdot f_{blade}$$

$$f_{stiff} < 0,8 \cdot f_{blade} \text{ or } f_{stiff} > 1,2 \cdot f_{blade}$$

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*

$= \frac{1}{60} \cdot n \cdot z$

n = *maximum revolution speed [1/min] of transverse thruster*

z = *number of propeller blades*

E. Docking Calculation

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 on board 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 shall 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.

1. 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 must be shown for all structural bottom elements which may be influenced by the keel block forces.

The nominal keel block load q_0 is calculated as follows, see also Fig.8.3.

$$q_0 = \frac{G_s \cdot C}{L_{KB}} \quad [\text{kN/m}]$$

where ship weight during docking including cargo, ballast and consumables [kN]

G_s = total ship weight [kN] during docking including cargo, ballast and consumables

L_{KB} = length of the keel block range [m]; i.e. in general the length of the horizontal flat keel

C = weighting factor

= 1,25 in general

= 2,0 in the following areas:

- within $0{,}075 \cdot L_{KB}$ from both ends of the length L_{KB}
- below the main engine
- in way of the transverse bulkheads along a distance of $2 \cdot e$
- in way of gas tank supports of gas tankers

e = distance of plate floors adjacent to the transverse bulkheads [m]; for e no value larger than 1,0 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 B.2, it may be assumed that the centre line girder carries 50% of the force and the two adjacent (see Section 6, B.5.2) keel block longitudinals 25% each.

2. 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.

3. Permissible stresses

The permissible equivalent stress σ_v is:

$$\sigma_v \leq \frac{R_{eH}}{1,05} \quad [N/mm^2]$$

4. Buckling strength

The bottom structures are to be examined according to Section 3, F. For this purpose a safety factor S = 1,05 has to be applied.

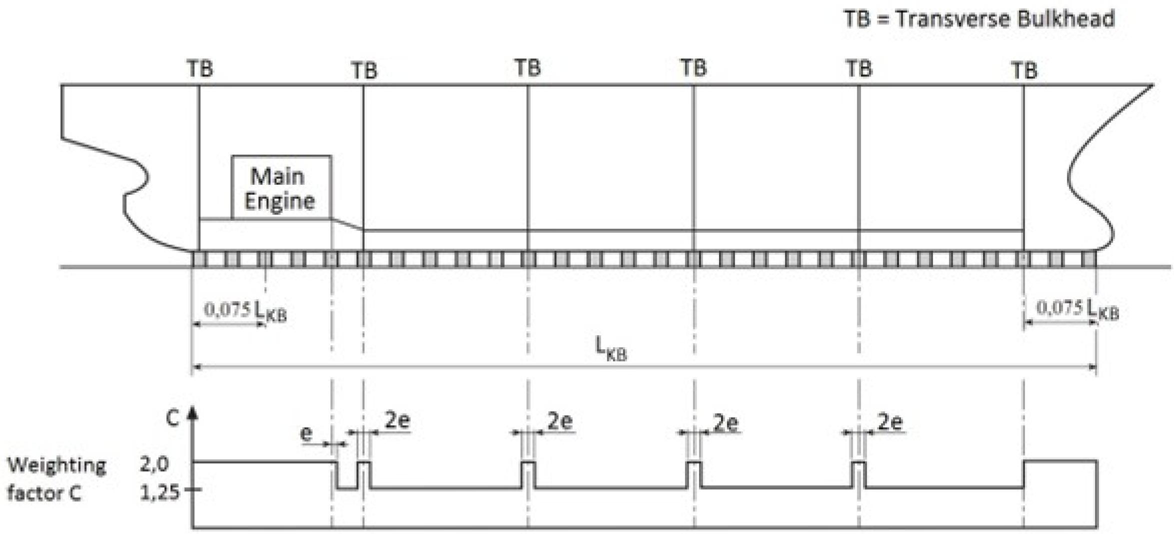


Fig. 8.3 Load on keel block

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Section 9 Framing System

A. Transverse Framing

1. General

1.1 Frame spacing

Forward of the collision bulkhead and aft of the after peak bulkhead, the frame spacing shall in general not exceed 600 mm.

1.2 Definitions

k	=	material factor according to Section 2, B
ℓ	=	unsupported span [m] according to Section 3, C, see also Fig. 9.1
ℓ_{min}	=	2,0 m for main frame.
ℓ_{Ku}, ℓ_{Ko}	=	length of lower/upper bracket connection of main frames within the length ℓ[m], see Fig. 9.1

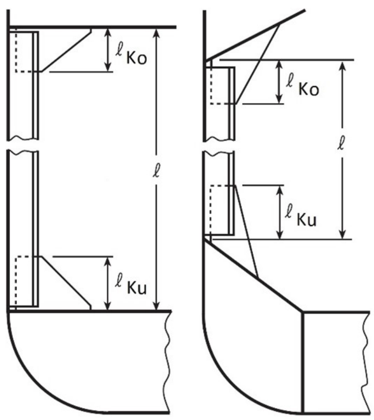

Fig. 9.1 Unsupported span of transverse frames

m_a	=	$0,204 \frac{a}{\ell}\left[4 - \left(\frac{a}{\ell}\right)^2\right]$, where, $\frac{a}{\ell} \leq 1$
e	=	spacing of web frames [m]
p	=	p_s or p_e as the case may be
p_s	=	load on ship's sides [kN/m^2] according to Section 4, B.2
p_e	=	load on bow structures [kN/m^2] according to Section 4, B.3 or stern structures according to Section 4, B.4 as the case may be

p_L = tween deck load [kN/m^2] according to Section 4, C.1

p_1, p_2 = pressure [kN/m^2] according to Section 4, D.1

H_u = depth up to the lowest deck [m]

c_r = factor for curved frames

= $1,0 - 2\,\dfrac{s}{\ell}$

c_{rmin} = 0,75

s = max. height of curve

2. Main frames

2.1 Scantlings

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:

$$W_R = n \cdot c \cdot \left[1 - m_a^2\right] \cdot c_r \cdot \mathbf{a} \cdot \ell^2 \cdot p \cdot k \qquad [\text{cm}^3]$$

upper end shear area :

$$A_{RO} = [1 - 0,817 \cdot m_a] \cdot 0,04 \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \qquad [\text{cm}^2]$$

lower end shear area :

$$A_{RU} = [1 - 0,817 \cdot m_a] \cdot 0,07 \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \qquad [\text{cm}^2]$$

n = $0,9 - 0,0035 \cdot \mathbf{L}$ for **L** < 100 m

= $0,55$ for **L** ≥ 100 m

c = $1,0 - \left(\dfrac{\ell_{Ku}}{\ell} + 0,4 \cdot \dfrac{\ell_{Ko}}{\ell}\right)$

c_{min} = 0,6

Within the lower bracket connection the section modulus is not to be less than the value obtained for c = 1,0

2.1.2 In ships with more than 3 decks the main frames are to extend at least to the deck above the lowest deck.

2.1.3 The scantlings of the main frames are not to be less than those of the 'tween deck frames above.

2.1.4 Where the scantlings of the main frames are determined by strength calculations, the following permissible stresses are to be observed:

- bending stress: $\sigma_b \leq \dfrac{150}{k}$ [N/mm^2]
- shear stress: $\tau \leq \dfrac{100}{k}$ [N/mm^2]
- equivalent stress: $\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} \leq \dfrac{180}{k}$ [N/mm^2]

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, J)

2.1.6 For main frames in holds of bulk carriers see also Section 23, B.5.2.

2.2 Frames in tanks

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 the greater of the following values :

$$W_1 = \left(1 - m_a^2\right) \cdot n \cdot c \cdot \mathbf{a} \cdot \ell^2 \cdot p_1 \cdot c_r \cdot k \qquad [cm^3]$$

$$W_2 = \left(1 - m_a^2\right) \cdot 0,44 \cdot c \cdot \mathbf{a} \cdot \ell^2 \cdot p_2 \cdot c_r \cdot k \qquad [cm^3]$$

$$A_1 = (1 - 0,817 \cdot m_a) \cdot 0,05 \cdot c \cdot \mathbf{a} \cdot \ell \cdot p_1 \cdot k \qquad [cm^2]$$

$$A_2 = (1 - 0,817 \cdot m_a) \cdot 0,04 \cdot c \cdot \mathbf{a} \cdot \ell \cdot p_2 \cdot k \qquad [cm^2]$$

n and c see 2.1.1.

2.3 End attachment

2.3.1 The lower bracket attachment to the bottom structure is to be determined according to Section 3, D.2 on the basis of the main frame section modulus.

2.3.2 The upper bracket attachment to the deck structure and/or to the tween deck frames is to be determined according to Section 3, D.2 on the basis of the section modulus of the deck beams or 'tween deck frames whichever is the greater.

2.3.3 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, D.2 on the basis of the section modulus of the frames.

3. Tween deck and superstructure frames

3.1 General

In ships having a speed exceeding $\mathbf{v}_0 = 1,6\sqrt{\mathbf{L}}$ [kn], the forecastle frames forward of 0,1**L** from **FP** 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 2.2 are to be observed.

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:

$$W_t = 0,55 \cdot m \cdot \mathbf{a} \cdot \ell^2 \cdot p \cdot c_r \cdot k \qquad [cm^3]$$

$$A_t = (1 - 0,817 \cdot m_a) \cdot 0,05 \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \quad [cm^2]$$

p is not to be taken less than:

$$p_{min} = 0,4 \cdot p_L \cdot \left(\frac{B}{\ell}\right)^2 \qquad [kN/m^2]$$

b = unsupported span of the deck beam below the respective 'tween deck frame [m]

For 'tween deck frames connected at their lower ends to the deck transverses, p_{min}, is to be multiplied by the factor :

$$f_1 = 0,75 + 0,2 \cdot \frac{e}{\mathbf{a}} \geq 1,0$$

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. 9.2.

For tween deck and superstructure frames 2.3.3 is to be observed, where applicable.

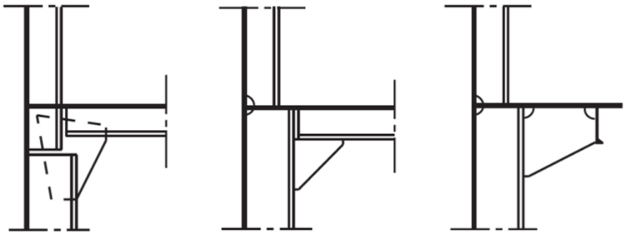

Fig. 9.2 Typical ends attachments of tween deck and superstructure frames

4. Peak frames and frames in way of the stern

4.1 Peak frames

4.1.1 Section modulus W_P and shear area A_P of the peak frames are not to be less than:

$$W_P = 0,55 \cdot m \cdot \mathbf{a} \cdot \ell^2 \cdot p \cdot c_r \cdot k \quad [cm^3]$$

$$A_P = (1 - 0,817 \cdot m_a) \cdot 0,05 \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \quad [cm^2]$$

4.1.2 The peak frames are to be connected to the stringer plates to ensure sufficient transmission of shear forces.

4.1.3 Where peaks are to be used as tanks, the section modulus of the peak frames is not to be less than required by Section 12, B.3.1 for W_2.

4.2 Frames in way of the stern

4.2.1 The frames in way of the cruiser stern arranged at changing angles to the transverse direction are to have a spacing not exceeding 600 mm and are to extend up to the deck above peak tank top maintaining the scantlings of the peak frames.

4.2.2 An additional stringer may be required in the after ship outside the after peak where frames are inclined considerably and not fitted vertically to the shell.

5. Strengthenings in fore- and aft body

5.1 General

In the fore body, i.e. from the forward end to 0,15**L** behind **FP**, flanged brackets have to be used in principle.

As far as practicable and possible, tiers of beams or web frames and stringers are to be fitted in the fore and after peak.

5.2 Tiers of beams

5.2.1 Forward of the collision bulkhead, tiers of beams (beams at every other frame) generally spaced not 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 scantlings of the stringer plates are to be determined from the following formulae:

— width $b = 75 \cdot \sqrt{L}$ [mm]

— thickness $t = 6,0 + \frac{L}{40}$ [mm]

5.2.2 The cross sectional area of each beam is to be determined according to Section 10, C.2 for a load

$$P = A \cdot p \quad [kN]$$

A = load area of a beam [m^2]

p = p_s or p_e, whichever is applicable.

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 5.2.1, as far as practicable with regard to the ship's shape.

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.

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.

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 5.2.2 are, however, to be complied with.

5.3 Web frames and stringers

5.3.1 Where web frames and supporting stringers are fitted instead of tiers of beams, their scantlings are to be determined as follows:

Section modulus:

$$W = 0,55 \cdot e \cdot \ell^2 \cdot p \cdot n_c \cdot k \quad [cm^3]$$

Web sectional area at the supports:

$$A_W = 0,05 \cdot e \cdot \ell_1 \cdot p \cdot k \quad [cm^2]$$

ℓ = unsupported span [m], without consideration of cross ties, if any

ℓ_1 = similar to ℓ, however, considering cross ties, if any

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
$\geq$ 3	0,2

5.3.2 Vertical transverses are to be interconnected by cross ties the cross sectional area of which is to be determined according to 5.2.2.

5.3.3 Where web frames and stringers in the fore body are dimensioned by strength calculations the stresses shall not exceed the permissible stresses in 2.1.4.

Note:

Where a large and long bulbous bow is arranged a dynamic pressure psdyn is to be applied unilaterally. The unilateral pressure can be calculated approximately as follows :

$$p_{sdyn} = p_o \cdot c_F \cdot \left(1 + \frac{z}{\mathbf{T}}\right) \qquad [\text{kN/m}^2]$$

p_o, c_F, zand f according to Section 4, with f = 0,75.

For the effective area of p_{sdyn}, the projected area of the z-x-plane from forward to the collision bulkhead may be assumed.

5.4 Web frames and stringers in 'tween decks and superstructure decks

Where the speed of the ship exceeds $\mathbf{v}_0 = 1,6\sqrt{\mathbf{L}}$ [kn] or in ships with a considerable bow flare respectively, stringers and transverses according to 5.3 are to be fitted within 0,1**L** from forward perpendicular in 'tween deck spaces and superstructures.

The spacing of the stringers and transverses shall be less than 2,8 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.

5.5 Tripping brackets

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 m, measured vertically, according to Fig. 9.3 are to be fitted. The thickness of the brackets is to be determined according to 5.2.1. Where proof of safety against tripping is provided tripping brackets may partly or completely be dispensed with.

5.5.2 In the same range. In 'tween deck spaces and superstructures of 3,0 m and more in height, tripping brackets according to 5.5.1 are to be fitted.

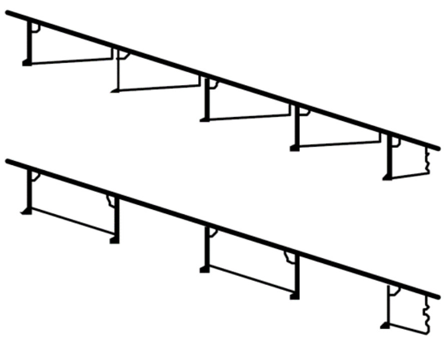

Fig. 9.3 Tripping brackets

5.5.3 Where peaks or other spaces forward of the collision bulkhead are intended to be used as tanks. tripping brackets according to 5.5.1 are to be fitted between tiers of beams or stringers.

5.5.4 For ice strengthening, see Section 15.

6. Web frames in machinery spaces

6.1 Arrangement

6.1.1 In the engine and boiler 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.

6.1.2 For combustion engines, web frames shall generally 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.

6.1.3 Where combustion engines are fitted aft, stringers spaced 2,6 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 shall 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 4,0 m.

6.1.4 For the bottom structure in machinery spaces, see Section 8, C.

6.2 Scantlings

6.2.1 The section modulus of web frames is not to be less than:

$$W = 0,8 \cdot e \cdot \ell^2 \cdot p_s \cdot k \qquad [cm^3]$$

The moment of inertia of web frames is not to be less than:

$$I = \mathbf{H} \cdot (4,5\,\mathbf{H} - 3,5) \cdot c_i \cdot 10^2 \qquad [cm^4] \qquad \text{for } 3,0 \text{ m} \le \mathbf{H} \le 10 \text{ m}$$

$$I = \mathbf{H} \cdot (7,25\,\mathbf{H} - 31) \cdot c_i \cdot 10^2 \qquad [cm^4] \qquad \text{for } \mathbf{H} > 10 \text{ m}$$

$$c_i = 1 + (H_u - 4) \cdot 0,07$$

The scantlings of the webs are to be calculated as follows :

depth $h = 50 \cdot \mathbf{H}$ [mm]

$h_{min} = 250$ mm

thickness $t = \dfrac{h}{32 + 0,03 \cdot h}$ [mm]

$t_{min} = 8,0$ mm

6.2.2 Ships with a depth of less than 3,0 m are to have web frames with web scantlings not less than 250 x 8 mm and a minimum face sectional area of 12 cm^2.

6.2.3 In very wide engine rooms it is recommended to provide side longitudinal bulkheads.

B. Bottom, Side and Deck Longitudinals, Side Transverses

1. General

1.1 Longitudinals shall preferably be continuous through floor plates and transverses. Attachments of their webs to the webs of floor plates and transverses are to be such that the support forces will be transmitted without exceeding a shear stress of 100/k [N/mm^2].

For longitudinal frames and beams sufficient fatigue strength according to Section 20 is to be demonstrated.

Ahead of 0,1**L** from **FP** webs of longitudinals are to be connected effectively at both ends. If the flare angle is more than 40° additional heel stiffeners or brackets are to be arranged.

1.2 Where longitudinals abut at transverse bulkheads or webs, brackets are to be fitted. These longitudinals are to be attached to the transverse webs or bulkheads 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.

1.3 Outside the upper and the lower hull flange, the cross sectional areas stipulated in 1.2 may be reduced by 20%.

1.4 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. (For longitudinal framing systems in double bottoms, see Section 8, B.7)

1.5 For buckling strength of longitudinals see Section 3, F.3.2.3.

2. Definitions

k = material factor according to Section 2, B

ℓ = unsupported span [m], see also Fig. 9.4

p = load [kN/m^2]

= p_B, p_{B1} according to Section 4, B.3 for bottom longitudinals

= p_s, p_{s1} or p_e according to Section 4, B.2.1 for side longitudinals

= p_1 according to Section 4, D.1.1 for longitudinals at ship's sides, at longitudinal bulkheads and inner bottom in way of tanks.

For bottom longitudinals in way of tanks p due to tank pressure need not to be taken larger than

$$p_1 - (10 \cdot \mathbf{T}_{min} - p_0 \cdot c_F) \qquad [\text{kN/m}^2]$$

For side longitudinals below $\mathbf{T}_{min}$ p need not to be taken larger than:

$$p_1 - 10 \cdot (\mathrm{T}_{min} - z) + p_0 \cdot c_F \left(1 + \frac{z}{\mathbf{T}_{min}}\right) \qquad [\text{kN/m}^2]$$

With p ≤ p1

= p_d according to Section 4, D.2 for longitudinals at ship's sides, at deck and at longitudinal bulkheads in tanks intended to be partially filled

= p_D according to Section 4, B.1 for deck longitudinals of the strength deck

= p_{DA} according to Section 4, B.5 for exposed decks which are not to be treated as strength deck

= p_i according to Section 4, C.2 for inner bottom longitudinals, however, not less than the load corresponding to the distance between inner bottom and deepest load waterline

= p_L according to Section 4, C.1 for longitudinals of cargo decks and for inner bottom longitudinals

p_0 = according to Section 4, A.2.2

c_F = according to Table 4.1

$\mathbf{T}_{min}$ = smallest ballast draught

σ_L = axial stress in the profile considered [N/mm^2] according to Section 5, D.1

z = distance of structure [m] above base line

x_ℓ = distance [mm] from transverse structure at I and J respectively (see Fig.9.4)

m = $\left(m_k^2 - m_a^2\right)$; $\qquad m \geq \dfrac{m_k^2}{2}$

m_a = see A.1.2

m_K = $1 - \dfrac{\ell_{KI} + \ell_{KJ}}{10^3 \cdot \ell}$

ℓ_{KI}, ℓ_{KJ} = effective supporting length [mm] due to heel stiffeners and brackets at frame I and J (see Fig. 9.4)

ℓ_K = $h_s + 0,3 \cdot h_b + \dfrac{1}{c_1} \le (\ell_b + h_s)$

c_1 = $\dfrac{1}{\ell_b - 0,3 \cdot h_b} + \dfrac{c_2\,(\ell_b - 0,3 \cdot h_b)}{h_e^2} \quad \left[\dfrac{1}{mm}\right]$ For $\ell_b \le 0,3 \cdot h_b$, $\dfrac{1}{c_1}$ = 0 is to be taken

h_s, ℓ_b, h_b, h_e see Fig. 9.4

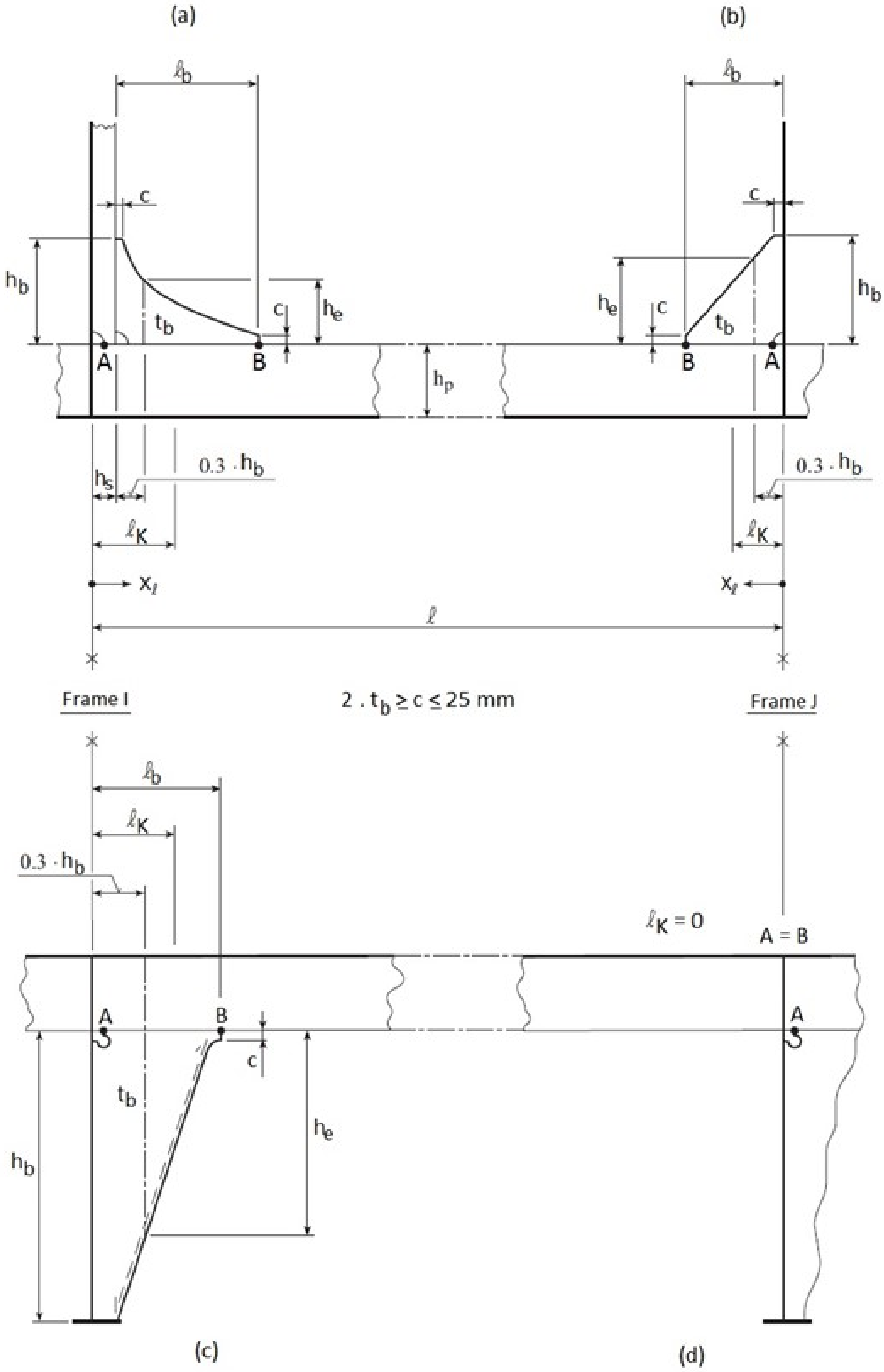

Fig. 9.4 End attachment

h_s = height of the heel stiffener [mm]

ℓ_b, h_b = dimensions of the brackets [mm]

c_2 = 3,0 in general

h_e = height of bracket [mm] in the distance

x_ℓ = $h_s + 0{,}3 \cdot h_b$ of frame I and J respectively

If no heel stiffeners or brackets are arranged the respective values are to be taken as $\left(h_s,\ h_b,\ \frac{1}{c_1}\right) = 0$ (see Fig. 9.4 (d)).

3. Scantlings of longitudinals and longitudinal beams

3.1 The section modulus W_ℓ and shear area A_ℓ of longitudinals and longitudinal beams of the strength deck is not to be less than :

$$W_\ell = \frac{83,3}{\sigma_{pr}} \cdot m \cdot \mathbf{a} \cdot \ell^2 \cdot p \qquad [cm^3]$$

$$A_\ell = (1 - 0,817 \cdot m_a) \cdot 0,05 \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \qquad [cm^2]$$

The permissible stress σ_{pr} is to be determined according to the following formulae:

$$\sigma_{pr} = \sigma_{perm} - |\sigma_L| \qquad [N/mm^2]$$

$$\sigma_{pr} \le \frac{150}{k} \qquad [N/mm^2]$$

$$\sigma_{perm} = \left(0,8 + \frac{\mathbf{L}}{450}\right) \cdot \frac{230}{k} \qquad [N/mm^2]$$

$$\sigma_{permmax} \le \frac{230}{k} \qquad [N/mm^2]$$

For side longitudinals W_ℓ and A_ℓ shall not be less than:

$$W_{\ell min} = \frac{83}{\sigma_{permax} - |\sigma_L|} \cdot m \cdot \mathbf{a} \cdot \ell^2 \cdot p_{s1} \qquad [cm^3]$$

$$A_{\ell_{min}} = (1-0,817 \cdot m_a) \cdot 0,037 \cdot \mathbf{a} \cdot \ell \cdot p_{s1} \cdot k \qquad [cm^2]$$

p_{s1} according to Section 4, B.2.1.1 and 2.1.2 respectively.

For fatigue strength calculations according to 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 from local stiffener bending due to lateral loads p can be calculated as follows:

for $0 \le x_\ell \le \ell_k$

$$\sigma_A = \frac{83 \cdot m \cdot \mathbf{a} \cdot \ell^2 \cdot p}{W_a} + \sigma_h \qquad [N/mm^2]$$

for $x_\ell = h_s + \ell_b$

$$\sigma_B = \sigma_A \cdot m_1 \qquad [N/mm^2]$$

W_a = section modulus of the profile [cm³] including effective plate width according to Section 3, F.5.2.3.5

σ_h = according to Section 3, L.1

m_1 = $1{,}0 - 4 \cdot c_3 \cdot [1 - 0{,}75 \cdot c_3]$

for position B at I

$$c_{3I} = \frac{h_{sI} + \ell_{bI} - \ell_{KI}}{10^3 \cdot \ell \cdot m_k}$$

for position B at J

$$c_{3J} = \frac{h_{sJ} + \ell_{bJ} - \ell_{KJ}}{10^3 \cdot \ell \cdot m_k}$$

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

In way of curved shell plates (e.g. in the bilge area) section modulus $W_{\ell min}$, shear area $A_{\ell min}$ and stress σ_B can be reduced by the factor C_R.

$$C_R = \frac{1,0}{1,0 + \frac{a \cdot \ell^4 \cdot t}{0,006 \cdot I_a \cdot R^2}}$$

t = thickness of shell plating [mm]

I_a = moment of inertia of the longitudinal frame [cm^4], including effective width

R = bending radius of the plate [m]

3.2 In tanks, the section modulus is not to be less than W_2 according to Section 12, B.3.1.1.

3.3 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 3.1.

3.4 If non symmentrical section are used additional stresses according to Section 3, L shall be considered.

3.5 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.

$$\sigma_{DF} = \pm 0,1 \cdot \frac{h_w}{\ell - \Sigma \ell_b} \left[\frac{\ell_R}{DF} C_p \ (1 - c_p)\right]^2 \quad [N/mm^2]$$

h_w	=	web height of profile i	[mm]	(see Fig. 3.3)
$\sum \ell_b$	=	$(hs_I + \ell_{bI} + h_{sJ} + \ell_{bJ}) \cdot 10^3$	[m]	(see Fig. 9.4)
ℓ_R	=	unsupported web frame length	[m]	(see Fig. 9.5)
DF	=	height of web frame	[m]	(see Fig. 9.5)

C_p = weighting factor regarding location of the profile:

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

z_{Ro} = z-coordinate of web frame outset above basis [m] (see Fig. 9.5), $z_{Ro} <$ **T**

C_T = correction regarding location of the profile i to the waterline

$$= 1,1 - \frac{z}{\mathbf{T}} \qquad 0 \le C_T \le 0,1$$

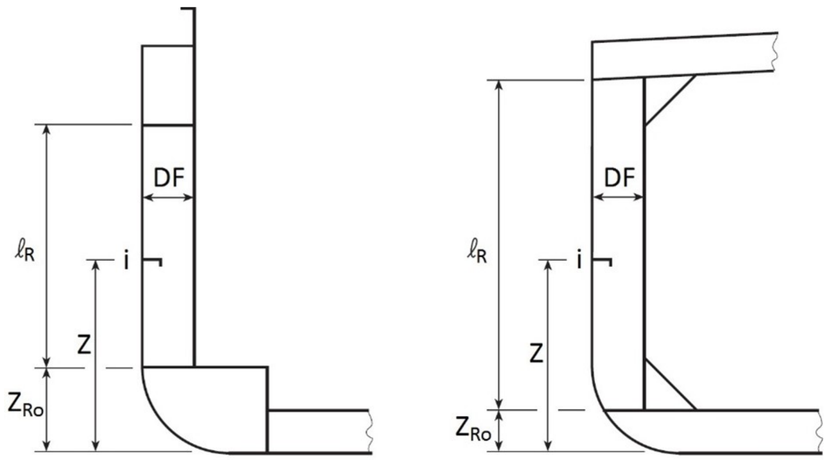

Fig. 9.5 Definitions

3.6 Where struts are fitted between bottom and inner bottom longitudinals, see Section 8, B.7.2.

3.7 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.5.

3.8 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 $\mathbf{T}_{min}-c_0$ shall not be larger than 2,6 m; c_0 see Section 4, A.2. Otherwise tripping brackets according to A.5.5 are to be arranged. c_0 see Section 4, A.2.

3.9 The side shell longitudinals within the range from 0,5 below the minimum draught up to 2,0 m above the maximum draught and a waterline breadth exceeding 0,9**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 :

P_f	=	$0{,}08 \cdot D$	[kN]	$0 < D \le 2\,100$	[t]
P_f	=	170	[kN]	$2\,100 < D \le 17\,000$	[t]
P_f	=	$D/100$	[kN]	$D > 17\,000$	[t]

D = displacement of the ship [t]

D_{max} = 100000 t

3.10 In order to withstand the load P_f the section modulus W_ℓ of side shell longitudinals are not to be less than :

$$W_\ell = \frac{k \cdot M_f}{235} \cdot 10^3 \quad [cm^3]$$

k = Material factor

M_f = bending moment

$$= \frac{P_f}{16}(\ell - 0{,}5) \quad [kNm]$$

ℓ = unsupported length [m]

4. Connections between transverse support member and intersecting longitudinal

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 4.7. At intersections of longitudinals with transverse tank boundaries the local bending of tank plating is to be prevented by effective stiffening.

4.2 The total force P transmitted from the longitudinal to the transverse support member is given by:

$$P = (1 - 0,817 \cdot m_a) \cdot \mathbf{a} \cdot \ell \cdot p \qquad [kN]$$

P = design load [kN/m^2] for the longitudinal according to 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.

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.

$$S_h = \frac{E \cdot \ell_h \cdot t_h \cdot \left(1 + \frac{450}{\ell_h}\right)}{380} \quad [N/mm] \quad \text{for heel stiffener}$$

$$S_S = \frac{G \cdot h_s \cdot t_s}{b_s} \quad [N/mm] \quad \text{for web}$$

$$S_c = \frac{G \cdot h_c \cdot t_c}{b_c} \quad [N/mm] \quad \text{for lug/collar plate}$$

G = shear modulus [N/mm^2]

ℓ_{hc} = connection length [mm] of heel stiffener

ℓ_h = length [mm] of the minimum heel stiffener cross-sectional area according to Fig. 9.6

t_h = thickness [mm] of the heel stiffener according to Fig. 9.6

b_s, h_s, t_s = dimensions [mm] of the connection of the stiffener to the web according to Fig. 9.6

b_c, h_c, t_c = dimensions [mm] of the connection of the stiffener to the lug plate according to Fig. 9.6

ℓ_k = effective supporting length [mm] due to heel stiffeners and brackets, see 2.

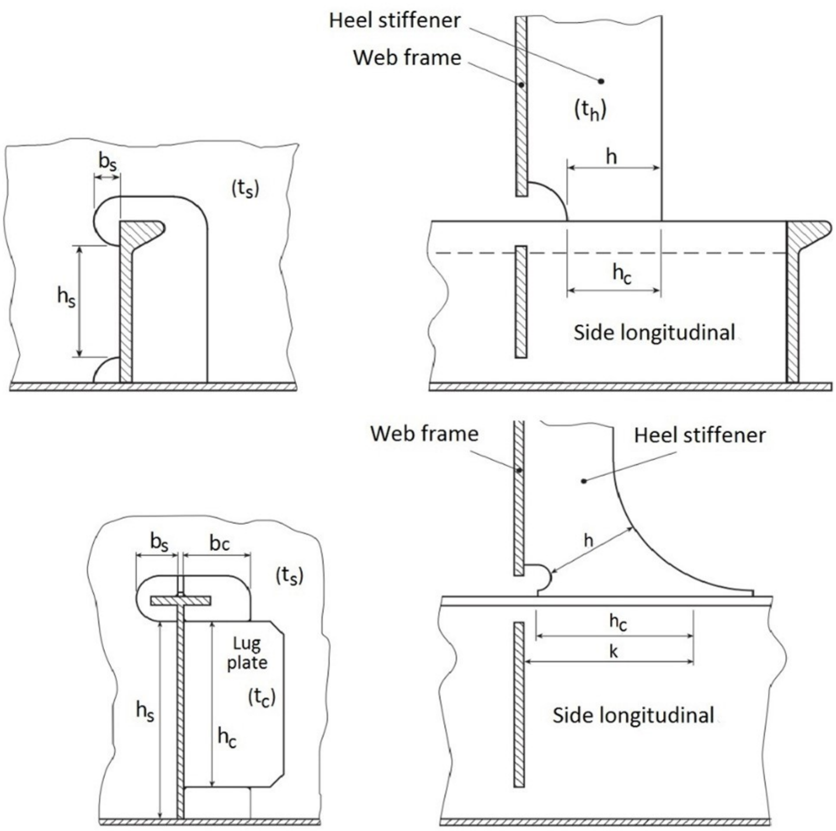

Fig. 9.6 Typical intersections of longitudinals and transverse support members

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:

$$P_h = \varepsilon_h \cdot P \qquad [kN]$$

ε_h = factor, defined as :

$$= \frac{S_h}{S_h + S_s + S_c} \; [kN]$$

P = force according to 4.2

4.5 The forces P_s and P_c transmitted through the shear connections to the transverse support member are to be taken as follows:

$$P_s = \varepsilon_s \cdot P \qquad [kN]$$

with

$$\varepsilon_s = \frac{S_h}{S_h + S_s + S_c}$$

$$P_c = \varepsilon_c \cdot P$$

with

$$\varepsilon_c = \frac{S_c}{S_h + S_s + S_c}$$

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:

$$\sigma_{axial} = \frac{P_h}{\ell_h \cdot t_h} \cdot 10^3 \qquad [N/mm^2] \qquad \text{with} \quad \sigma_{axial} \le \frac{150}{k} \; [N/mm^2]$$

- normal stress in the fillet weld connection of heel stiffener:

$$\sigma_{weld} = \frac{P_h}{2 \cdot a \cdot (\ell_{hc} + t_h + a)} \cdot 10^3 \quad [N/mm^2] \qquad \text{with} \quad \sigma_{weld} \le \sigma_{vp} \; [N/mm^2]$$

a = throat thickness of fillet weld according to Section 19, B.3.3

σ_{vp} = permissible equivalent stress in the fillet weld according to Table 19.3

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:

$$\tau_i = \frac{P_i}{h_i \cdot t_i} \cdot 10^3 \qquad [N/mm^2] \qquad \text{with} \quad \tau_i \le \frac{100}{k} \qquad [N/mm^2]$$

- shear stress in the shear connections in way of fillet welds:

$$\tau_{weld,i} = \frac{P_i}{2 \cdot a \cdot h_i} \cdot 10^3 \quad [N/mm^2] \qquad \text{with} \quad \tau_{weld,i} \le \tau_p \qquad [N/mm^2]$$

τ_p = permissible shear stress in the fillet weld according to Table 19.3

i = index, defined as:

= s for the shear connection of longitudinal and transverse support member

= c for the shear connection of longitudinal and lug plate

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::

$$\sigma_c = \frac{3 \cdot P_c \cdot b_c}{h_c^2 \cdot t_c} \cdot 10^3 \quad [N/mm^2] \quad \text{with} \quad \sigma_c \leq \frac{150}{k} \quad [N/mm^2]$$

- bending stress in the fillet weld connection of the lug plate:

$$\sigma_{weld,c} = \frac{1,5 \cdot P_c \cdot b_c}{h_c^2 \cdot a} \cdot 10^3 \quad [N/mm^2] \quad \text{with} \quad \sigma_{weld,c} \leq \sigma_{vp} \quad [N/mm^2]$$

4.9 For typical heel stiffeners (Fig. 9.6, upper part) at outer shell the fatigue strength is to be approximated by a simplified approach.

4.9.1 The fatigue relevant pressure range Δ_p 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 Table 20.1.

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 Table 20.2 for welded joints

C = factor, defined as:

= 1,0 if a lug/collar plate is fitted

= 2,0 if no lug/collar plate is fitted

k_{sp} = factor for additional stresses in non-symmetrical longitudinal sections according to Table 3.7

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.

5. Side transverses

5.1 The section modulus W and shear area AW of side transverses supporting side longitudinals is not to be less than:

$$W = 0,55 \cdot e \cdot \ell^2 \cdot p \cdot k \quad [cm^3]$$

$$A_W = 0,05 \cdot e \cdot \ell \cdot p \cdot k \quad [cm^2]$$

5.2 Where the side transverses are designed on the basis of strength calculations the following stresses are not to be exceeded:

$$\sigma_b \leq \frac{150}{k} \quad [N/mm^2]$$

$$\tau \leq \frac{100}{k} \quad [N/mm^2]$$

$$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} \leq \frac{180}{k} \quad [N/mm^2]$$

Side transverses and their supports (e. g. decks) are to be checked according to Section 3, F with regard to their buckling strength.

Note:

The web thickness can be dimensioned depending on the size of the unstiffened web field as follows :

$$t = \frac{f \cdot b}{1 + \frac{b^2}{a^2}} \sqrt{\frac{200}{k}\left(2 + \frac{b^2}{a^2}\right)}$$

a, b	=	*length of side*	*of the unstiffened web plate field, a ≥ b*
f	=	*0,75*	*in general*
	=	*0,9*	*in the aft body with extreme flare and in the fore body with flare angles a are less or equal 40°*
	=	*1,0*	*the fore body where flare angles a are greater than 40°*

In the fore body where flare angles $\alpha$are larger than 40° the web in way of the deck beam has to be stiffened.

5.3 In tanks the web thickness shall not be less than the minimum thickness according to Section 12, A.7, 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.3.

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**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 3.9.

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	=	see 3.9
P_{fu}	=	$t_s^2 \cdot \sqrt{R_{eH}} \cdot [C + 0,27]$ [kN]
C	=	0,17 in general
	=	0,1 for web frame cutouts with free edges in way of continuous longitudinal
t_s	=	web thickness of the side transverses [mm]
R_{eH}	=	minimum nominal upper yield strength [N/mm^2] of the steel used for the webs of side transverses

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 A.5.

Section 10 Deck Beams and Supporting Deck Structures

A. General

1. Definitions

k = material factor according to Section 2, B

ℓ = unsupported span [m] according to Section 3, C

e = width of deck supported, measured from centre to centre of the adjacent unsupported fields [m]

p = deck load p_D, p_{DA} or p_L [kN/m^2], according to Section 4, B and C

c = 0,55

= 0,75 for beams, girders and transverses which are simply supported on one or both ends

P_s = pillar load

= $P \cdot A + P_i$ [kN]

A = load area for one pillar [m^2]

P_i = load from pillars located above the pillar considered [kN]

λ_s = degree of slenderness of the pillar

$$= \frac{\ell_s}{i_s . \pi}\sqrt{\frac{R_{eH}}{E}} \geq 0,2$$

ℓ_s = length of the pillar [cm]

R_{eH} = nominal yield point [N/mm^2]

E = Young's modulus [N/mm^2]

= 2,06 x 10^5 [N/mm^2]

i_s = radius of gyration of the pillar

$$= \sqrt{\frac{I_s}{A_s}} \quad \text{[cm]}$$

= $0,25 \cdot d_s$ [cm] for solid pillars of circular cross section

= $0,25 \cdot \sqrt{d_a^2 + d_i^2}$ [cm] for tubular pillars

I_s = moment of inertia of the pillar [cm^4]

A_s = sectional area of the pillar [cm^2]

d_s = pillar diameter [cm]

d_a = outside diameter of pillar [cm]

d_i = inside diameter of pillar [cm]

m_a = factor according to Section 9, A.1.2

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:

$$\sigma_b = \frac{150}{k} \quad [N/mm^2]$$

$$\tau = \frac{100}{k} \quad [N/mm^2]$$

$$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} \leq \frac{180}{k} \quad [N/mm^2]$$

3. Buckling strength

The buckling strength of the deck structures is to be examined according to Section 3, F. For this purpose the design stresses according to Section 5, D.1 and the stresses due to local loads are to be considered.

In the fore and aft ship region this includes also pressures due to slamming according to Section 4, B.2.2 and 2.3.

B. Deck Beams and Girders

1. Transverse deck beams and deck longitudinals

The section modulus W_d and shear area A_d of transverse deck beams and of deck longitudinals between 0,25**H** and 0,75**H** above base line is to be determined by the following formula:

$$W_d = c \cdot m \cdot \mathbf{a} \cdot p \cdot \ell^2 \cdot k \quad [cm^3]$$

$$A_d = (1 - 0,817 \cdot m_a) \cdot 0,05 \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \quad [cm^2]$$

m see Section 9, B.2

2. Deck longitudinals in way of the upper and lower hull flange

The section modulus of deck longitudinals of decks located below 0,25**H** and/or above 0,75**H** from baseline is to be calculated according to Section 9, B.

3. Attachment

3.1 Transverse deck beams are to be connected to the frames by brackets according to Section 3, D.2.

3.2 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.

3.3 Deck beams may be attached to hatchway coamings and girders by double fillet welds where there is no constraint. The length of weld is not to be less than 0,6 x depth of the section.

3.4 Where deck beams are to be attached to hatchway coamings and girders of considerable rigidity (e.g. box girders), brackets are to be provided.

3.5 Within 0,6**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.

3.6 Regarding the connection of deck longitudinals to transverses and bulkheads, Section 9, B is to be observed.

4. Girders and transverses

4.1 The section modulus W, the shear area Aw and the moment of inertia I are not to be less than:

$$W = c \cdot e \cdot \ell^2 \cdot p \cdot k \qquad [cm^3]$$

$$A_W = 0,05 \cdot p \cdot e \cdot \ell \cdot k \qquad [cm^2]$$

$$I = c_I \cdot W \cdot \ell \qquad [cm^4]$$

c_I = factor to take boundary conditions into account, defined as:
= 4,0 if boundary end are simply supported
= 2,0 if one end is constrained
= 1,5 if both end are constrained

4.2 The depth of girders is not to be less than 1/25 of the unsupported span. The web depth of girders scalloped for continuous deck beams is to be at least 1,5 times the depth of the deck beams.

Scantlings of girders of tank decks are to be determined according to Section 12, B.3.

4.3 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.

4.4 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.

4.5 Face plates are to be stiffened by tripping brackets according to Section 3, H.3.5. At girders of symmetrical section, they are to be arranged alternately on both sides of the web.

4.6 For girders in line of the deckhouse sides under the strength deck, see Section 16, A.3.2.

4.7 For girders forming part of the longitudinal hull structure and for hatchway girders see E.

5. Supporting structure of windlasses and chain stoppers

5.1 For the supporting structure under windlasses and chain stoppers, the following permissible stresses are to be observed:

$$\sigma_b \leq \frac{200}{k} \qquad [N/mm^2]$$

$$\tau \leq \frac{120}{k} \qquad [N/mm^2]$$

$$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} \leq \frac{220}{k} \qquad [N/mm^2]$$

5.2 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

See also Rules for Machinery Installations (Pt.1, Vol.III) Sec.14.D and Rules for Materials (Pt.1, Vol.V) Sec.13 and Table 13.7.

C. Pillars

1. General

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 1,0 cm^2 cross-sectional area is available for 10 kN of load.

Where pillars are likely to be subjected to tensile loads doubling plates replaced by insert plate, the head and heel of pillars shall be efficiently secured to withstand the tensile loads, e.g. by fitting end brackets.

In general, the net thickness of doubling plates shall not be less than 1,5 times the net thickness of the pillar. Pillars shall be attached at their heads and heels by continuous welding.

1.2 Pillars in tanks are to be checked for tension. Tubular pillars are not permitted in tanks for flammable liquids.

1.3 For structural elements of the pillars' transverse section, sufficient buckling strength according to Section 3, F 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:

$$t_W = 4{,}5 + 0{,}015\, d_a \quad [mm] \quad \text{for} \quad d_a \le 300\ mm$$

$$t_W = 0{,}03\, d_a \quad [mm] \quad \text{for} \quad d_a > 300\ mm$$

d_a = outside diameter of tubular pillar [mm]

1.4 This section includes requirements for pillars loaded by normal forces due to local loads. Pillars also loaded by bending moments due to local load are to be specially considered.

For pillars supporting deck of effective superstructures normal forces and bending moment due to global hull bending are to be specially considered.

1.5 Pillars shall be provided in line with double bottom girders and/or floors or as close thereto as practicable, and the structure above and below the pillars shall be of sufficient strength to provide effective distribution of the load. Where pillars connected to the inner bottom are not located in way of the intersection of floors and girders, partial floors or girders or equivalent structures shall be fitted as necessary to support the pillars.

2. Scantlings

The sectional area of pillars is not to be less than:

$$A_{s,req} = 10 \cdot \frac{P_s}{\sigma_p} \quad [cm^2]$$

σ_p = permissible compressive stress [N/mm^2]

$= \frac{\kappa}{S} \cdot R_{eH}$

κ = reduction factor

$$= \frac{1}{\Phi + \sqrt{\Phi^2 - \lambda_s^2}}$$

Φ = $0,5 \cdot \left[1 + n_p \cdot (\lambda_s - 0,2) + \lambda_s^2\right]$

n_p = 0,34 for tubular and rectangular pillars

= 0,49 for open sections

S = safety factor

= 2,0 in general

= 1,66 in accommodation area

D. Cantilevers

1. General

1.1 In order to withstand the bending moment arising from the load P, 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.

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.

1.3 Face plates are to be secured against tilting by tripping brackets fitted to the webs at suitable distances (see also Section 3, H.3.5).

1.4 Particulars of calculation, together with drawings of the cantilever construction are to be submitted for approval.

2. Permissible stresses

2.1 When determining the cantilever scantlings, the following permissible stresses are to be observed:

— Where single cantilevers are fitted at greater distances:

$\sigma_b \leq \frac{125}{k}$ [N/mm^2] for bending stress

$\tau \leq \frac{80}{k}$ [N/mm^2] for shear stress

— Where several cantilevers are fitted at smaller distances (e.g. at every frame):

$\sigma_b \leq \frac{150}{k}$ [N/mm^2] for bending stress

$\tau \leq \frac{100}{k}$ [N/mm^2] for shear stress

$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} \leq \frac{180}{k}$ [N/mm^2] for equivalent stress

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

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 C.

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 : $\sigma_\ell \leq \dfrac{150}{k}$ [N/mm^2] deck level: $\sigma_\ell \leq \dfrac{70}{k}$ [N/mm^2]	$\sigma_\ell \leq \dfrac{150}{k}$ [N/mm^2]

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:

$$\sigma_L + \sigma_\ell \leq \frac{200}{k} \quad [\text{N/mm}^2]$$

σ_ℓ = local bending stress in the ship's longitudinal direction

σ_L = design longitudinal hull girder bending stress according to Section 5, D.1

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:

$$\sigma_\ell \leq \frac{150}{k} \quad [\text{N/mm}^2] \qquad \text{for stresses in ship's longitudinal direction}$$

$$\sigma_t \leq \frac{150}{k} \quad [\text{N/mm}^2] \qquad \text{for stresses in ship's transvers direction}$$

$$\tau \leq \frac{90}{k} \quad [\text{N/mm}^2] \qquad \text{for shear stresses}$$

$$\sigma_v = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \cdot \sigma_y + 3 \cdot \tau^3} \leq \sigma_{v,perm} \qquad \text{for equivalent stresses}$$

$\sigma_{v,perm}$ = permissible equivalent stress [N/mm^2], defined as:

$$= \left(0,8 + \frac{\mathbf{L}}{450}\right)\frac{230}{k} \qquad \text{for} \quad \mathbf{L} < 90\ \text{m}$$

$$= \frac{230}{k} \quad [\text{N/mm}^2] \qquad \text{for} \quad \mathbf{L} \geq 90\ \text{m}$$

σ_x, σ_y = stress component of equivalent stress, defined as :

σ_x = $\sigma_L + \sigma_\ell$

σ_y = σ_t

5. The requirements regarding buckling strength according to A.3 are to be observed.

6. Weldings at the top of hatch coamings are subject to special approval.

Section 11 Watertight Bulkheads

A. General

1. Watertight subdivision

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 2.2).

1.2 For ships without longitudinal bulkheads in the cargo hold area the number of watertight transverse bulkheads should, in general, not be less than given in Table 11.1.

Table 11.1 Number of watertight transverse bulkheads

L [m]	Arrangement of machinery space	
	aft	elsewhere
$L \leq 65$	3	4
$65 < L \leq 85$	4	4
$85 < L \leq 105$	4	5
$105 < L \leq 125$	5	6
$125 < L \leq 145$	6	7
$145 < L \leq 165$	7	8
$165 < L \leq 185$	8	9
$L > 185$	to be special considered	

1.3 One or more of the watertight bulkheads required by 1.2, may be dispensed with where the transverse strength of the ship is adequate. The number of watertight bulkheads will be entered into the Register.

1.4 Number and location of transverse bulkheads fitted in addition to those specified in 1.1 are to be so selected as to ensure sufficient transverse strength of the hull.

1.5 For ships which require proof of survival capability in damaged conditions, the watertight sub-division will be determined by damage stability calculations. For oil tankers see Section 24, A.2, for passenger vessels see Section 29-I, for special purpose ships see Section 29-II, C, for cargo ships see Section 36 and for supply vessels see Section 34, A.2. For liquefied gas tankers see Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX) Sec.2, for chemical tankers see Rules for Ships Carrying Dangerous Chemicals in Bulk (Pt.1, Vol.X) Sec. 2.

2. Arrangement of watertight bulkheads

2.1 Collision bulkhead

2.1.1 A collision bulkhead shall be located at a distance from the forward perpendicular of not less than $0{,}05\mathbf{L}_c$ or 10 m, whichever is the less, and, except as may be permitted by the Administration, not more than $0{,}08\mathbf{L}_c$ or $0{,}05\mathbf{L}_c + 3{,}0$ m, whichever is the greater.

(SOLAS II-1, 12.1)

2.1.2 Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g., a bulbous bow, the distance x shall be measured from a point either:

— at the mid-length of such extension, i.e. x = 0,5 · a

— at a distance 0,015$\mathbf{L_C}$ forward of the forward perpendicular, i.e. x = 0,015$\mathbf{L_C}$, or

— at a distance 3,0 m forward of the forward perpendicular, i.e. x = 3,0 m

whichever gives the smallest measurement.

The length $\mathbf{L_C}$ and the distance a are to be specified in the approval documents.

(SOLAS II-1, 12.3)

2.1.3 If 2.1.2 is applicable, the required distances specified in 2.1.1 are to be measured from a reference point located at a distance x forward of the **FP**

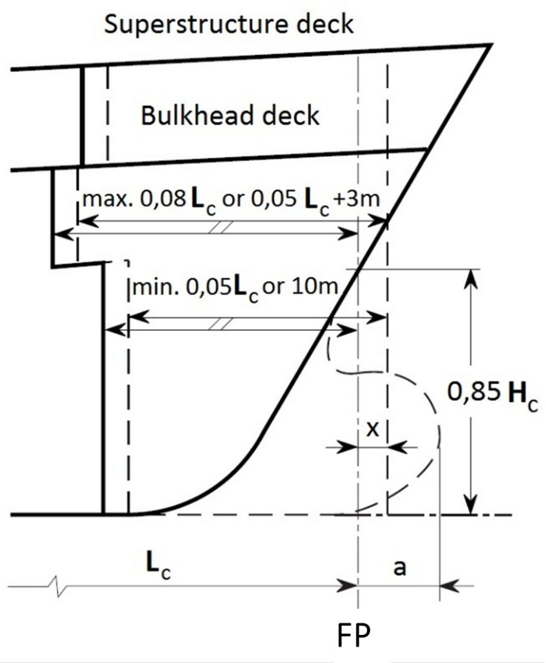

Fig. 11.1 Location of collision bulkhead

2.1.4 The collision bulkhead shall extend watertight up to the bulkhead deck. The bulkhead may have steps or recesses provided they are within the limits prescribed in 2.1.1.

(SOLAS II-1, 12.4)

2.1.5 No doors, manholes, access openings, or ventilation ducts are permitted in the collision bulkhead below the bulkhead deck.

(SOLAS II-1, 12.5)

2.1.6 For ships constructed before 1 January 2024, except as provided in 2.1.8 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 screwdown 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. Alternatively, for cargo ships, the pipe may be fitted with a butterfly valve suitably supported by a seat or flanges and capable of being operated from above the freeboard deck. All valves shall be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

(SOLAS II-1, 12.6.1)

2.1.7 For ships constructed on or after 1 January 2024, except as provided in paragraph 2.1.8, 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 remotely controlled valve capable of being operated from above the bulkhead deck. The valve shall be normally closed. If the remote control system should fail during operation of the valve, the valve shall close automatically or be capable of being closed manually from a position above the bulkhead deck. The valve shall be located at the collision bulkhead on either the forward or aft side, provided the space on the aft side is not a cargo space. The valve shall be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

(SOLAS II-1, 12.6.2)

Note:

The interpretation of valve piercing ship's collision bulkhead requirements, as stated in paragraph 2.1.7, should be in accordance with Guidance for Code and Convention Interpretation (Pt.1, Vol.Y), Sec.11, SC.306

2.1.8 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 2.1.6 and 2.1.7, 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, 12.6.3)

2.1.9 Where a long forward superstructure is fitted the collision bulkhead shall 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 2.1.1 or 2.1.3 with the exception permitted by 2.1.9 and that the part of the deck which forms the step is made effectively weathertight. The extension shall 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, 12.7)

2.1.10 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 shall 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 2.1.1 or 2.1.3. Ramps not meeting the above requirements shall be disregarded as an extension of the collision bulkhead.

(SOLAS II-1, 12.8)

2.1.11 The number of openings in the extension of the collision bulkhead above the bulkhead deck shall be restricted to the minimum compatible with the design and normal operation of the ship. All such openings shall be capable of being closed weathertight.

(SOLAS II-1, 12.9)

2.2 Stern tube and remaining watertight bulkheads

2.2.1 Bulkheads shall 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 after peak bulkhead shall also be fitted and made watertight up to the bulkhead deck. The after peak 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, 12.10)

2.2.2 In all cases stern tubes shall be enclosed in watertight spaces of moderate volume. In passenger ships the stern gland shall 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, 12.11)

Note:

The interpretation of enclosure of stern tubes on cargo ships requirements, as stated in paragraph 2.2.2, should be in accordance with Guidance for Code and Convention Interpretation (Pt.1, Vol.Y), Sec.11, SC.93

3. Openings in watertight bulkheads

3.1 General

3.1.1 Type and arrangement of doors are to be submitted for approval.

3.1.2 Regarding openings in the collision bulkhead see 2.1.5 and 2.1.11.

3.1.3 In the other watertight bulkheads, watertight doors may be fitted.

Watertight doors required to be open at sea are to be of the sliding type and capable of being operated both at the door itself, on both sides, and from an accessible position above the bulkhead deck. Means are to be provided at the latter position to indicate whether the door is open or closed, as well as arrows indicating the direction in which the operating gear is to be operated.

Watertight doors may be of the hinged type if they are always intended to be closed during navigation. Such doors are to be framed and capable of being secured watertight by handle-operated wedges which are suitably spaced and operable at both sides.

3.1.4 On ships for which proof of floatability in damaged condition is to be provided, hinged doors are permitted above the most unfavourable damage waterline for the respective compartment only. Deviating and additional requirements hereto are given in Chapter II-1, Reg. 13-1 of SOLAS (as amended by MSC.216 (82)).

3.1.5 For bulkhead doors in passenger ships, see Section 29-I, C.

3.1.6 Watertight doors are to be sufficiently strong and of an approved design. The thickness of plating is not to be less than the minimum thickness according to B.2.

3.1.7 Openings for watertight doors in the bulkheads are to be effectively framed such as to facilitate proper fitting of the doors and to guarantee perfect watertightness.

3.1.8 Before being fitted, the watertight bulkhead doors, together with their frames, are to be tested by a head of water corresponding to the bulkhead deck height. After having been fitted, the doors are to be hose- or soap-tested for tightness and to be subjected to an operational test. Deviating and additional requirements hereto are given in Chapter II-1 Reg. 16 of SOLAS as amended.

3.2 Hinged doors

Hinged doors are to be provided with rubber sealings and toggles or other approved closing appliances which guarantee a sufficient sealing pressure. The toggles and closing appliances are to be operable from both sides of the bulkhead. Hinges are to have oblong holes. Bolts and bearings are to be of corrosion resistant material. A warning notice requiring the doors to be kept closed at sea is to be fitted at the doors.

3.3 Sliding doors

Sliding doors are to be carefully fitted and are to be properly guided in all positions. Heat sensitive materials are not to be used in systems which penetrate watertight subdivision bulkheads, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkheads.

The closing mechanism is to be safely operable from each side of the bulkhead and from above the freeboard deck. If closing of the door cannot be observed with certainty, an indicator is to be fitted which shows, if the door is closed or open; the indicator is to be installed at the position from which the closing mechanism is operated.

3.4 Penetrations through watertight bulkheads

Where bulkhead fittings are penetrating watertight bulkheads, care is to be taken to maintain water tightness by observation of Chapter II-1 Reg. 12 of SOLAS as amended. For penetrations through the collision bulkhead, 2.1.6 is to be observed.

B. Scantlings

1. General, Definitions

1.1 Where holds are intended to be filled with ballast water, their bulkheads are to comply with the requirements of Section 12.

1.2 Bulkheads of holds intended to be used for carrying ore are to comply with the requirements of Section 23, as far as their strength is concerned.

1.3 Definitions

t_K = corrosion addition according to Section 3, K

a = spacing of stiffeners [m]

ℓ = unsupported span [m], according to Section 3, C

p = $9{,}81 \cdot h$ [kN/m^2] in general

= p_c if the ship is intended to carry dry cargo in bulk

h = distance from the load centre of the structure to a point 1,0 m above the bulkhead deck at the ship side, for the collision bulkhead to a point 1,0 m above the upper edge of the collision bulkhead at the ship side.

For the definition of "load centre" see Section 4, A.2.1.

c_p, c_s = coefficients according to Table 11.2

f = $\frac{235}{R_{eH}}$

R_{eH} = minimum nominal upper yield point [N/mm^2] according to Section 2, B

Table 11.2 Coefficients c_p and c_s

Coefficient c_p and c_s		Collision bulkhead	Other bulkheads
Plating	c_p	$1{,}1\sqrt{f}$	$0{,}9\sqrt{f}$
Stiffeners, corrugated bulkhead elements	c_s: in case of constraint of both ends	$0{,}33 \cdot f$	$0{,}265 \cdot f$
	c_s: in case of simple support of one end and constraint at the other end	$0{,}45 \cdot f$	$0{,}36 \cdot f$
	c_s: both ends simply supported	$0{,}66 \cdot f$	$0{,}53 \cdot f$
For the definition of "constraint" and "simply supported", see Section 3, D.1			

2. Bulkhead plating

2.1 The thickness of the bulkhead plating is not to be less than:

$$t = c_p \cdot \mathbf{a} \cdot \sqrt{p} + t_k \qquad [\text{mm}]$$

$$t_{min} = 6{,}0 \cdot \sqrt{f} \qquad [\text{mm}]$$

For ships with large deck openings according to Section 5, F.1.2, the plate thickness of transverse bulkheads is not to be less than:

$$t = c \cdot \sqrt[3]{\frac{\Delta\ell}{F_1 \cdot R_{eH} \cdot \left(\frac{1}{a^2} + \frac{1}{b^2}\right)} \cdot \sqrt{\frac{\mathbf{H}}{2}\left(\frac{\mathbf{H}}{2} - \mathbf{H}\right) + \mathbf{T}^2}} + t_k \qquad [\text{mm}]$$

Where:

$\Delta\ell$ = distance from the mid of hold before to the mid of hold aft of the considered transverse bulkhead or supporting bulkhead [m]

a, b = spacing of stiffeners [m]

t_K = corrosion addition [mm] according to Section 3, K

R_{eH} = nominal upper yield stress of material [N/mm^2] according to Section 2, B

F_{tran} = correction factor according to Section 3, F.5.2.2.3

c = 13 in general

= 15 below z = 0,2**H** and above 0,8**H** and generally in the fore ship before x/**L** = 0,8

2.2 In small ships, the thickness of the bulkhead plating need not exceed the thickness of the shell plating for a frame spacing corresponding to the stiffener spacing.

2.3 The stern tube bulkhead is to be provided with a strengthened plate in way of the stern tube.

2.4 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, B.5.4 and 5.5.

2.5 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 shall be taken into account.

3. Stiffeners

3.1 The section modulus of bulkhead stiffeners is not to be less than:

$$W = c_s \cdot m \cdot \mathbf{a} \cdot \ell^2 \cdot p \qquad [\text{cm}^3]$$

3.2 In horizontal part of bulkheads, the stiffeners are also to comply with the rules for deck beams according to Section 10.

3.3 The scantlings of the brackets are to be determined in dependence of the section modulus of the stiffeners according to Section 3, D.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.

3.4 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.

3.5 If the length of stiffeners between bulkhead deck and the deck below is 3,0 m and less, no end attachment according to 3.4 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, D.3)

3.6 Bulkhead stiffeners cut in way of watertight doors are to be supported by carlings or stiffeners.

4. Corrugated bulkheads

4.1 The plate thickness of corrugated bulkheads is not to be less than required according to 2.1. For the spacing a, the greater one of the values b or s [m] according to 4.3 is to be taken.

4.2 The section modulus of a corrugated bulkhead element is to be determined according to 3.1. For the spacing a, the width of an element e, [m] according to 4.3 is to be taken. For the end attachment see Section 3, D.4.

4.3 The actual section modulus of a corrugated bulkhead element is to be assessed according to the following formulae:

$$W = t \cdot d \left(b + \frac{s}{3}\right) \quad [cm^3]$$

where :

e	=	width of element [cm]
b	=	breadth of face plate [cm]
s	=	breadth of web plate [cm]
d	=	distance between face plates [cm]
t	=	plate thickness[cm]
α	$\geq$	$45°$

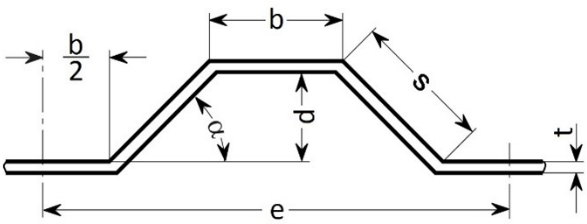

Fig. 11.2 Element of corrugated bulkhead

4.4 For watertight bulkheads of corrugated type on ship according to Section 23, E.

5. primary Supporting Members

5.1 General

Primary supporting members are to be dimensioned using direct calculation as to ensure the stress criteria according to 5.3.1 for normal operation and the criteria according to 5.3.2 if any cargo hold is flooded.

Regarding effective breadth and buckling proof in each case Section 3, E and F has to be observed.

In areas with cut-outs 2^{nd}-order bending moments shall be taken into account.

5.2 Load assumptions

5.2.1 Loads during operation

Loads during operation are the external water pressure, see Section 4, and the loads due to cargo and filled tanks, see Section 17, B.2.6, Section 21, H and if relevant depending on the deck opening Section 5, F.

5.2.2 Loads in damaged condition

The loads in case of hold flooding result from 1.3 considering 5.3.2.

5.3 Strength criteria

5.3.1 Load case "operation"

With loads according to 5.2.1 the following permissible stresses are to be used:

$$\sigma_V = \sqrt{\sigma_N^2 + 3\,\tau^2} \leq \frac{180}{k} \quad [\text{N/mm}^2]$$

σ_N = normal stress, $\sigma_N \leq \frac{150}{k}$ [N/mm²]

τ = shear stress, $\tau \leq \frac{100}{k}$ [N/mm²]

k = material factor according Section 2, B

If necessary Section 5, F.2 shall be observed in addition.

5.3.2 Load case "hold flooding"

The thickness of webs shall not be smaller than:

$$t_w = \frac{10^3 \cdot Q}{\tau_{perm} \cdot h_w} + t_k \quad [\text{mm}]$$

$$\tau_{perm} = 727 \sqrt{\frac{Q}{b \cdot h_w} \sqrt{R_{eH}\left(1 + 0{,}75\,\frac{b^2}{a^2}\right)}} \leq \frac{R_{eH}}{2{,}08} \quad [\text{N/mm}^2]$$

Q = shear force [kN]

h_w = height of web [mm]

a, b = lengths of stiffeners of the unstiffened web field, where $h_w \geq b \leq a$

5.3.3 Dimensioning of Primary Supporting Members

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 idealized bulkhead.

When a linear girder grillage calculation is done, only those moments and shear forces are taken as boundary conditions at the supports, which can be absorbed by the relevant sections at these locations in full plastic condition.

The plastic moments [kNm] are calculated by:

$$M_p = \frac{W_p \cdot R_{eH}}{c \cdot 1200}$$

c = 1,1 for the collision bulkhead

= 1,0 for cargo hold bulkheads

The plastic shear forces [kN] are calculated by :

$$Q_p = \frac{A_s \cdot R_{eH}}{c \cdot 2080}$$

For the field moments and shear forces resulting thereof the sections are defined in such a way that the condition

$\sigma_v \leq R_{eH}$ is fulfilled

The plastic section moduli are to be calculated as follows:

$$W_p = \frac{1}{1000} \sum_{i=1}^{n} A_i \cdot e_{pi} \quad [cm^3]$$

e_{pi} = distance [mm] of the centre of the partial area A_i from the neutral axis of the yielded section. The neutral axis shall not be taken in a position lower than the lowest point of the web

A_i = effective partial area [mm^2] considering Section 3, F.5.2.3.5. In this connection the area A_s of webs transferring shear shall not be taken into account

That part of the web height related to shear transfer shall not be less than:

$$\Delta h_w = h_w \cdot \frac{t_w}{t_{wa}}$$

t_{wa} = as built thickness of the web $\geq t_w$

Where girders are built up by partial areas A_i with different yield stress R_{eHi} the plastic moments are calculated by:

$$M_p = \frac{\sum_{i=1}^{n} A_{si} \cdot R_{eHi} \cdot e_{pi}}{c \cdot 1,2 \cdot 10^6} \quad [kNm]$$

The plastic shear forces are:

$$Q_p = \frac{\sum_{i=1}^{n} A_{si} \cdot R_{eHi}}{c \cdot 2080} \quad [kN]$$

6. Watertight longitudinal structures

The plating and stiffeners of watertight longitudinal structures shall be dimensioned according to Table 11.2, column "Other bulkheads".

C. Shaft Tunnels

1. General

1.1 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.

1.2 The access opening between engine room and shaft tunnel is to be closed by a watertight sliding door complying with the requirements according to A.3.3. 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 SOLAS 74, Chapter II-1, Regulation 11/8 as amended.

1.3 Tunnel ventilators and the emergency exit are to be constructed watertight up to the freeboard deck.

2. Scantlings

2.1 The plating of the shaft tunnel is to be dimensioned as for a bulkhead according to B.2.1.

2.2 The plating of the round part of tunnel tops may be 10% less in thickness.

2.3 In the range of hatches, the plating of the tunnel top is to be strengthened by not less than 2,0 mm unless protected by a ceiling.

On container ships this strengthening can be dispensed with.

2.4 The section modulus of shaft tunnel stiffeners is to be determined according to B.3.1.

2.5 Horizontal parts of the tunnel are to be treated as horizontal parts of bulkheads and as cargo decks respectively.

2.6 Shaft tunnels in tanks are to comply with the requirements of Section 12.

Section 12 Tank Structures

A. General

Note:

The arrangement and subdivision of fuel oil tanks has to be in compliance with MARPOL, Annex I, Reg. 12 A "Oil Fuel Tank Protection".

1. Subdivision of tanks

1.1 In tanks extending over the full breadth of the ship intended to be used for partial filling, (e.g. oil fuel and freshwater tanks), at least one longitudinal bulkhead is to be fitted, which may be a swash bulkhead

1.2 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**B** or 6,0 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**B** in the aft peak.

1.3 Peak tanks exceeding 0,06**L** or 6,0 m in length, whichever is greater, shall be provided with a transverse swash bulkhead.

2. Air, overflow and sounding pipes

For the arrangement of pipes see Section 21, F.

3. Forepeak tank

Oil is not to be carried in a forepeak tank or a tank forward of the collision bulkhead. See also SOLAS 2015 Amend, Chapter II-2, Reg. 4.2 and MARPOL 73/78, Annex I, Reg. 14.4.

4. Cross references

4.1 Where a tank bulkhead forms part of a watertight bulkhead, its strength is not to be less than required by Section 11.

4.2 For pumping and piping, see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.11. For Oil fuel tanks see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.10. For tanks in the double bottom, see Section 8, B.5.

4.3 For cargo oil tanks see Section 24.

4.4 For dry cargo holds which are also intended to be used as ballast water tanks, see C.2.

4.5 For testing of tanks, see Section 3, M.

4.6 Where tanks are provided with cross flooding arrangements the increase of the pressure head is to be taken into consideration (see also Section 36, H).

5. Oil fuel tanks

5.1 General

5.1.1 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)

5.1.2 As far as practicable, parts of the oil fuel system containing heated oil under pressure exceeding 0,18 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)

5.1.3 Fuel oil, lubrication oil and other flammable oils are not to be carried in forepeak tanks.

(SOLAS II-2, 4.2.2.3.1)

5.1.4 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 °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)

5.1.5 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)

5.1.6 Surfaces with temperatures above 220 °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)

5.2 Separation of fuel oil tanks from tanks for other liquids

5.2.1 Fuel oil tanks are to be separated from tanks for lubricating oil, hydraulic oil, thermal oil, vegetable oil, feed water, condensate water and potable water by cofferdams [1)].

[1)] For Indonesian flag ship, the cofferdams are also required between accommodation spaces and oil tanks.

5.2.2 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. 12.1.
- Where the common boundary cannot be constructed continuously according to Fig. 12.1, 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 · 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 2,5 mm.

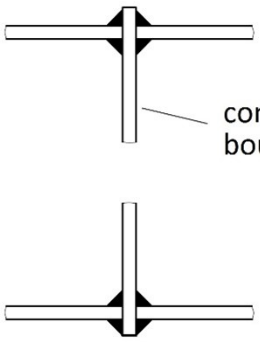

Fig. 12.1 Continuous common boundary replacing a cofferdam

5.2.3 Fuel oil tanks adjacent to lubricating oil circulation tanks are not permitted.

5.2.4 For fuel tanks which are heated up to a temperature which is higher than the flash point -10 °C of the relevant fuel, Rules for Machinery Installations (Pt.1, Vol.III) Sec.10.B.5 is to be observed specifically.

6. Tanks for heated liquids

6.1 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
	=	80 °C	in case of transverse framing

6.2 The calculations are to be carried out for both temperatures, the actual carriage temperature and the limit temperature T according to 6.1.

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 strengthening will be required on the basis of the results of the calculation for both temperatures.

7. Minimum thickness

7.1 The thickness of all tank structures is not to be less than the following minimum value:

$$t_{min} = 5{,}5 + 0{,}02 \cdot \mathbf{L} \quad [mm]$$

7.2 For fuel oil, lubrication oil and fresh water tanks t_{min} need not be taken greater than 7,5 mm.

7.3 For ballast tanks of dry cargo ships t_{min} need not be taken greater than 9,0 mm.

7.4 For minimum thickness of all structures in tanks of oil tankers see Section 24, A.12.

8. *Recommendation Plating and stiffeners in the propeller area and in the engine room*

8.1 *General*

From a vibration point of view shell and tank structures in the vicinity of the propeller(s) and the main engine should be designed such that the design criteria defined in 8.3 to 8.5 are fulfilled (see also Section 6, F.1 and Section 8, A.1.2.3).

8.2 *Definitions*

f_{plate}[2)] = *lowest natural frequency of isotropic plate field under consideration additional outfitting and hydrodynamic masses [Hz]*

f_{stiff}[2)] = *lowest natural frequency of stiffener under consideration of additional outfitting and hydrodynamic masses [Hz]*

d_p = *propeller diameter [m]*

r = *distance of plate field or stiffener to 12 o'clock propeller blade tip position [m]*

d_r = *ratio* $\frac{r}{d_p}$

a = $\frac{P}{\Delta}$

P = *nominal main engines output [kW]*

= *ship's design displacement [t]*

n = *maximum propeller shaft revolution rate [1/min]*

z = *number of propeller blades*

f_{blade} = *propeller blade passage excitation frequency at n [Hz]*

$= \frac{1}{60} \cdot n \cdot z \qquad [Hz]$

n_e = *maximum main engine revolution rate [1/min]*

n_c = *number of cylinders of main engine*

k_{stroke} = *number indicating the type of main engine*

= *1,0 for 2-stroke (slow-running) main engines*

= *0,5 for 4-stroke (medium speed) main engines*[3)]

$f_{ignition}$ = *main engine ignition frequency at* n_e

$= \frac{1}{60} \cdot k_{stroke} \cdot n_c \cdot n_e \qquad [Hz]$

8.3 *Shell structures in propeller area*

see Section 6, F.

8.4 *Tank structures in propeller area*

For vessel with a single propeller, plate fields and stiffeners of tank structures should fulfil the frequency criteria in Table 12.1. 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.

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2) The natural frequencies of plate fields and stiffeners can be estimated by approved computer program

3) The number 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.

Table 12.1 ***Frequency criteria***

$\alpha \geq 0,3$				$\alpha < 0,3$	
$0 < d_r \leq 1$	$1 < d_r \leq 2$	$2 < d_r \leq 4$	$4 < d_r \leq 6$	$0 < d_r \leq 2$	$2 < d_r \leq 4$
$4,40 \cdot f_{blade}$	$3,45 \cdot f_{blade}$	$2,40 \cdot f_{blade}$	$1,20 \cdot f_{blade}$	$2,40 \cdot f_{blade}$	$1,20 \cdot f_{blade}$

8.5 *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 summarized in Table 12.2.

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 12.2 ***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* $f_{plate} > 1,2 \cdot f_{ignition}$ *and* $f_{stiff} < 0,8 \cdot f_{ignition}$ *or* $f_{stiff} > 1,2 \cdot f_{ignition}$
	Resilient	*Tanks within engine length up to next platform deck above inner bottom*	$f_{plate} < 0,9 \cdot f_{ignition}$ *or* $f_{plate} > 1,1 \cdot f_{ignition}$

B. Scantlings

1. Definitions

k = material factor according to Section 2, B

a = spacing of stiffeners or load width [m]

ℓ = unsupported span [m] according to Section 3, C

p = load p_1 or p_d [kN/m^2] according to Section 4, D the greater load to be taken.

For tank structures on the shell of pressure p below $\mathbf{T}_{min}$ need not be larger than :

$$p = p_1 - \left[10\left(\mathbf{T}_{min} - z\right) - p_0 \cdot c_f \left(1 + \frac{z}{\mathbf{T}_{min}}\right)\right] \qquad [\text{kN/m}^2] \quad \text{with } p \leq p_1$$

$\mathbf{T}_{min}$ = smallest design ballast draught [m]

z = distance of structural member above baseline [m]

p_2 = load [kN/m^2] according to Section 4, D.1

t_k = corrosion addition according to Section 3, K

h = filling height of tank [m]

e_t = characteristic tank dimension ℓ_t or b_t [m]

ℓ_t = tank length [m]

b_t = tank breadth [m]

$$\sigma_{p\ell} = \sqrt{\left(\frac{235}{k}\right)^2 - 3 \cdot \tau_L^2} - 0,89 \cdot \sigma_L \qquad [N/mm^2]$$

σ_L = membrane stress at the position considered [N/mm^2] according to Section 5, D.1

τ_L = shear stress [N/mm^2] at the position considered see also Section 5, D.1

n_f = 1,0 for transverse stiffening

= 0,83 for longitudinal stiffening

m, m_a see Section 9, A.1.2

For the terms "constraint" and "simply supported" see Section 3, D.

2. Plating

2.1 The plate thickness is not to be less than:

$$t_1 = 1,1 \cdot a \cdot \sqrt{p \cdot k} + t_k \qquad [mm]$$

$$t_2 = 0,9 \cdot a \cdot \sqrt{p_2 \cdot k} + t_k \qquad [mm]$$

2.2 Above the requirements specified in 2.1 the thickness 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:

$$t = 16,8 \cdot n_f \cdot a \sqrt{\frac{p}{\sigma_{p\ell}}} + t_k \qquad [mm]$$

2.3 Proof of plating of buckling strength of longitudinal and transverse bulkheads is to be carried out according to Section 3, F. For longitudinal bulkheads the design stresses according to Section 5, D.1 and the stresses due to local loads are to be considered.

3. Stiffeners and girders

3.1 Stiffeners and girders, which are not considered as longitudinal strength members

3.1.1 The section modulus of stiffeners and girders constrained at their ends, is not to be less than:

$$W_1 = 0,55 \cdot m \cdot a \cdot \ell^2 \cdot p \cdot k \qquad [cm^3]$$

$$W_2 = 0,44 \cdot m \cdot a \cdot \ell^2 \cdot p_2 \cdot k \qquad [cm^3]$$

Where one or both ends are simply supported, the section moduli are to be increased by 50%.

The shear area of the girder webs is not to be less than:

$$A_{w1} = (1 - 0,817 \cdot ma) \cdot 0,05 \cdot a \cdot \ell \cdot p \cdot k \qquad [cm^2]$$

$$A_{w2} = (1 - 0,817 \cdot ma) \cdot 0,04 \cdot a \cdot \ell \cdot p_2 \cdot k \qquad [cm^2]$$

In case of girders supporting longitudinal stiffeners and in case of hell stiffeners the factors m = 1,0 and m_a = 0 are to be used. Otherwise these factors are to be determined according to Section 9, B.2 as for longitudinals.

A_{w2} is to be increased by 50% at the position of constraint for a length of $0{,}1\ell$.

The buckling strength of the webs is to be checked according to Section 3, F

3.1.2 Where the scantlings of stiffeners and girders are determined according to strength calculations, the following permissible stress values apply:

— if subjected to load p :

$$\sigma_b \leq \frac{150}{k} \quad [N/mm^2]$$

$$\tau \leq \frac{100}{k} \quad [N/mm^2]$$

$$\sigma_v = \sqrt{\sigma_b^2 + 3\,\tau^2} \leq \frac{180}{k} \quad [N/mm^2]$$

— if subjected to load p_2 :

$$\sigma_b \leq \frac{180}{k} \quad [N/mm^2]$$

$$\tau \leq \frac{115}{k} \quad [N/mm^2]$$

$$\sigma_v = \sqrt{\sigma_b^2 + 3\,\tau^2} \leq \frac{200}{k} \quad [N/mm^2]$$

3.2 Stiffeners and girders, which are to be considered as longitudinal strength members

3.2.1 The section moduli and shear areas of horizontal stiffeners and girders are to be determined according to Section 9, B.3.1 as for longitudinal. In this case for girders supporting transverse stiffeners the factors m = 1,0 and m_a = 0 are to be used.

3.2.2 Regarding buckling strength of girders the requirements of 2.3 are to be observed.

3.3 The scantlings of beams and girders of tank decks are also to comply with the requirements of Section 10.

3.4 For frames in tanks, see Section 9, A.2.2 .

3.5 The stiffeners of tank bulkheads are to be attached at their ends by brackets according to Section 3, D.2. The scantlings of the brackets are to be determined according to the section modulus of the stiffeners. Brackets have to be fitted where the length of the stiffeners exceeds 2,0 m.

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.

3.6 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. 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 formulae:

$$\tau_{St} = \frac{P_{st}}{2 \cdot b_{st} \cdot t} \quad [N/mm^2]$$

P_{st} = supporting force of stringer or vertical girder [kN]

b_{st} = breadth of stringer or depth of vertical girder including end bracket (if any) [m] a the supporting point

t = see 2.2

The additional shear stress τ_{st} is to be added to the shear stress τ_L due to longitudinal bending according to Section 5, D.1 in the following area:

- 0,5 m on both sides of the stringer in the ship's longitudinal direction
- $0{,}25 \cdot b_{st}$ above and below the stringer

Thereby the following requirement shall be satisfied:

$$\frac{110}{k} \geq \frac{P_{st}}{2 \cdot b_{st} \cdot t} + \tau_L$$

3.7 Connection between primary support members and intersecting stiffeners

3.7.1 At intersections of stiffeners with primary support members the shear connection and attached heel stiffeners are to be designed according to Section 9, B.4.7 to Section 9, B.4.9 subjected to tank loads p and p_2.

3.7.2 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:

$$\sigma_{axial} = \frac{10^3 \cdot P_h}{\ell_h \cdot t_h} \leq \frac{150}{k} \qquad \text{for load p} \qquad [\mathrm{N/mm^2}]$$

$$\sigma_{axial} \leq \frac{180}{k} \qquad \text{for load } p_2 \qquad [\mathrm{N/mm^2}]$$

- normal stress in the fillet weld connection of heel stiffener:

$$\sigma_{weld} = \frac{10^3 \cdot p_h}{2 \cdot a \cdot (\ell_{hc} + t_h + a)} \leq \sigma_{vp} \qquad \text{for load p} \qquad [\mathrm{N/mm^2}]$$

$$\sigma_{weld} \leq \frac{\sigma_{vp}}{0,8} \qquad \text{for load } p_2 \qquad [\mathrm{N/mm^2}]$$

a = throat thickness [mm] of fillet weld, see Section 19, B.3.3

σ_{vp} = permissible equivalent stress in the fillet weld according to Table 19.3

3.7.3 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:

$$\tau_i = \frac{10^3 \cdot P_i}{h_i \cdot t_i} \leq \frac{100}{k} \qquad \text{for load p} \qquad [\mathrm{N/mm^2}]$$

$$\tau_i \leq \frac{115}{k} \qquad \text{for load } p_2 \qquad [\mathrm{N/mm^2}]$$

— shear stress in the shear connections in way of fillet welds:

$$\tau_{weld,i} = \frac{10^3 \cdot P_i}{2 \cdot a \cdot h_i} \leq \tau_p \qquad \text{for load p} \qquad [N/mm^2]$$

$$\tau_{weld,i} \leq \frac{\tau_p}{0,8} \qquad \text{for load } p_2 \qquad [N/mm^2]$$

τ_p = permissible shear stress in the fillet weld according to Table 19.3

i = s for the shear connection of longitudinal and transverse support member

= c for the shear connection of longitudinal and collar plate

3.7.4 The cross-sectional area of a collar plate is to be such that the calculated bending stress does not exceed the permissible stresses.

— bending stress of collar plate

$$\sigma_c = \frac{3 \cdot 10^3 \cdot P_c \cdot b_c}{h_c^2 \cdot t_c} \leq \frac{150}{k} \qquad \text{for load p } [N/mm^2]$$

$$\sigma_c \leq \frac{180}{k} \qquad \text{for load } p_2$$

— bending stress in the fillet weld connection of the collar plate

$$\sigma_{weld,c} = \frac{1,5 \cdot 10^3 \cdot P_c \cdot b_c}{h_c^2 \cdot t_c} \leq \sigma_{vp} \qquad \text{for load p } [N/mm^2]$$

$$\sigma_{weld,c} \leq \frac{\sigma_{vp}}{0,8} \qquad \text{for load } p_2$$

a, σ_{vp} according to 3.7.2

4. Corrugated bulkheads

4.1 The plate thicknesses of corrugated bulkheads as well as the required section moduli of corrugated bulkhead elements are to be determined according to 2. and 3., proceeding analogously to Section 11, B.4. The plate thickness is not to be less than t_{min}, according to A.7, or

- if subjected to load p

$$t_{crit} = \frac{b}{905}\sqrt{\sigma_D} + t_k \qquad [mm]$$

- if subjected load p_2

$$t_{crit} = \frac{b}{960}\sqrt{\sigma_D} + t_k \qquad [mm]$$

σ_D = compressive stress [N/mm²]

b = breadth of face plate strip [mm]

4.2 For the end attachment Section 3, D.4 is to be observed.

5. Thickness of clad plating

5.1 Where the yield point of the cladding is not less than that of the base material the plate thickness is to be determined according to 2.1.

5.2 Where the yield point of the cladding is less than that of the base material the plate thickness is not to be less than:

$$t_1 = 0,55 \cdot \mathbf{a} \sqrt{p \cdot \frac{k}{A}} + t_k \quad [mm]$$

$$t_2 = 0,45 \cdot \mathbf{a} \sqrt{p_2 \cdot \frac{k}{A}} + t_k \quad [mm]$$

For one side clad steel:

$$A = 0,25 - \frac{t_p}{2 \cdot t}\left[1 - r - \frac{t_p}{2 \cdot t}\left(1 - r^2\right)\right]$$

For both side clad steel:

$$A = 0,25 - \frac{t_p}{t}\left[1 - \frac{t_p}{t}\right](1 - r)$$

t = plate thickness including cladding [mm]

t_p = thickness of the cladding [mm]

r = $\frac{R_{ep}}{R_{eH}}$

R_{ep} = minimum nominal upper yield point of the cladding [N/mm^2] at service temperature

R_{eH} = minimum nominal upper yield point of the base material [N/mm^2] according to Section 2, B

5.3 The plate thicknesses determined in accordance with 5.1 and 5.2 respectively may be reduced by 0,5 mm. For chemical tankers however the reductions as per Rules for Ships Carrying Dangerous Chemicals in Bulk (Pt.1, Vol.X) Sec.4, 4.2 – 0.1.3 apply.

C. Tanks with Large Lengths or Breadths

1. General

Tanks with lengths ℓ_t > 0,1**L** or breadths b_t > 0,6**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:

Natural period of liquid in tank:

$$T_{\ell b} = 1,132\sqrt{\frac{e_t}{f}} \quad [s]$$

f = hyperbolic function as follows:

$$= \tanh\left(\frac{\pi \cdot h}{e_t}\right)$$

Period of wave excited maximum pitch motion:

$$T_s = \frac{\mathbf{L}}{1,17 \cdot \sqrt{\mathbf{L}} + 0,15 \cdot \mathbf{v}_0} \quad [s]$$

$\mathbf{v}_0$ = ahead speed of ship [kn] as defined in Section 1, H.5

Period of roll motion:

$$T_r = \frac{c_r \cdot \mathbf{B}}{\sqrt{\overline{GM}}} \quad [s]$$

c_r = 0,78 in general

= 0,70 for tankers in ballast

$\overline{GM} \approx 0{,}07 \cdot \mathbf{B}$ in general

$\overline{GM} \approx 0{,}12 \cdot \mathbf{B}$ for tankers and bulk carriers

2. Hold spaces for ballast water

In addition to the requirements specified under 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 Section 9, A.2.2 is to be observed.

D. Vegetable Oil Tanks

1. Further to the regulations stipulated under A and B for vegetable oil tanks, the following requirements are to be observed.

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 A.1.2. Filling ratios between 70% and 90% should be avoided.

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

1. General

1.1 Detached tanks are to be adequately secured against forces due to the ship's motions.

1.2 Detached tanks in hold spaces are also to be provided with anti-floatation devices. It is to be assumed that the hold spaces are flooded to the load waterline. The stresses in the anti-floatation devices caused by the floatation forces are not to exceed the material's yield stress.

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.

1.4 Fittings and piping 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.

2. Scantlings

2.1 The thickness of plating of detached tanks is to be determined according to B.2.1 using the formulae for t_1 and the pressure p as defined in 2.2.

2.2 The section modulus of stiffeners of detached tanks is not to be less than:

$$W = c \cdot \mathbf{a} \cdot \ell^2 \cdot p \cdot k \quad [cm^3]$$

c = 0,36 if stiffeners are constrained at both ends

= 0,54 if one or both ends are simply supported

p = $9{,}81 \cdot h$ [kN/m^2]

h = distance from the load centre of plate panel or stiffener respectively to the 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 1,0 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 = $2{,}5 \cdot \rho$ [m]

ρ = density [t/m^3] of liquid to carry

2.3 For minimum thickness the requirements of A.7 apply in general.

F. Potable Water Tanks

1. Potable water tanks shall be separated from tanks containing liquids other than potable water, ballast water, distillate or feed water.

2. In no case sanitary arrangement or corresponding piping are to be fitted directly above the potable water tanks.

3. Manholes arranged in the tank top are to have sills.

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.

5. Air and overflow pipes of potable water tanks are to be separated from pipes of other tanks.

G. Swash Bulkheads

1. The total area of perforation in swash bulkheads is to approximately 20% of the bulkhead area.

2. The plate thickness shall, in general, be equal to the minimum thickness according to A.7. Strengthening may be required for load bearing structural parts. The free lower edge of a wash bulkhead is to be adequately stiffened.

3. The section modulus of the stiffeners and girders is not to be less than W_1 as per B.3, however, in lieu of p the load pd according to Section 4, D.2, but disregarding pv is to be taken.

4. For swash bulkheads in oil tankers see also Section 24, D.G-H

H. Fuel and Lubrication Oil Tanks in Double Bottom

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, B.6.1, 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.3.2.

2. For minimum thickness the requirements A.7.1 apply in general

Section 13 Stem and Sternframe Structures

A. Definition

R_{eH} = minimum nominal upper yield point [N/mm^2] according to Section 2,B

k = material factor according to Section 2,B, for cast steel k = k_r according to Section 14, A.4.2

C_R = rudder force [N] according to Section 14, B.1

B_1 = support force [N] according to Section 14, C.3

t_K = corrosion addition [mm] according to Section 3, K

a_B = spacing of fore-hooks [m]

B. Stem

1. Bar stem

1.1 The cross sectional area of a bar stem below the load waterline is not to be less than:

$$A_b = 1{,}25 \cdot \mathbf{L} \quad [\text{cm}^2].$$

1.2 Starting from the load waterline, the sectional area of the bar stem may be reduced towards the upper end to $0{,}75 A_b$.

2. Plate stem and bulbous bows

2.1 The thickness is not to be less than:

$$t = (0{,}6 + 0{,}4\, a_B) \cdot (0{,}08 \cdot \mathbf{L} + 6{,}0)\sqrt{k} \quad [\text{mm}]$$

$$t_{max} = 25\sqrt{k} \quad [\text{mm}]$$

The plate thickness shall not be less than the required thickness according to Section 6, C.2.

The extension ℓ of the stem plate from its trailing edge afterwards shall not be smaller than:

$$\ell = 70\sqrt{\mathbf{L}} \quad [\text{mm}]$$

Dimensioning of the stiffening has to be done according to Section 9.

2.2 Starting from 600 mm above the load waterline up to **T** + c_0, the plate thickness may gradually be reduced to 0,8t.

2.3 Plate stems and bulbous bows have to be stiffened by fore-hooks and/or cant frames. In case of large and long bulbous bows, see Section 9, A.5.3.3.

C. Stern frame

1. General

1.1 Propeller post and rudder post are to be led into the hull in their upper parts and connected to it in a suitable and efficient manner. In way of the rudder post the shell is to be strengthened according to Section 6, F.

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.

1.2 The following value is recommended for the propeller clearance $d_{0,9}$ related to 0,9R (see Fig. 13.1):

$$d_{0,9} \geq 0,004 \cdot n \cdot d_p^3 \cdot \sqrt{\frac{\mathbf{v_0}\left[1 - \sin(0,75 \cdot \gamma)\right] \cdot \left(0,5 + \frac{z_B}{x_F}\right)}{D}} \quad [m]$$

R = propeller radius [m]

$\mathbf{v_0}$ = ship's speed, see Section 1, H.5 [knot]

n = number of propeller revolutions per minute

D = maximum displacement of ship [t]

d_p = propeller diameter [m]

γ = skew angle of the propeller [°], see Fig. 13.2

z_B = height of wheelhouse deck above weather deck [m]

x_F = distance of deckhouse front bulkhead from aft edge of stern [m], see Fig. 13.1.

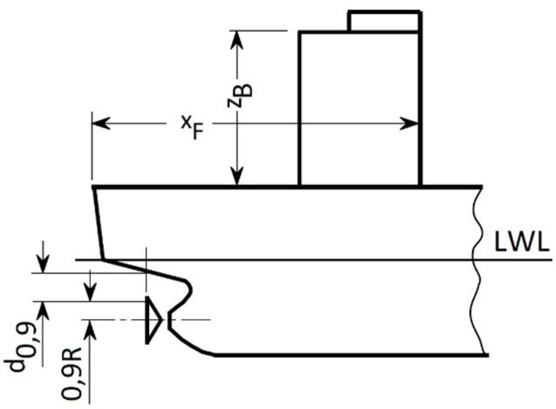


Fig. 13.1 Propeller clearance $d_{0,9}$

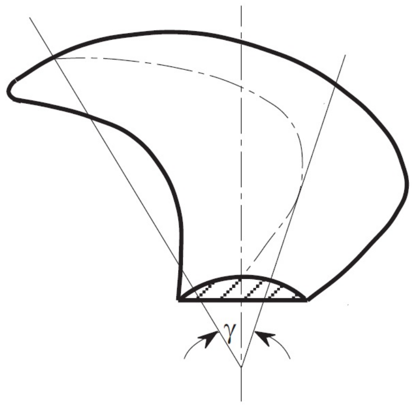


Fig. 13.2 Skew angle

1.3 For single screw ships, the lower part of the stern frame 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 stern frame.

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.

1.5 The plate thickness of sterns of welded construction for twin screw vessels shall not be less than:

$t = (0,07 \cdot \mathbf{L} + 5,0)\sqrt{k}$ [mm]

$t_{max} = 22\sqrt{k}$ [mm]

2. Propeller post

2.1 The scantlings of rectangular, solid propeller posts are to be determined according to the following formulae:

ℓ = $1{,}4 \cdot \mathbf{L} + 90$ [mm]

b = $1{,}6 \cdot \mathbf{L} + 15$ [mm]

Where other sections than rectangular ones are used, their section modulus is not to be less than that resulting from ℓ and b.

2.2 The scantlings of propeller posts of welded construction are to be determined according to the following formulae:

ℓ = $50\sqrt{\mathbf{L}}$ [mm]

b = $36\sqrt{\mathbf{L}}$ [mm]

t = $2,4\sqrt{\mathbf{L} \cdot k}$ [mm]

2.3 Where the cross sectional configuration is deviating from Fig. 13.3 and for cast steel propeller posts the section modulus of the cross section related to the longitudinal axis is not to be less than:

W_X = $1{,}2 \cdot \mathbf{L}^{1,5} \cdot k$ [cm^3]

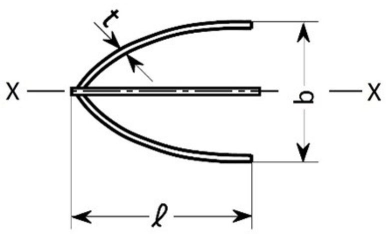


Fig. 13.3 Length ℓ_{50} of a sole piece

Note:

With single-screw ships having in the propeller region above the propeller flaring frames of more than α = 75° the thickness of the shell should not be less than the thickness of the propeller stem. For α ≤ 75° the thickness may be 0,8 t. In no case the thickness shall 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 · propeller diameter.

Sufficient stiffening should be arranged, e.g. by floors at each frame and by longitudinal girders.

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 2.1.

2.5 The wall thickness of the boss in propeller posts of welded construction according to 2.2 shall not be less than 0,9 the wall thickness of the boss according to D.2.

3. Sole piece

3.1 The section modulus of the sole piece related to the z-axis is not to be less than :

W_z = $\dfrac{B_1 \cdot x \cdot k}{80}$ [cm^3]

B_1 = See A.

For rudders with two supports the support force is approximately $B_1 = C_R/2$ (see Fig.13.9) when the elasticity of the sole piece is ignored.

x	=	distance of the respective cross section from the rudder axis [m]
x_{min}	=	$0,5 \cdot \ell_{50}$
x_{max}	=	ℓ_{50}
ℓ_{50}	=	see Fig. 13.4 and Section 14, C.3.2

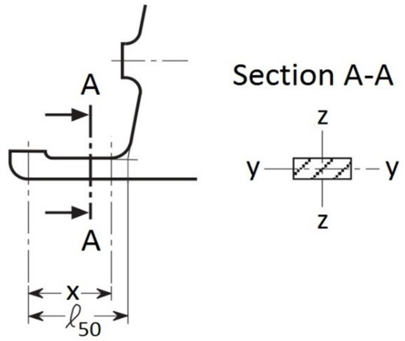


Fig. 13.4 Length ℓ_{50} of a sole piece

3.2 The section modulus W_z may be reduced by 15% where a rudder post is fitted.

3.3 The section modulus related to the y-axis is not to be less than:

$$w_y = \frac{W_z}{2} \quad \text{where no rudder post or rudder axle is fitted}$$

$$w_y = \frac{W_z}{3} \quad \text{where a rudder post or rudder axle is fitted}$$

3.4 The sectional area at the location $x = \ell_{50}$ is not to be less than:

$$A_s = \frac{B_1}{48} \cdot k \quad [mm^2]$$

3.5 The equivalent stress taking into account bending and shear stresses at any location within the length ℓ_{50} is not to exceed:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\,\tau^2} \leq \frac{115}{k} \quad [N/mm^2]$$

$$\sigma_b \leq \frac{B_1 \cdot x}{W_z} \quad [N/mm^2]$$

$$\tau \leq \frac{B_1}{A_s} \quad [N/mm^2]$$

(IACS UR. S 10.9)

4. Rudder horn of semi spade rudders

4.1 The section modulus of the rudder horn in transverse direction related to the horizontal x-axis is at any location z not to be less than :

$$W_X = \frac{M_b \cdot k}{67} \quad [cm^3]$$

4.2 At no cross section of the rudder horn the shear stress τ due to the shear force Q is to exceed the value:

$$\tau \leq \frac{48}{k} \quad [N/mm^2]$$

The shear stress is to be determined by the following formulae:

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

A_h = effective shear area of the rudder horn in y-direction [mm^2].

4.3 The equivalent stress at any location (z) of the rudder horn are not to exceed the following value:

$$\sigma_v \leq \sqrt{\sigma_b^2 + 3(\tau^2 + \tau_T^2)} \leq \frac{120}{k} \quad [N/mm^2]$$

σ_b, τ_T = stress components [N/mm^2] of the equivalent stress, defined as :

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

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

M_b, M_T = bending and torsional moment at a rudders horn of semi spade rudders according to 5.1 or 6.1

A_T = sectional area [mm^2] enclosed by the rudder horn at the location considered

t_h = thickness of the rudder horn plating [mm]

4.4 When determining the thickness of the rudder horn plating the provisions of 4.1 – 4.3 are to be complied with. The thickness is, however, not to be less than:

$$t_{min} = 2,4 \cdot \sqrt{\mathbf{L} \cdot k} \quad [mm]$$

(IACS UR S10.9.2.2)

4.5 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. 13.5.

Brackets or stringer are to be fitted internally in horn, in line with outside shell plate, as shown in Fig. 13.5.

(IACS UR S10.9.2.3)

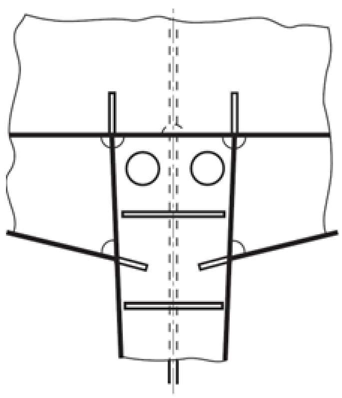


Fig. 13.5 Rudder horn integration into the aft ship structure

4.6 Transverse webs of the rudder horn are to be led into the hull up to the next deck in a sufficient number and shall be of adequate thickness.

4.7 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.

4.8 The centre line bulkhead (wash-plate) in the afterpeak is to be connected to the rudder horn.

4.9 Scallops are to be avoided in way of the connection between transverse webs and shell plating

4.10 The weld connection between the rudder horn plating and the side shell is to be full penetration. The welding radius is to be as large as practicable and may be obtained by grinding.

(IACS UR S10.9.2.3)

4.11 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 · r above the beginning of the transition zone. See Fig. 13.6.

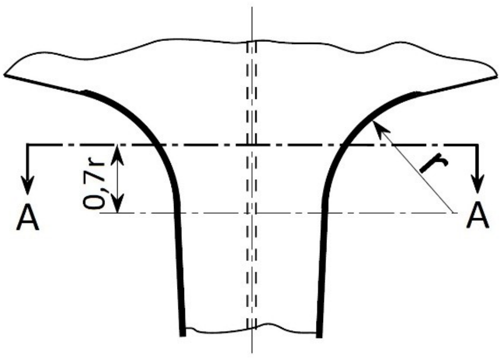


Fig. 13.6 Transition between rudder horn and shell

5. Rudder horn of semi spade rudders with one elastic support

5.1 The distribution of the bending moment, shear force and torsional moment is to be determined according to the following formulae:

—	bending moment	:	M_b	$= B_1 \cdot z$	[Nm]
			M_{bmax}	$= B_1 \cdot d$	[Nm]
—	shear force	:	Q	$= B_1$	[N]
—	torsional moment	:	M_T	$= B_1 \cdot e(z)$	[Nm]

For determining preliminary scantlings the flexibility of the rudder horn may be ignored and the supporting force B_l be calculated according to the following formula :

$$B_1 = C_R . \frac{b}{c} \quad [N]$$

b, c, d, e(z) and z see Fig. 13.7 and Fig. 13.8.

b result from the position of the centre of gravity of the rudder area.

(IACS URUR S10.5 ANNEX)

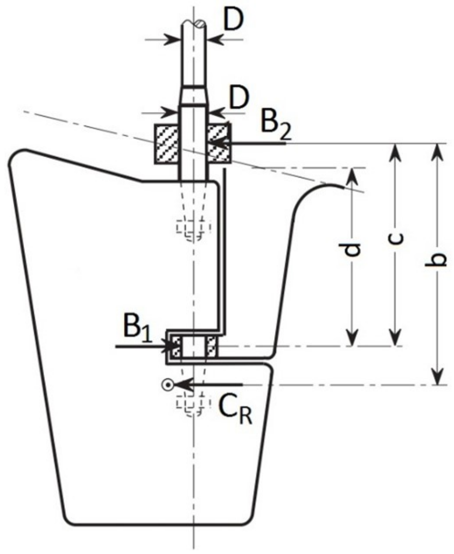


Fig. 13.7 Arrangement of bearings of a semi spade rudder

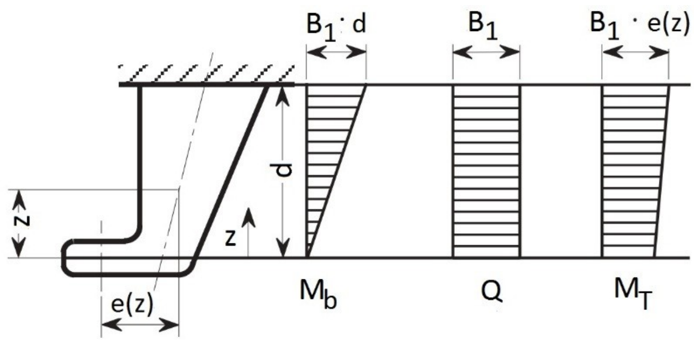


Fig. 13.8 Loads on the rudder horn (rudder with one elastic support)

(IACS URS10.5 ANNEX Figure A5)

6. Rudder horn of semi spade rudders with two conjugate elastic supports

6.1 Rudder horn bending moment and shear force

The bending moment acting on the generic section of the rudder horn is to be obtained [Nm] from the following formulae:

M_H = $F_{A1} \cdot z$ between the lower and upper supports provided by the rudder horn

M_H = $F_{A1} \cdot z + F_{A2} \cdot (z \cdot d_{lu})$ above the rudder horn upper-support

F_{A1} = Support force at the rudder horn lower-support [N] to be obtained according to Fig. 13.9, and taken equal to B_1.

F_{A2} = Support force at the rudder horn upper-support [N] to be obtained according to Fig. 13.9, and taken equal to B_2.

z = Distance, in m, defined in Fig. 13.9, to be taken less than the distance d [m] defined in the same figure.

d_{lu} = Distance [m] between the rudder-horn lower and upper bearings (according to Fig. 13.3, d_{lu}= d - λ).

The shear force Q_H acting on the generic section of the rudder horn is to be obtained [N] from the following formulae:

Q_H	=	F_{A1}	between the lower and upper rudder horn bearings
Q_H	=	$F_{A1} + F_{A2}$	above the rudder horn upper-bearing
F_{A1}, F_{A2}	=	Support forces [N]	

The torque acting on the generic section of the rudder horn is to be obtained [Nm] from the following formulae:

M_T	=	$F_{A1} \cdot e(z)$	between the lower and upper rudder horn bearings
M_T	=	$F_{A1} \cdot e(z) + F_{A2} \cdot e(z)$	above the rudder horn upper-bearing
e(z)	=	Torsion lever [m] defined in Fig. 13.9	

(IACS UR S10.6 ANNEX)

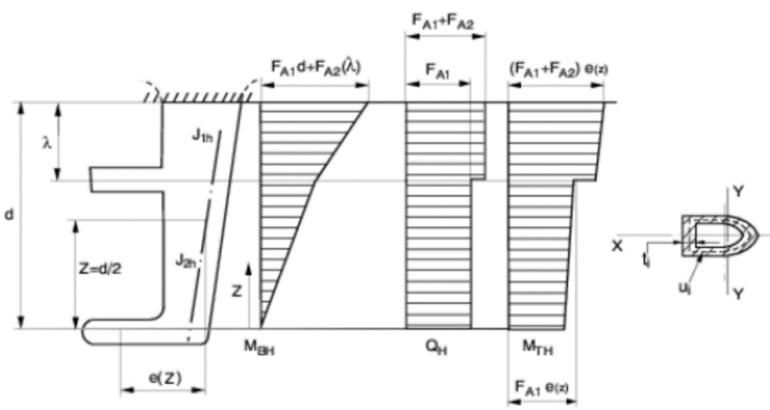


Fig. 13.9 Loads on the rudder horn (rudder with two elastic supports

(IACS URS10.5 ANNEX Figure A7)

6.2 Rudder horn shear stress calculation

For a generic section of the rudder horn, located between its lower and upper bearings, the following stresses are to be calculated:

τ_S = Shear stress [N/mm^2] to be obtained from the following formula:

$$= \frac{F_{A1}}{F_H}$$

τ_T = Torsional stress [N/mm^2] to be obtained for hollow rudder horn from the following formula:

$$= \frac{M_T \cdot 10^{-3}}{2 \cdot F_T \cdot t_H}$$

For solid rudder horn, τ_T is to be considered by the BKI on a case by case basis.

For a generic section of the rudder horn, located in the region above its upper bearing, the following stresses are to be calculated:

τ_S = Shear stress [N/mm^2] to be obtained from the following formula:

$$= \frac{F_{A1} + F_{A2}}{A_H}$$

τ_T = Torsional stress [N/mm^2] to be obtained for hollow rudder horn from the following formula:

$$= \frac{M_T \cdot 10^{-3}}{2 \cdot F_T \cdot t_H}$$

F_{A1}, F_{A2} = Support forces [N]

A_H = Effective shear sectional area of the rudder horn [mm^2] in y-direction;

M_T = Torque [Nm];

F_T = Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn [m^2].

t_H = Plate thickness of rudder horn [mm]. For a given cross section of the rudder horn, the maximum value of τ_T is obtained at the minimum value of t_H.

(IACS UR S10.6 ANNEX)

6.3 Rudder horn bending stress calculation

For the generic section of the rudder horn within the length d, the following stresses are to be calculated:

σ_B = Bending stress [N/mm^2] to be obtained from the following formula:

$$= \frac{M_H}{W_X}$$

M_H = Bending moment at the section considered [Nm].

W_X = Section modulus [cm^3] around the x-axis (see Fig. 13.9).

(IACS UR S10.6 ANNEX)

D. Propeller Brackets

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 bossing, see Section 6, F. The requirements of Section 19, B.4.3 are to be observed.

2. The scantlings of solid struts are to be determined as outlined below depending on shaft diameter d:

- thickness : $0{,}44 \cdot d$
- cross-sectional area in propeller bracket : $0{,}44 \cdot d^2$
- length of boss : see Rules for Machinery Installations (Pt.1, Vol.III), Sec.4. D.5.2
- wall thickness of boss : $0{,}25 \cdot d$

3. Propeller brackets and shaft bossing of welded construction are to have the same strength as solid ones according to 2.

4. For single strut propeller bracket 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.

Single strut propeller bracket may also be determined as follows:

$$W = 0{,}068 \cdot d^3$$

$$I = 0{,}018 \cdot d^4$$

where;

W = section modulus of strut [mm^3]

I = moment inertia of strut [mm^4]

d = required shaft diameter [mm]

Above formulae applies for bracket length, measured from the outside perimeter of the strut bracket or boss is not to exceed 10,6 · d. Where this length is exceeded the scantling of the strut has to be increased.

E. Elastic Stern Tube

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:

1.1 Static load

Bending stresses caused by static weight loads are not to exceed 0,35 · R_{eH}.

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 are to be observed:

σ_{perm} = 0,40 · R_{eH} for R_{eH} = 235 N/mm^2

σ_{perm} = 0,35 · R_{eH} 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.

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

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

IACS UR S10 Rev.7, Corr.2

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

1. Manoeuvring arrangement

1.1 Each ship is to be provided with a manoeuvring arrangement which will guarantee sufficient manoeuvring capability.

1.2 The manoeuvring arrangement includes all parts from the rudder and steering gear to the steering position necessary for steering the ship.

1.3 Rudder stock, rudder coupling, rudder bearings and the rudder body are dealt with in this Section. The steering gear is to comply with Rules for Machinery Installations (Pt.1, Vol.III) Sec.14.

1.4 The steering gear compartment shall be readily accessible and, as far as practicable, separated from the machinery space. (See also Chapter II-I, Reg. 29.13 of SOLAS 74.)

1.5 For ice-strengthening see Section 15.

2. Structural details

2.1 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)

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

(IACS UR S10.1.2.2)

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.

2.3 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 waterline at scantling draught (without trim), two separate watertight seals/stuffing boxes are to be provided.

(IACS UR S10.1.2.3)

Note:

The following measures are recommended for preventive measures to avoid or minimize rudder cavitation:

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.*

3. *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:

$$A = c_1 \cdot c_2 \cdot c_3 \cdot c_4 \, \frac{1,75 \cdot \boldsymbol{L} \cdot \boldsymbol{T}}{100} \qquad [m^2]$$

c_1 = *factor for the ship type:*
= *1,0 in general*
= *0,9 for bulk carriers and tankers having a displacement of more than 50 000 ton*
= *1,7 for tugs and trawlers*

c_2 = *factor for the rudder type:*
= *1,0 in general*
= *0,9 for semi-spade rudders*
= *0,7 for high lift rudders*

c_3 = *factor for the rudder profile:*
= *1,0 for NACA-profiles and plate rudder*
= *0,8 for hollow profiles and mixed profiles*

c_4 = *factor for the rudder arrangement:*
= *1,0 for rudders in the propeller jet*
= *1,5 for rudders outside the propeller jet*

For semi-spade rudder 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%.

4. Materials and Welding

4.1 For materials for rudder stock, pintles, coupling bolts and cast parts of rudders are to be made of rolled, forged or cast carbon manganese steel in accordance with Rules for Materials (Pt.1, Vol.V) and Rules for Welding (Pt.1, Vol.VI). Special material requirements are to be observed for the ice Class Notations **ES3** and **ES4**.

4.2 In general materials having a minimum nominal upper yield point R_{eH} of less than 200 N/mm^2 and a minimum tensile strength of less than 400 N/mm^2 or more than 900 N/mm^2 shall not be used for rudder stocks, pintles, keys and bolts.

The requirements of this Section are based on a material's minimum nominal upper yield point 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 as follows:

$$k_r = \left(\frac{235}{R_{eH}}\right)^{0,75} \quad \text{for } R_{eH} > 235 \quad [\mathrm{N/mm^2}]$$

$$= \frac{235}{R_{eH}} \quad \text{for } R_{eH} \leq 235 \quad [\mathrm{N/mm^2}]$$

R_{eH} = minimum nominal upper yield point of material used [N/mm^2].
R_{eH} is not to be taken greater than $0,7 \cdot R_m$ or 450 N/mm^2, whichever is less.

R_m = tensile strength [N/mm^2] of the material used.

(IACS UR S10.1.3.5)

4.3 Before significant reductions in rudder stock diameter due to the application of steels with R_{eH} exceeding 235 N/mm^2 are granted, BKI 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 S10.4.3)

4.4 Steel grade of plating materials for rudders and rudder horns are to be in accordance with Table 2.9.

(IACS UR S10.1.3.3)

4.5 Welded parts of rudders are to be made of approved rolled hull materials.

(IACS UR S10.1.3.1)

4.6 Slot-welding is to be limited as far as possible. Slot welding is not to be used in areas with large in-plane stresses transversely to the slots or in way of cut-out areas of semi-spade rudders.

When slot welding is applied, the length of slots is to be minimum 75 mm with breadth of $2 \cdot t$, where t is the rudder plate thickness [mm]. The distance between ends of slots is not to be more than 125 mm. The slots are to be fillet welded around the edges and filled with a suitable compound, e.g. epoxy putty. Slots are not to be filled with weld.

Continuous slot welds are to be used in lieu of slot welds. When continuous slot welding is applied, the root gap is to be between 6-10 mm. The bevel angle is to be at least 15°.

(IACS UR S10.1.4.1)

4.7 In way of the rudder horn recess of semi-spade rudders, the radii in the rudder plating except in way of solid part in cast steel are not to be less than 5 times the plate thickness, but in no case less than 100 mm. Welding in side plate is to be avoided in or at the end of the radii. Edges of side plate and weld adjacent to radii are to be ground smooth.

(IACS UR S10.1.4.2)

4.8 Welds in the rudder side plating subjected to significant stresses from rudder bending and welds between plates and heavy pieces (solid parts in forged or cast steel or very thick plating) are to be made as full penetration welds. In way of highly stressed areas e.g. cut-out of semi-spade rudder and upper part of spade rudder, cast or welding on ribs is to be arranged. Two sided full penetration welding is normally to be arranged. Where back welding is impossible welding is to be performed against ceramic backing bars or equivalent. Steel backing bars may be used and are to be fitted with continuous welded on one side to the bevelled edge, See Fig. 14.1. The bevel angle is to be at least 15° for one sided welding.

(IACS UR S10.1.4.3)

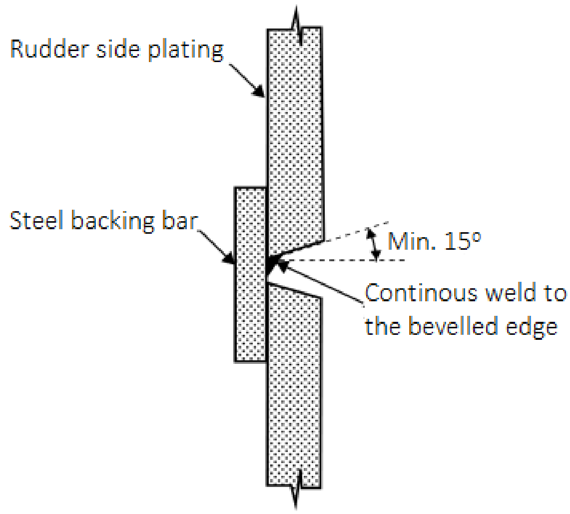


Fig. 14.1 Use of steel backing bar in way of full penetration welding of rudder side plating

5. Definitions

C_R	=	rudder force [N]
Q_R	=	rudder torque [Nm]
A	=	total movable area of the rudder [m^2], measured at the mid-plane of the rudder. For nozzle rudders, A is not to be taken less than 1,35 times the projected area of the nozzle.
A_t	=	A + area of a rudder horn, if any, [m^2]
A_f	=	portion of rudder area located ahead of the rudder stock axis [m^2]
A_{1a}	=	portion of A_1 situated aft of the centre line of the rudder stock.
A_{1f}	=	portion of A_1 situated ahead of the centre line of the rudder stock.
A_{2a}	=	portion of A_2 situated aft of the centre line of the rudder stock.
A_{2f}	=	portion of A_2 situated ahead of the centre line of the rudder stock.
b	=	mean height of the rudder area, in [m]. Mean breadth and mean height of rudder are calculated according to the coordinate system in Fig. 14.1a
c	=	mean breadth of rudder area [m] (see Fig. 14.1a)
Λ	=	aspect ratio of rudder area A_t

$= \dfrac{b^2}{A_t}$

v_0 = ahead speed of ship [kn] as defined in Section 1, H.5; if this speed is less than 10 kn, v_0 is to be taken as

v_{min} = $\dfrac{(v_0 + 20)}{3}$ [kn]

v_a = astern speed of ship [kn], as defined in SOLAS Regulation II-1/3.15; however in no case taken less then 0,5 · v_0

k = material factor according to Section 2, B

For ships strengthened for navigation in ice Section 15, B.9 have to be observed.

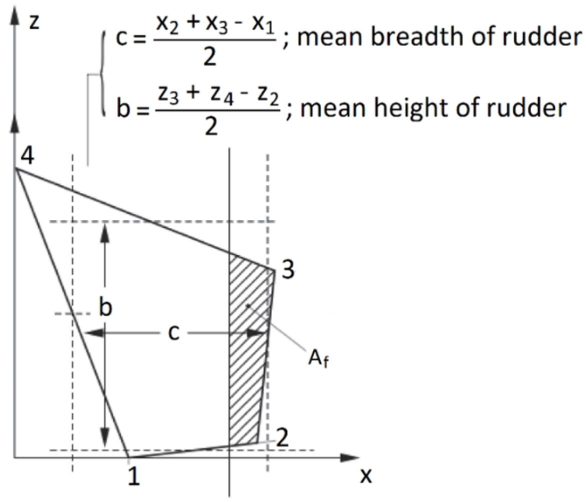


Fig. 14.2 Rudder area geometry

B. Rudder Force and Torque

1. Rudder force and torque for normal rudders

1.1 The rudder force is to be determined according to the following formula:

$$C_R = 132 \cdot A \cdot v^2 \cdot \kappa_1 \cdot \kappa_2 \cdot \kappa_3 \qquad [N]$$

v = v_0 for ahead condition

= v_a for astern condition

κ_1 = coefficient, depending on the aspect ratio Λ

= $(\Lambda + 2)/3$, where Λ need not be taken greater than 2,0

κ_2 = coefficient, depending on the type of the rudder and the rudder profile according to Table 14.1

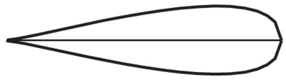
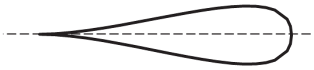
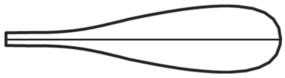
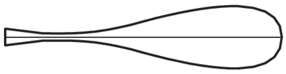
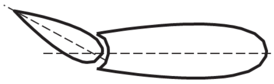
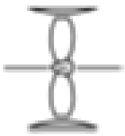
$\varkappa_3$ = coefficient, depending on the location of the rudder

= 0,8 for rudders outside the propeller jet

= 1,0 elsewhere, including also rudders within the propeller jet

= 1,15 for rudders aft of the propeller nozzle

Table 14.1 Coefficient κ_2

	Profile Type	κ_2	
		Ahead Condition	**Astern Condition**
1	Single plate 	1,0	1,0
2	NACA-00 series Göttingen profiles 	1,1	0,80
3	Flat Side 	1,1	0,90
4	Mixed profiles (e.g. NACA-series 63, 64; HSVA MP71, MP73) 	1,21	0,90
5	Hollow 	1,35	0,90
6	Fish tail (e.g., Schilling high-lift rudder) 	1,4	0,8
7	Flap rudder 	1,7	1,3
8	Nozzle rudder 	1,9	1,5

(IACS UR S10.2.1.1)

1.2 The rudder torque is to be determined by the following formula:

$Q_R = C_R \cdot r$ [Nm]

r = lever, defined as :

= $c \cdot (\alpha - k_b)$ [m]

α = 0,33 for ahead condition

= 0,66 for astern condition (general)

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

α = 0,25 for ahead condition

= 0,55 for astern condition.

k_b = balance factor as follows:

$$= \frac{A_f}{A}$$

r_{min} = $0{,}1 \cdot c$ [m] for ahead condition.

(IACS UR S10.2.1.2)

2. Rudder force and torque for rudder blades with cut-outs (semi-spade rudders)

2.1 The total rudder force C_R is to be calculated according to 1.1. The pressure distribution over the rudder area, upon which the determination of rudder torque and rudder blade strength is to be based, is to be derived as follows:

The rudder area may be divided into two rectangular or trapezoidal parts with areas A_1 and A_2 so that $A = A_1 + A_2$ (see Fig. 14.3).

The resulting force of each part may be taken as:

$$C_{R1} = C_R \frac{A_1}{A} \quad [N]$$

$$C_{R2} = C_R \frac{A_2}{A} \quad [N]$$

(IACS UR S10.2.2)

2.2 The resulting torque of each part may be taken as:

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

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

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

$$r_1 = c_1 \,(\alpha - k_{bl}) \quad [m]$$

$$r_2 = c_2 \,(\alpha - k_{b2}) \quad [m]$$

$$k_{b1} = \frac{A_{1f}}{A_1}$$

$$k_{b2} = \frac{A_{2f}}{A_2}$$

A_{1f}, A_{2f} see Fig. 14.3

(IACS UR S10.2.2)

$$c_1 = \frac{A_1}{b_1}$$

$$c_2 = \frac{A_2}{b_2}$$

b_1, b_2 = mean heights of the partial rudder areas A_1 and A_2 (see Fig. 14.3)

c_1, c_2 = mean breadth of partial areas A_1 and A_2 (see Fig. 14.3)

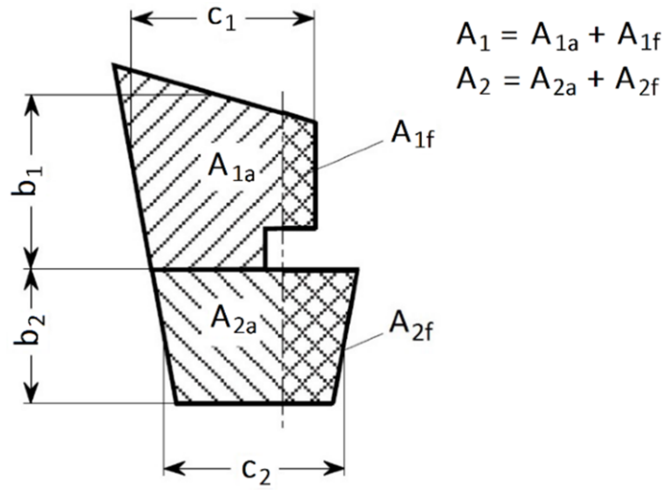


Fig. 14.3 - Partial area A_1 **and** A_2

2.3 The total rudder torque is to be determined according to the following formulae:

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

$_{Rmin} = C_R \cdot r_{1,2min}$ [Nm]

The greater value is to be taken.

$r_{1,2min}$ = minimum total lever, defined as :

$= \dfrac{0,1}{A}(c_1 \cdot A_1 + c_2 \cdot A_2)$ [m] for ahead condition

(IACS UR S10.2.2)

C. Scantlings of the Rudder Stock

1. Rudder stock diameter

1.1 The diameter of the rudder stock for transmitting the torsional moment is not to be less than:

$D_t = 4,2 \cdot \sqrt[3]{Q_R \cdot k_r}$ [mm]

Q_R see B.1.2 and B.2.2 - 2.3.

The related torsional stress is:

$\tau \leq \dfrac{68}{k_r}$ [N/mm^2]

k_r see A.4.2.

(IACS UR S10.4.1)

1.2 The steering gear is to be determined according to Rules for Machinery Installations (Pt.1, Vol.III) Sec.14 for the rudder torque Q_R as required in B.1.2, B.2.2 or B.2.3 and under consideration of the frictional losses at the rudder bearings.

1.3 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 0,9D_t. The length of the edge of the quadrangle for the auxiliary tiller shall not be less than 0,77D_t and the height not less than 0,8D_t.

1.4 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.

2. Strengthening of rudder stock

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:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} \leq \frac{118}{k_r} \quad [N/mm^2]$$

Bending stress:

$$\sigma_b \leq \frac{10,2 \cdot M_b}{D_1^3} \cdot 10^3 \quad [N/mm^2]$$

M_b = bending moment at the neck bearing [Nm]

Torsional stress:

$$\tau \leq \frac{5,1 \cdot Q_R}{D_1^3} \cdot 10^3 \quad [N/mm^2]$$

D_1 = increased rudder stock diameter [mm]

The increased rudder stock diameter may be determined by the following formula:

$$D_1 = D_t \sqrt[6]{1 + \frac{4}{3}\left[\frac{M_b}{Q_R}\right]^2} \quad [mm]$$

Q_R see B.1.2 and B.2.2 - 2.3.

D_t see 1.1.

For a spade rudder with trunk extending inside the rudder, the rudder stock scantlings shall be checked against the two cases defined in 3.

(IACS UR S10.4.2)

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.

3. Analysis

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. 14.4 – Fig. 14.8 as outlined in 3.2 - 3.3.

(IACS UR S10 Annex)

3.2 Data for the analysis

ℓ_{10} - ℓ_{50} = lengths of the individual girders of the system [m]

I_{10} – I_{50} = moments of inertia of these girders [cm^4]

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

ℓ_{50} = effective length of sole piece [m]

I_{50} = moments of inertia of sole piece around z-axis [cm^4]

Load on rudder body:

— Load on spade rudder and rudder support by sole piece

$$p_R = \frac{C_R}{\ell_{10} \cdot 10^3} \quad [kN/m]$$

— Load on spade rudder with trunk

$$p_R = \frac{C_R}{(\ell_{10} + \ell_{20}) \cdot 10^3} \quad [kN/m]$$

— Load on semi-spade rudders with one elastic support and two elastic support

$$p_{R10} = \frac{C_{R2}}{\ell_{10} \cdot 10^3} \quad [kN/m]$$

$$p_{R20} = \frac{C_{R1}}{\ell_{20} \cdot 10^3} \quad [kN/m]$$

C_R, C_{R1}, C_{R2} see B.1 and B.2.

Z = spring constant of support in the sole piece or rudder horn respectively

$= \frac{6,18 \cdot I_{50}}{\ell_{50}^3}$ [kN/m] for the support in the sole piece (Fig. 14.4)

$= \frac{1}{f_b + f_t}$ [kN/m] for the support in the rudder horn (one elastic support) (Fig. 14.5)

f_b = unit displacement of rudder horn [m] due to a unit force of 1,0 kN acting in the centre of support

$= 0,21 \frac{d^3}{I_n}$ [m/kN] (guidance value for steel)

I_n = moment of inertia of rudder horn around the x-axis at d/2 [cm^4] (see also Fig. 14.5)

f_t = unit displacement due to torsional moment of the amount $1 \cdot e$ [kNm]

$= \frac{d \cdot e^2}{G \cdot J_t}$ [m/kN] in general

$= \frac{d \cdot e^2 \cdot \Sigma u_i/t_i}{3,14 \cdot 10^8 \cdot F_T^2}$ [m/kN] for steel

G = modulus of rigidity

$= 7,92 \cdot 10^7$ [kN/m^2] for steel

J_t = torsional moment of inertia [m^4]

F_T = mean sectional area of rudder horn [m^2]

u_i = breadth [mm] of the individual plates forming the mean horn sectional area

t_i = plate thickness within the individual breadth u_i [mm]

e, d = distances [m] according to Fig. 14.5

K_{11}, K_{12}, K_{22} = rudder horn compliance constants calculated for rudder horn with 2-conjugate elastic supports (Fig. 14.8). The 2-conjugate elastic supports are defined in terms of horizontal displacements, y_i, by the following equations :

y_1 = $-K_{12}\,B_2 - K_{22}\,B_1$ at the lower rudder horn bearing

y_2 = $-K_{11}\,B_2 - K_{12}\,B_1$ at the upper rudder horn bearing

y_1, y_2 = horizontal displacements [m] at the lower and upper rudder horn bearings, respectively.

B_1, B_2 = horizontal support forces [kN] at the lower and upper rudder horn bearings, respectively.

K_{11}, K_{12}, K_{22} = Obtained [m/kN] from the following formulae:

$$K_{11} = 1,3\,\frac{\lambda^3}{3E\,J_{1h}} + \frac{e^2\,\lambda}{G\,J_{th}}$$

$$K_{12} = 1,3\left[\frac{\lambda^3}{3E\,J_{1h}} + \frac{\lambda^2(d-\lambda)}{2E\,J_{1h}}\right] + \frac{e^2\,\lambda}{G\,J_{th}}$$

$$K_{22} = 1,3\left[\frac{\lambda^3}{3\,E\,J_{1h}} + \frac{\lambda^2(d-\lambda)}{E\,J_{1h}} + \frac{\lambda(d-\lambda)^2}{E\,J_{1h}} + \frac{(d-\lambda)^3}{3\,E\,J_{2h}}\right] + \frac{e^2\,d}{G\,J_{th}}$$

d = height if the rudder horn [m] according to Fig. 14.8. This value is to be measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the lower rudder horn pintle

λ = Length, in m, as defined in Fig. 14.8. This length is measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the upper rudder horn bearing. For $\lambda = 0$, the above formulae converge to those of spring constant Z for a rudder horn with 1-elastic support, and assuming a hollow cross section for this part.

e = Rudder-horn torsion lever [m] as defined in Fig. 14.8 (value taken at z = d/2).

J_{1h} = Moment of inertia of rudder horn about the x axis [m^4] for the region above the upper rudder horn bearing. Note that J_{1h} is an average value over the length λ (see Fig. 14.8).

J_{2h} = Moment of inertia of rudder horn about the x axis [m^4] for the region between the upper and lower rudder horn bearings. Note that J_{2h} is an average value over the length d - λ (see Fig. 14.8).

J_{th} = Torsional stiffness factor of the rudder horn [m^4] for any thin wall closed section to be calculated from the following formula:

$$= \frac{4\,F_T^2}{\sum_i \frac{u_i}{t_i}}$$

F_T = Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn [m^2].

u_i = Length [mm] of the individual plates forming the mean horn sectional area.

t_i = Thickness [mm] of the individual plates mentioned above.

Note that the J_{th} value is taken as an average value, valid over the rudder horn height.

(IACS UR S10.1-6 ANNEX)

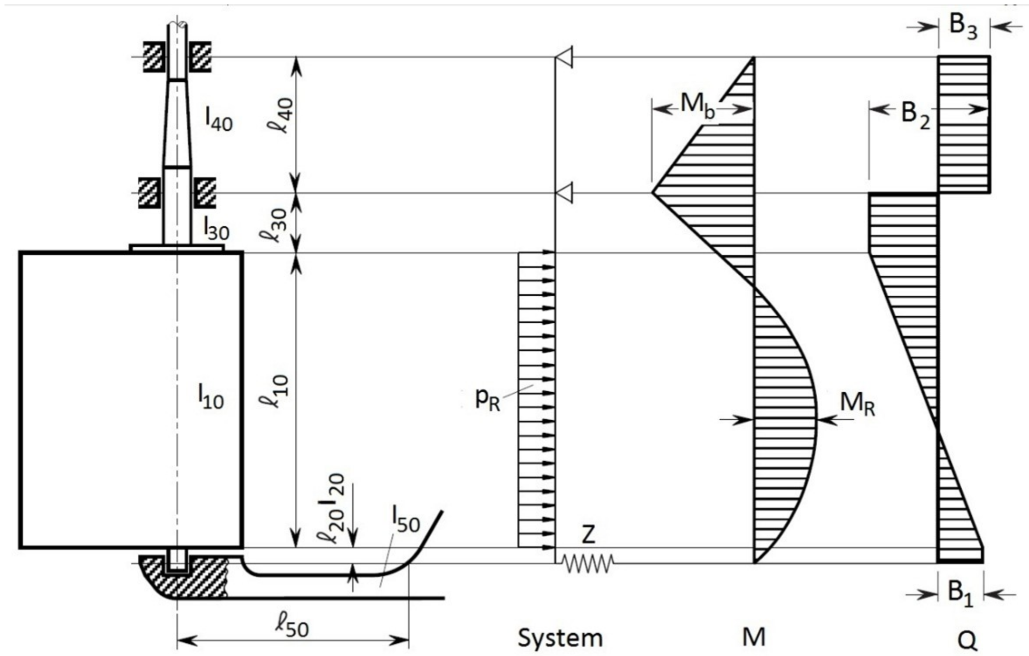


Fig. 14.4 Rudder supported by sole piece

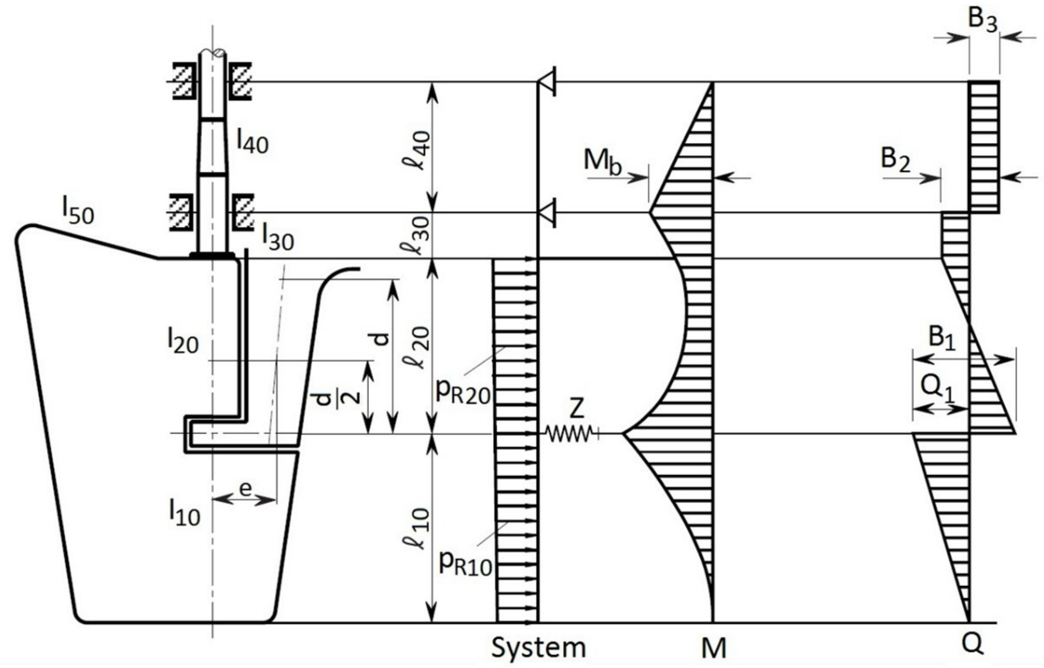


Fig. 14.5 Semi-spade rudder with one elastic support

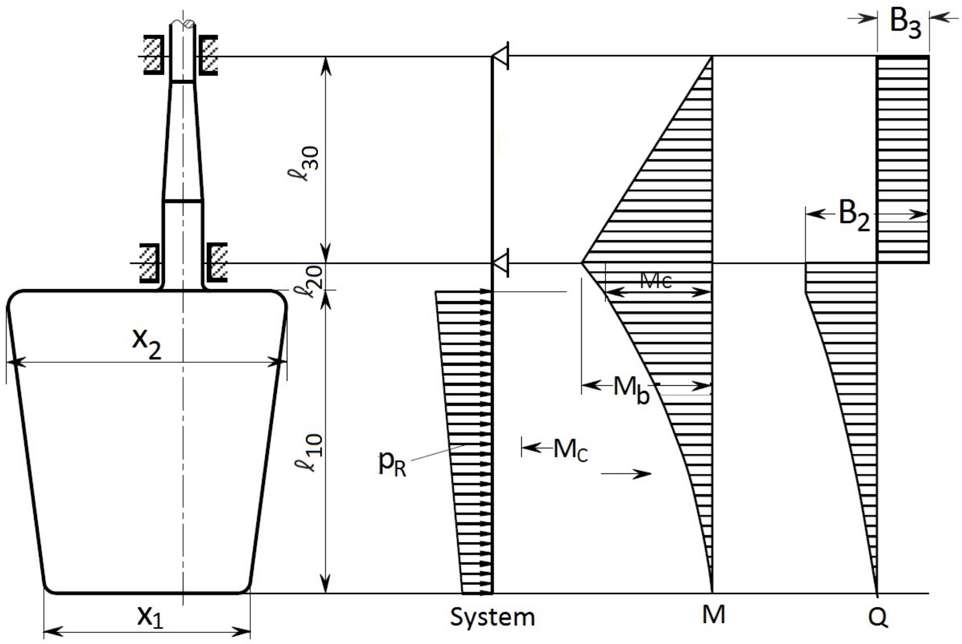
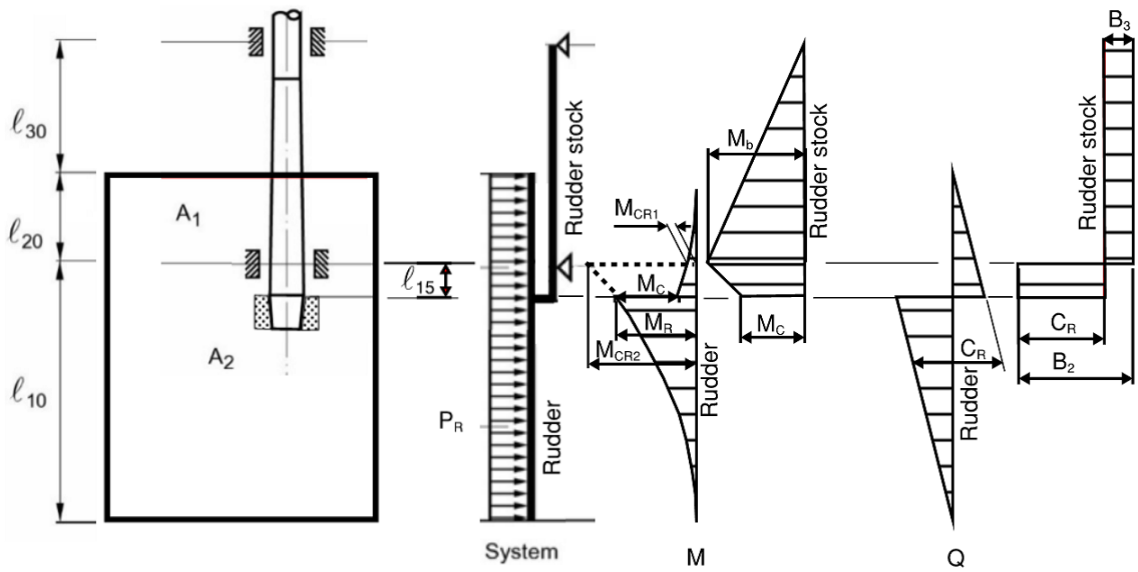
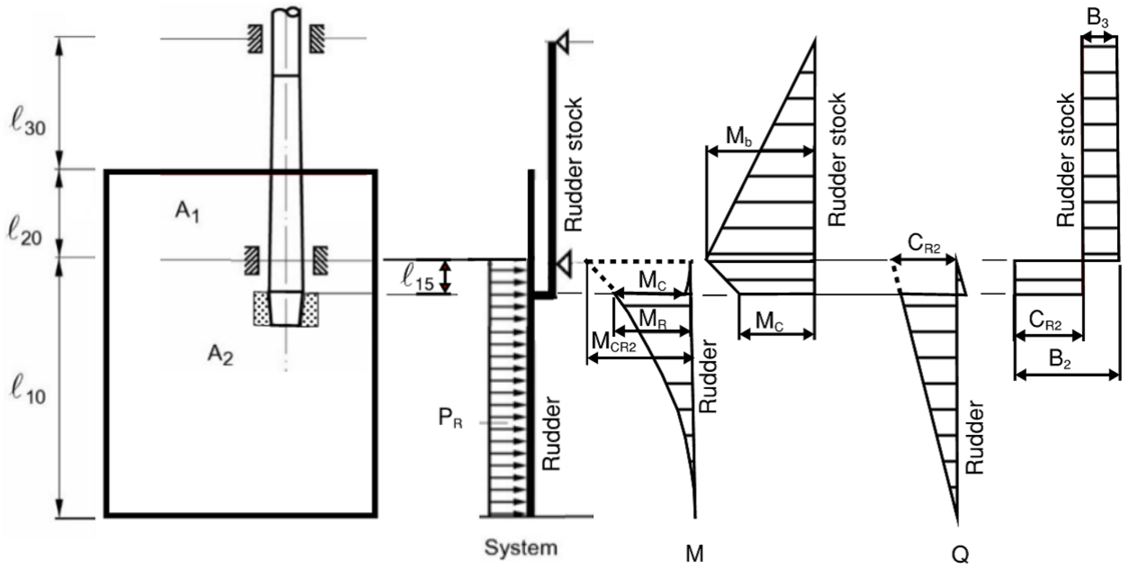


Fig. 14.6 Spade rudder



Full rudder force $C_R = C_{R1} + C_{R2}$ and total rudder torque $Q_R = Q_{R1} + Q_{R2}$ with rudders stock bending moment $M_b = M_{CR2} - M_{CR1}$

Fig. 14.7a Spade rudders with rudder trunks inside the rudder body



Rudder force C_{R2} corresponding to rudder torque Q_{R2} acting at rudder blade area A_2 with rudders stock bending moment $M_b = M_{CR2}$

Fig. 14.7b Spade rudders with rudder trunks inside the rudder body

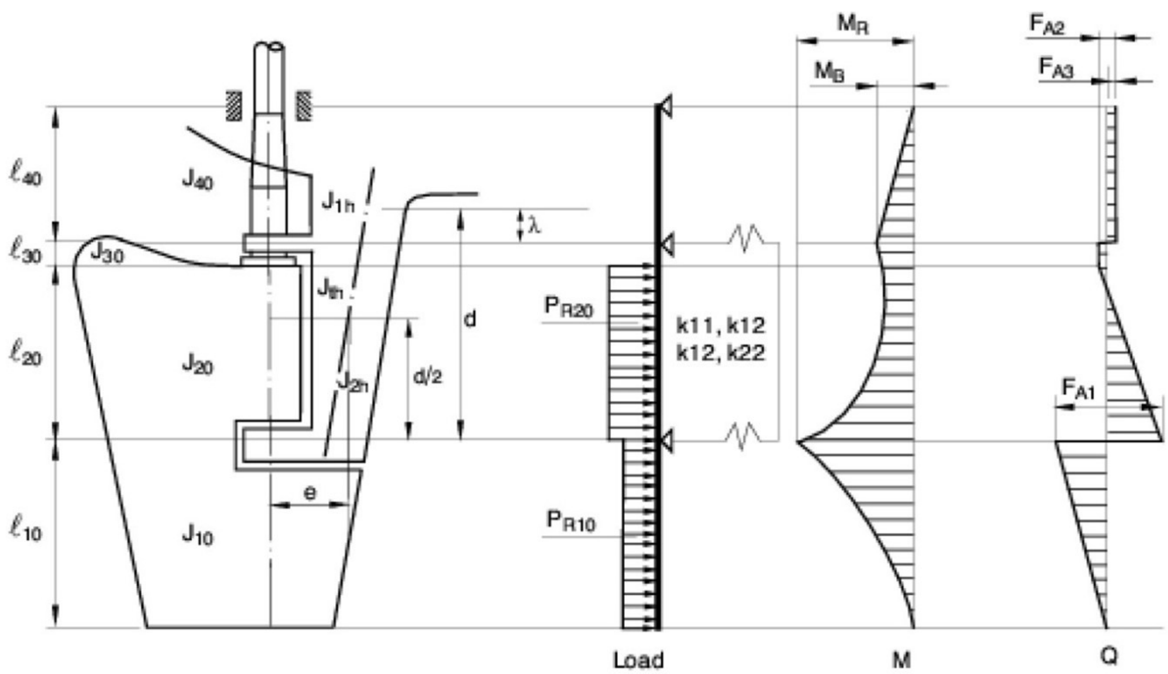


Fig. 14.8 Semi-spade rudders with two elastic supports

3.3 Moments and shear forces to be evaluated

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_l, B_2, B_3 are to be evaluated.

The so evaluated moments and forces are to be used for the stress analyses required by 2 and E.1 of this Section and by Section 13, C.3 - C.6 for rudder horn of semi spade rudder.

3.3.2 For spade rudders (see Fig. 14.6) the moments and shear forces may be determined by the following formulae:

$$M_b = C_R \cdot \left[\ell_{20} + \frac{\ell_{10} \cdot (2x_1 + x_2)}{3 \cdot (x_1 + x_2)}\right] \quad [Nm]$$

$$B_3 = \frac{M_b}{\ell_{30}} \quad [N]$$

$$B_2 = C_R + B_3 \quad [N]$$

The maximum moment, M_C, in top of the cone coupling as shown in Fig. 14.6 is applicable for the connection between the rudder and the rudder stock.

(IACS UR S10.2 ANNEX)

3.3.3 For a spade rudder with trunk extending inside the rudder body, the strength shall be checked against the following two cases:

1) pressure applied on the entire rudder area
2) pressure applied only on rudder area below the middle of neck bearing.

The moments and shear forces for the two cases defined according to Fig. 14.7a and b, may be determined by the following formulae:

C_{R1} = rudder force over the partial rudder area A_1 according to B.2.1 [N]

C_{R2} = rudder force over the partial rudder area A_2 according to B.2.1 [N]

$$M_{CR1} = C_{R1} \cdot \ell_{20} \cdot \left[1 + \frac{2 \cdot x_2 + x_3}{3 \cdot (x_2 + x_3)}\right] \quad [Nm]$$

$$M_{CR2} = C_{R2} \cdot \frac{\ell_{10} \cdot (2 \cdot x_1 + x_2)}{3 \cdot (x_1 + x_2)} \quad [Nm]$$

$$M_R = \text{Max}\,(M_{CR1}, M_{CR2}) \quad [Nm]$$

M_b = bending moment [Nm], as defined in Fig. 14.7a and b

$$C_R = C_{R1} + C_{R2}$$

$$B_3 = \frac{M_{CR2} - M_{CR1}}{\ell_{20} + \ell_{30}} \quad [N]$$

$$B_2 = C_R + B_3 \quad [N]$$

(IACS UR S10.3 ANNEX)

3.3.4 Moment and shear force rudder support by sole piece are indicated in Fig. 14.4

(IACS UR S10.4 ANNEX)

3.3.5 For semi spade rudder with one elastic support the moment and shear force are indicated in Fig. 14.5. The calculation of the rudder horn may be determined using the requirements in Section 13, C.5.

(IACS UR S10.5 ANNEX)

3.3.6 For semi spade rudder with two elastic support the moment and shear force are indicated in Fig. 14.8. The calculation of the rudder horn may be determined using the requirements in Section 13, C.6.

(IACS UR S10.6 ANNEX)

4. Rudder trunk

4.1 In case where the rudder stock is fitted with a rudder trunk configurations which are extended below stern frame and arranged in such a way the rudder trunk is loaded by the pressure induced on the rudder blade, as given in B.1.1, the bending stress in the rudder trunk, in N/mm^2, is to be in compliance with the following formula:

$$\sigma_b \leq 80/k$$

where the material factor k for the rudder trunk is not to be taken less than 0,7.

The equivalent stress due to bending and shear is not to exceed 0,35 · R_{eH}.

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.

(IACS UR S10.9.3.2)

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.

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.

For rudder trunks extending below shell or skeg. The fillet shoulder radius r [mm] (see Fig. 14.9) is to be as large as practicable and to comply with the following formulae:

$$r = 0{,}1 \cdot \frac{D_1}{k}$$

without being less than:

$$r = 60 \quad [\text{mm}] \quad \text{when } \sigma \geq 40 / k \quad [\text{N/mm}^2]$$

$$r = 30 \quad [\text{mm}] \quad \text{when } \sigma < 40 / k \quad [\text{N/mm}^2]$$

where:

D_1 = rudder stock diameter axis defined in 2

σ = bending stress in the rudder trunk [N/mm^2]

k = material factor for rudder trunk, as given in Section 2 or A.4.2 respectively

(IACS UR S10.9.3.1)

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.

4.4.1 In case the rudder trunk is welded directly into the skeg bottom or shell, hot spot stress has to be determined according to Secction 20, C.

In this case FAT class $\Delta\sigma_R$ = 100 has to be used, see Section 20, C.3.

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 E2 or E3 according to 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 3.2.

4.4.3 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.

Rudder trunks comprising of materials other than steel are to be specially considered by BKI.

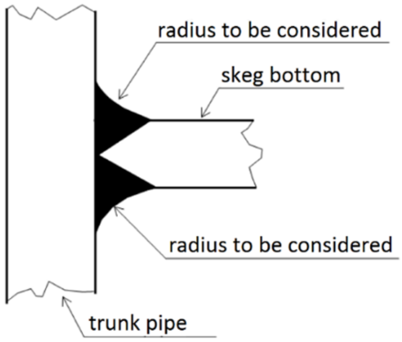


Fig. 14.9 Fillet shoulder radius

(IACS UR S10.9.3.1)

D. Rudder Couplings

1. General

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.

1.2 The distance of bolt axis from the edges of the flange is not to be less than 1,2 the diameter of the bolt. In horizontal couplings, at least 2 bolts are to be arranged forward of the stock axis.

1.3 The coupling bolts are to be fitted bolts. The bolts and nuts are to be effectively secured against loosening, e.g. according to recognized standards.

(IACS UR S10.6.1.5)

1.4 For spade rudders horizontal couplings according to 2. are permissible only where the required thickness of the coupling flanges t_f is less than 50 mm, otherwise cone couplings according to 4. are to be applied. For spade rudders of the high lift type, only cone couplings according to 4. are permitted.

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 D.4), the contact area between the mating surfaces is to be demonstrated to the Surveyor by 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.

2. Horizontal couplings

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

$$d_b = 0,62 \cdot \sqrt{\frac{D^3 \cdot k_b}{k_r \cdot n \cdot e}} \quad [mm]$$

D = rudder stock diameter according to C [mm]

n = total number of bolts, which is not to be less than 6

e = mean distance of the bolt axes from the centre of bolt system [mm]

k_r = material factor for the rudder stock as given in A.4.2

k_b = material factor for the bolts analogue to A.4.2.

(IACS UR S10.6.1.1)

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

$$t_f = 0,62 \cdot \sqrt{\frac{D^3 \cdot k_f}{k_r \cdot n \cdot e}} \quad [mm]$$

$$t_{fmin} = 0,9 \cdot d_b \quad [mm]$$

k_f = material factor for the coupling flanges analogue to A.4.2

The thickness of the coupling flanges clear of the bolt holes is not to be less than 0,65 · t_f.

The width of material outside the bolt holes is not to be less than 0,67 · d_b.

(IACS UR S10.6.1.2 and IACS UR S10.6.1.3)

2.3 The coupling flanges are to be equipped with a fitted key according to DIN 6885 or equivalent standards for relieving the bolts.

The fitted key may be dispensed with if the diameter of the bolts is increased by 10%.

2.4 Horizontal coupling flanges should either be forged together with the rudder stock or be welded to the rudder stock as outlined in Section 19, B.4.4.3.

(IACS UR S10.6.1.4)

2.5 For the connection of the coupling flanges with the rudder body see also Section 19, B.4.4.

3. Vertical couplings

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

$$d_b = \frac{0,81 \cdot D}{\sqrt{n}} \sqrt{\frac{k_b}{k_r}} \quad [mm]$$

D, k_b, k_r, n see 2.1, where n is not to be less than 8.

3.2 The first moment of area of the bolts about the centre of the coupling is not to be less than:

$$S = 0,00043 \,.\, D^3 \quad [cm^3]$$

3.3 The thickness of the coupling flanges is not to be less than:

$$t_f = d_b \quad [mm]$$

The width of material outside the bolt holes is not to be less than 0,67 · d_b.

3.4 Coupling bolts are to be fitted bolts and their nuts are to be locked effectively.

(IACS UR S10.6.1.5)

4. Cone couplings

4.1 Cone couplings with key

4.1.1 Cone couplings without hydraulic arrangements for mounting and dismounting should have a taper c on diameter of 1: 8 - 1:12.

$$c = \frac{(d_O - d_U)}{\ell}$$

The diameters d_0 [mm] and d_u [mm] are shown in Fig. 14.10 and the cone length, ℓ_C [mm], is defined in Fig. 14.11b.

The cone shapes should fit very exact. The nut is to be carefully secured, e.g. by securing plate as shown in Fig. 14.10

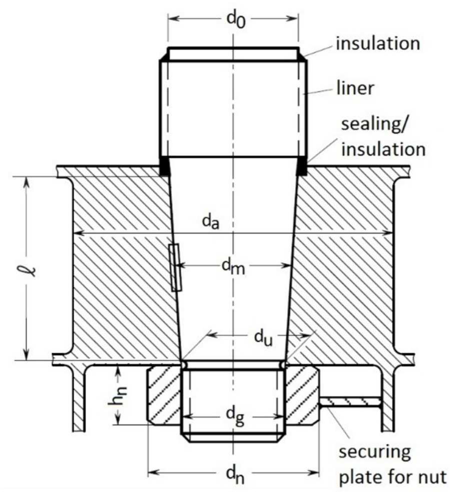


Fig. 14.10 Cone coupling with key and securing plate

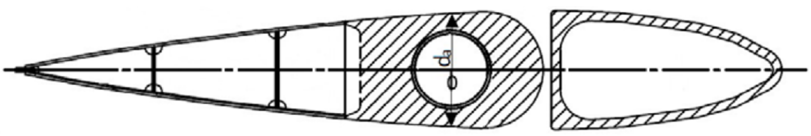


Fig. 14.11a Gudgeon outer diameter(d_a) measurement

(IACS UR S10.6.3.1)

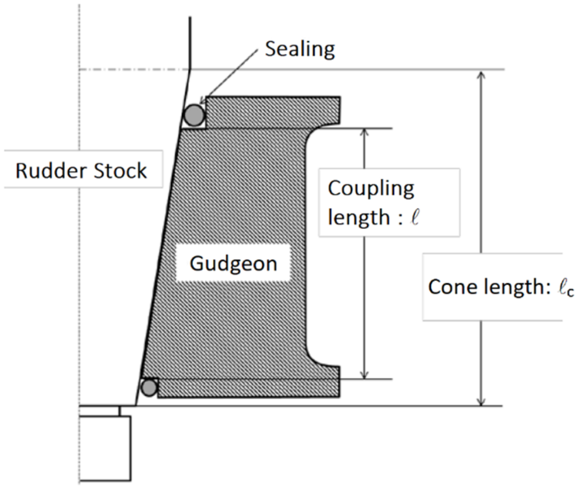


Fig. 14.11b Cone length and coupling length

(IACS UR S10.6.3.1)

4.1.2 The coupling length ℓ [mm] shall, in general, not be less than 1,5 · d_0.

4.1.3 For couplings between stock and rudder a key is to be provided, the shear area of which is not to be less than:

$$a_s = \frac{17,55 \cdot Q_F}{d_k \cdot R_{eH,1}} \quad [cm^2]$$

Q_F = design yield moment of rudder stock [Nm] according to F.

d_k = diameter of the conical part of the rudder stock [mm] at the key

R_{eH1}, = minimum nominal upper yield point of the key material [N/mm^2]

(IACS UR S10.6.3.2)

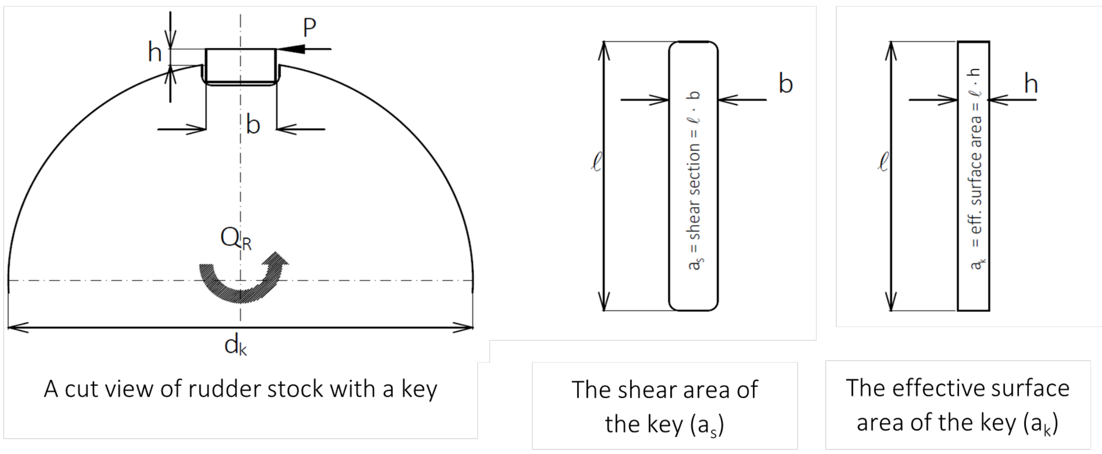
4.1.4 The effective surface area of the key (without rounded edges) between key and rudder stock or cone coupling, is not to be less than:

$$a_k = \frac{5 \cdot Q_F}{d_k \cdot R_{eH,2}} \quad [cm^2]$$

$R_{eH,2}$, = minimum nominal upper yield point of the key, stock or coupling material [N/mm^2], whichever is less.

(IACS UR S10.6.3.2)

Note:
Ilustration of spie dimensions.



4.1.5 The dimensions of the slugging nut are to be as follows, see Fig. 14.10:

— height:

$h_n \geq 0,6 \cdot d_g$

— outer diameter (the greater value to be taken):

$d_n \geq 1,2 \cdot d_u$ or $d_n \geq 1,5 \cdot d_g$

— external thread diameter:

$d_g \geq 0,65 \cdot d_0$

(IACS UR S10.6.3.3)

4.1.6 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 4.2.3 for a torsional moment $Q_F' = 0{,}5 \cdot Q_F$

(IACS UR S10.6.3.4)

4.2 Cone couplings with special arrangements for mounting and dismounting the couplings

4.2.1 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 should be more slender, c $\approx$ 1:12 to $\approx$ 1 : 20.

(IACS UR S10.6.4.1)

4.2.2 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. 14.12.

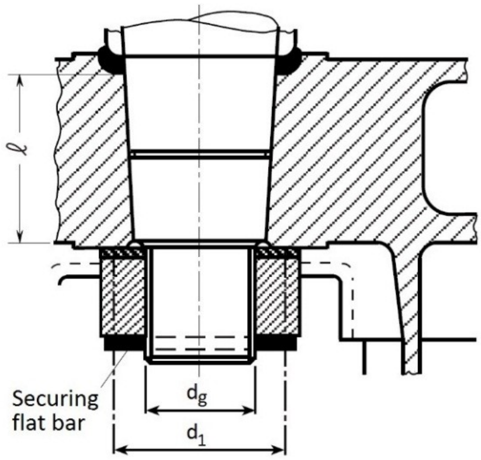


Fig. 14.12 Cone coupling without key and with securing flat bar

A securing flat bar will be regarded as an effective securing device of the nut, if its shear area is not less than:

$$A_s = \frac{P_s \cdot \sqrt{3}}{R_{eH}} \qquad [mm^2]$$

P_s = shear force as follows

$$= \frac{P_e}{2} \cdot \mu_1 \cdot \left[\frac{d_1}{d_g} - 0,6\right] \qquad [N]$$

P_e = push-up force according to 4.2.3.2 [N]

μ_1 = frictional coefficient between nut and rudder body, normally μ_1 = 0,3

d_1 = mean diameter of the frictional area between nut and rudder body, see Fig. 14.12

d_g = thread diameter of the nut

4.2.3 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.

4.2.3.1 Push-up pressure

The push-up pressure is not to be less than the greater of the two following values :

$$p_{req1} = \frac{2 \cdot Q_F \cdot 10^3}{d_m^2 \cdot \ell \cdot \pi \cdot \mu_0} \qquad [N/mm^2]$$

$$p_{req2} = \frac{6 \cdot M_c \cdot 10^3}{\ell^2 \cdot d_m} \quad [N/mm^2]$$

Q_F = design yield moment of rudder stock according to F [Nm]

d_m = mean cone diameter [mm], see Fig. 14.10

ℓ = coupling length [mm]

μ_0 = 0,15 (frictional coefficient)

M_C = bending moment in rudder stock at the top of the cone coupling (e.g. in case of spade rudders) [Nm]

For spade rudder with trunk extending inside the rudder, the coupling shall be checked against the two cases defined in C.3.

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 :

$$p_{perm} = \frac{0,95 \cdot R_{eH}(1 - \alpha^2)}{\sqrt{3 + \alpha^4}} - p_b \quad [N/mm^2]$$

where:

p_b = $\frac{3,5 \cdot M_C}{d_m \cdot \ell^2} \cdot 10^3$

R_{eH} = yield point [N/mm²] of the material of the gudgeon

α = d_m / d_a (see Fig. 14.10)

d_a = the outer diameter of the gudgeon [mm], see Fig. 14.10 and Fig. 14.11a. The diameter shall not be less than values below (the least diameter is to be considered):

= $1,25 \cdot d_o$ [mm]

For d_o, see Fig. 14.10.

(IACS UR S10.6.4.2)

4.2.3.2 Push-up length

The required push-up length $\Delta\ell$ [mm], $\Delta\ell$ is to comply with the following formula:

$$\Delta\ell_1 \leq \Delta\ell \leq \Delta\ell_2$$

$$\Delta\ell_1 = \frac{p_{req} \cdot d_m}{E \left[\frac{1-\alpha^2}{2}\right] c} + 0,8 \cdot \frac{R_{tm}}{c} \quad [mm]$$

$$\Delta\ell_2 = \frac{p_{perm} \cdot d_m}{E \left[\frac{1-\alpha^2}{2}\right] c} + \frac{0,8 \cdot R_{tm}}{c} \quad [mm]$$

R_{tm} = mean roughness [mm]

$\approx$ 0,01 mm

c = taper on diameter according to 4.1.1

(IACS UR S10.6.4.3)

Note:
In case of hydraulic pressure connections the required push-up force P_e for the cone may be determined by the following formula :

$$P_e = p_{req} \cdot d_m \cdot p \cdot \ell \cdot \left(\frac{c}{2} + 0,02\right) \quad [N]$$

The value 0,02 in above formula is a reference value 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 BKI.

4.2.4 The required push-up pressure [N/mm^2] for pintle in case of dry fitting is to be determined by p_{req1} as given below.

The required push-up pressure for pintle in case of oil injection fitting, is to be determined by the maximum pressure of p_{req1} and p_{req2} as given below:

$$p_{req1} = 0,4 \frac{B_1 \cdot d_0}{d_m^2 \cdot \ell} \quad [N/mm^2]$$

$$p_{req2} = \frac{6 \cdot M_{bp}}{\ell^2 \cdot d_m} 10^3 \quad [N/mm^2]$$

B_l = supporting force in the pintle bearing [N], see also Fig. 14.5

d_m, ℓ = see 4.2.3

d_0 = pintle diameter [mm] according to Fig. 14.10.

M_{bp} = bending moment in the pintle cone coupling to be determined by:

= $B_1 \cdot \ell_a$

ℓ_a = length between middle of pintle-bearing and top of contact surface between cone coupling and pintle [m], see Fig. 14.13)

The required push-up length ($\Delta\ell$) is to be calculated similarly as in D.4.2.3.2 using the required push-up pressure as defined above, and properties for the pintle.

(IACS UR S10.7.2.2)

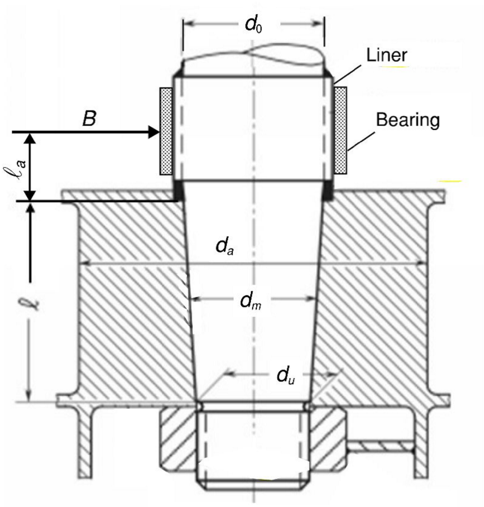


Fig. 14.13 Pintle cone coupling indicating ℓ_a

(IACS UR S10 Figure 9)

E. Rudder Body, Rudder Bearings

1. Strength of rudder body

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 should be additionally stiffened at the aft edge.

(IACS UR S10.3.1)

1.2 The strength of the rudder body is to be proved by direct calculation according to C.3.

(IACS UR S10.3.2)

1.3 For rudder bodies without cut-outs the permissible stress are limited to:

bending stress due to M_R:

$$\sigma_b \leq \frac{110}{k} \qquad [N/mm^2]$$

shear stress due to Q_l:

$$\tau \leq \frac{50}{k} \qquad [N/mm^2]$$

stress due to bending and shear:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\,\tau^2} \leq \frac{120}{k} \qquad [N/mm^2]$$

M_R, Q_1 see C.3.3 and Fig .14.4 and 14.5.

(IACS UR S10.5.1(a))

In case of openings in the rudder plating for access to cone coupling or pintle nut the permissible stresses according to 1.4 apply. Smaller permissible stress values may be required if the corner radii are less than $0{,}15 \cdot h_0$, where h_0 = height of opening.

1.4 In rudder bodies with cut-outs (semi-spade rudders) the following stress values are not to be exceeded:

bending stress due to M_R :

$$\sigma_b \leq 75 \qquad [N/mm^2]$$

shear stress due to Q_l :

$$\tau \leq 50 \qquad [N/mm^2]$$

torsional stress due to M_t :

$$\tau_t \leq 50 \qquad [N/mm^2]$$

equivalent stress due to bending and shear and equivalent stress due to bending and torsion:

$$\sigma_{v1} = \sqrt{\sigma_b^2 + 3\,\tau^2} \leq 100 \qquad [N/mm^2]$$

$$\sigma_{v2} = \sqrt{\sigma_b^2 + 3\,\tau_T^2} \leq 100 \qquad [N/mm^2]$$

(IACS UR S10.5.1(b))

$$M_R = C_{R2} \cdot f_1 + B_1 \cdot \frac{f_2}{2} \qquad [Nm]$$

$$Q_1 = C_{R2} \qquad [N]$$

f_1, f_2 see Fig. 14.14.

As first approximation the torsional stress may be calculated in a simplified manner as follows:

$$\tau_t = \frac{M_T}{2 \cdot \ell \cdot h \cdot t} \qquad [N/mm^2]$$

$$M_t = C_{R2} \cdot e \qquad [Nm]$$

C_{R2} = partial rudder force [N] of the partial rudder area A_2 below the cross section under consideration

e = lever for torsional moment [m] (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. 14.14. The centre of pressure is to be assumed at 0,33 · c_2 aft of the forward edge of area A_2, where c_2 = mean breadth of area A_2)

h, ℓ, t [cm], see Fig. 14.14

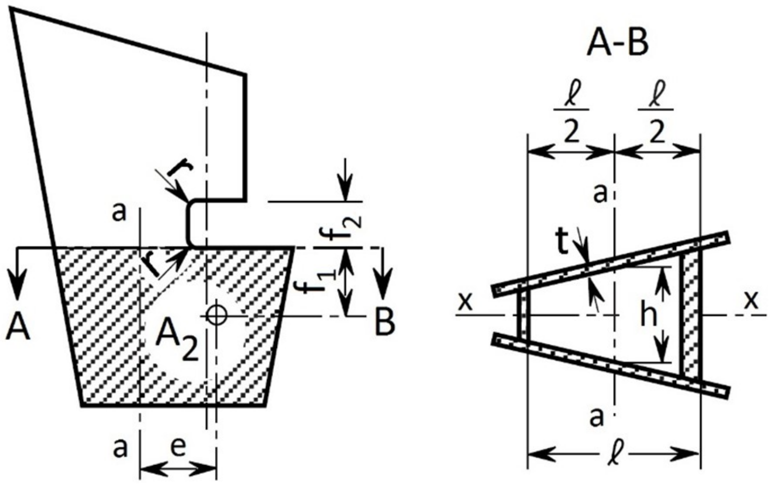


Fig. 14.14 Geometry of semi-spade rudder

Note:

It is recommended to keep the natural frequency of the fully immersed rudder and of local structural components at least 10% above the exciting frequency of the propeller (number of revolutions x number of blades) or if relevant, above higher order.

2. Rudder plating

2.1 Double plate rudders

2.1.1 The thickness of the rudder plating is to be determined according to the following formula:

$$t = 5,5 \cdot f_2 \cdot a \sqrt{p_R \cdot k} + 2,5 \quad [mm]$$

$$p_R = T_{SC} + \frac{C_R}{10^4 \cdot A} \quad [kN/m^2]$$

a = the smaller unsupported width of a plate panel [m].

f_2 = aspect ratio factor as defined in Section 3, A.3

T_{SC} = scantling draught [m], as defined in Section 1, H.4

(IACS UR S10.5.2)

The thickness shall, however, not be less than the thickness t_{min} according to Section 6, B.3.

To avoid resonant vibration of single plate fields the frequency criterion as defined in Section 12, A.8.3 for shell structures applies analogously.

Regarding dimensions and welding for rudder plating in way of coupling flange Section 19, B.4.4.1 has to be observed in addition.

2.1.2 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.

2.1.3 The thickness of the webs is not to be less than 70% of the thickness of the rudder plating according to 2.1.1, but not less than:

t_{min} = 8,0 [mm]

(IACS UR S10.5.2)

Webs exposed to seawater must be dimensioned according to 2.1.1.

2.2 Single plate rudders

2.2.1 Main piece diameter

The main piece diameter is calculated according to C.1 and C.2 respectively. For spade rudders the lower third may taper down to 0,75 times stock diameter.

2.2.2 Blade thickness

.1 The blade thickness is not to be less than:

$$t_b = 1{,}5 \cdot \mathbf{a} \cdot \mathbf{v_0} \cdot \sqrt{k} + 2{,}5 \quad [\text{mm}]$$

a = spacing of stiffening arms [m], not to exceed 1,0 m;

$\mathbf{v_0}$ = ahead speed of ship [kn]

.2 After edge of rudder plating to be rounded.

2.2.3 Arms

The thickness of the arms " t_a" is not to be less than the blade thickness according to 2.2.2.

The section modulus is to be determined as follow:

$$W_a = 0{,}5 \cdot a \cdot c_1^2 \cdot \mathbf{v}_0^2 \cdot k \quad [\text{cm}^3]$$

c_1 = horizontal distance from the aft edge of the rudder to the centreline of the rudder stock [m]

(IACS UR S10.5.4)

3. Transmitting of the rudder torque

3.1 For transmitting the rudder torque, the rudder plating according to 2.1.1 and 2.2.2.1 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.

3.2 If the torque is transmitted by a prolonged shaft extended into the rudder, the latter shall 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 0,6D_t, in spade rudders to 0,4 times the strengthened diameter, if sufficient support is provided for.

4. Rudder bearings

4.1 In way of bearings liners and bushes are to be fitted. For rudder stocks and pintles having diameter less than 200 mm, liners in way of bushes may be provided optionally. Their minimum thickness is:

t_{min} = 8,0 mm for metallic materials and synthetic material

= 22 mm for lignum material

(IACS UR S10.8.1.1)

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.

4.2 An adequate lubrication is to be provided.

4.3 The bearing forces result from the direct calculation mentioned in C.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:

— support force in the rudder horn:

$$B_1 = C_R \cdot \frac{b}{c} \quad [N]$$

— support force in the neck bearing:

$$B_2 = C_R - B_1 \quad [N]$$

For b and c see Section 13, Fig. 13.7.

4.4 The projected bearing surface A_b (bearing height x external diameter of liner) is not to be less than:

$$A_b = \frac{B_1}{q} \quad [mm^2]$$

B_i = support force $B_1 \cdot B_3$ according to Fig. 14.4 to Fig. 14.8 [N]

q = allowable surface pressure according to Table 14.2

Table 14.2 Allowable surface pressure q

Bearing material	q [N/mm^2]
lignum vitae	2,5
white metal, oil lubricated	4,5
synthetic material with hardness greater than 60 shore[1]	5,5[2]
Steel [3], bronze and hot-pressed bronze-graphite materials	7,0

[1] Indentation hardness test at 23°C and with 50 % moisture, are to be carried out according to a recognized standard. Synthetic bearing materials are to be of an approved type.

[2] 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.

[3] 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

(IACS UR S10.8.2)

4.5 Stainless and wear resistant steels, bronze and hot-pressed bronze-graphite materials have a considerable difference in potential to non-alloyed steel. Respective preventive measures are required.

4.6 The bearing height shall 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 S10.8.3)

4.7 The wall thickness of pintle bearings in sole piece and rudder horn shall be not less than ¼ of the pintle diameter.

(IACS UR S10.7.4)

4.8 The length of the pintle housing in the gudgeon is not to be less than the pintle diameter d_p, d_p is to be measured on the outside of the liners.

(IACS UR S10.7.4)

5. Pintles

5.1 Pintles are to have scantlings complying with the conditions given in 4.4 and 4.6. The pintle diameter is not to be less than:

$$d = 0,35 \cdot \sqrt{B_1 \cdot k_r} \qquad [mm]$$

B_1 = support force [N]

k_r = see A.4.2

(IACS UR S10.7.1)

5.2 The thickness of any liner or bush shall not be less than:

$$t = 0,01 \cdot \sqrt{B_1} \qquad [mm]$$

or the values in 4.1 respectively.

(IACS UR S10.8.1.2)

5.3 Where pintles are of conical shape, they are to comply with the following:

taper on diameter 1:8 to 1:12 if keyed by slugging nut,

taper on diameter 1:12 to 1:20 if mounted with oil injection and hydraulic nut.

(IACS UR S10.7.2)

5.4 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 D.4.1.5 and D.4.2.2 apply accordingly.

(IACS UR S10.7.3)

6. Guidance values for bearing clearances

6.1 For metallic bearing material the bearing clearance shall generally not be less than:

$$\frac{d_b}{1000} + 1,0 \qquad [mm]$$

d_b = inner diameter of bush.

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 and to be in accordance with maker recommendation.

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 recommendation and there is documented evidence of satisfactory service history with a reduced clearance.

(IACS UR S10.8.4)

Note:

Bushing fitted by means of shrink fittings alone is not considered effectively secured. Additional physical stoppers need to be arranged to prevent the bushing from accidentally rotating or shifting in vertical direction.

7. Connections of rudder blade structure with solid parts

7.1 Solid parts in forged or cast steel, which house the rudder stock or the pintle, are to be provided with protrusions, except where not required as indicated below:

These protrusions are not required when the web plate thickness is less than:

— 10 mm for web plates welded to the solid part on which the lower pintle of a semi-spade rudder is housed and for vertical web plates welded to the solid part of the rudder stock coupling of spade rudders.

— 20 mm for other web plates.

(IACS UR S10.5.3.1)

7.2 The solid parts are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

(IACS UR S10.5.3.2)

7.3 Minimum section modulus of the connection with the rudder stock housing

The section modulus of the cross-section of the structure of the rudder blade [cm^3] formed by vertical web plates and rudder plating, which is connected with the solid part where the rudder stock is housed is to be not less than:

$$W_S = c_S \cdot d_c^3 \cdot \left(\frac{H_E - H_X}{H_E}\right)^2 \cdot \frac{k}{k_S} \cdot 10^{-4} \quad [\text{cm}^3]$$

c_S = coefficient, to be taken equal to:

= 1,0 if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate

= 1,5 if there is an opening in the considered cross-section of the rudder

d_c = rudder stock diameter [mm]

H_E = vertical distance between the lower edge of the rudder blade and the upper edge of the solid part [m]

H_X = vertical distance between the considered cross-section and the upper edge of the solid part [m]

k = material factor for the rudder blade plating

k_S = material factor for the rudder stock, according to A.4.2

The actual section modulus of the cross-section of the structure of the rudder blade is to be calculated with respect to the symmetrical axis of the rudder.

The breadth of the rudder plating [m] to be considered for the calculation of section modulus is to be not greater than:

$$b = s_V + \frac{2\,H_X}{3} \quad [\text{m}]$$

s_V = spacing between the two vertical webs [m] (see Fig. 14.15)

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate, they are to be deducted.

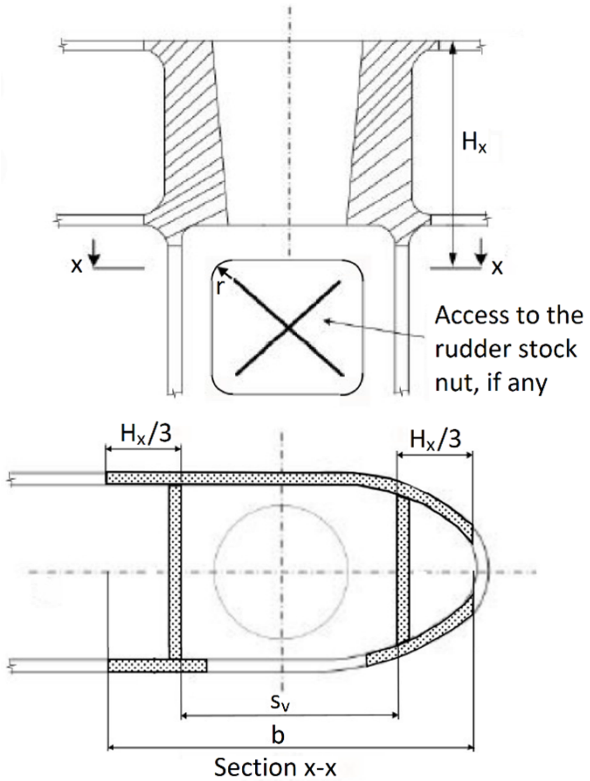


Fig. 14.15 Cross-section of the connection between rudder blade structure and rudder stock housing, example with opening in only one side shown

(IACS UR S10.5.3.3)

7.4 The thickness of the horizontal web plates connected to the solid parts [mm] as well as that of the rudder blade plating between these webs, is to be not less than the greater of the following values:

$t_H = 1{,}2 \cdot t$ [mm]

$t_H = 0{,}045 \cdot d_S^2 / s_H$ [mm]

t defined in 2.1.1

d_S diameter [mm], to be taken equal to:

= D_1, as per C.2 for the solid part housing the rudder stock

= d, as per 5.1 for the solid part housing the pintle

s_H spacing between the two horizontal web plates [mm]

The increased thickness of the horizontal webs is to extend fore and aft of the solid part at least to the next vertical web.

(IACS UR S10.5.3.4)

7.5 The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained [mm] from Table 14.3.

Table 14.3 Thickness of side plating and vertical web plates

Type of rudder	Thickness of vertical web plates [mm]		Thickness of rudder plating [mm]	
	Rudder blade without opening	Rudder blade with opening	Rudder blade without opening	Area with opening
Rudder supported by sole piece	1,2 t	1,6 t	1,2 t	1,4 t
Semi-spade and spade Rudders	1,4 t	2,0 t	1,3 t	1,6 t
t thickness of the rudder plating [mm] as defined in E.2.1.1				

The increased thickness is to extend below the solid piece at least to the next horizontal web.

(IACS UR S10.5.3.5)

F. Design Yield Moment of Rudder Stock

The design yield moment 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 C.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 · D_t.

G. Stopper, Locking Device

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 point of the applied materials is not exceeded at the design yield moment of the rudder stock.

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 point of the applied materials is not exceeded at the design yield moment of the rudder stock as specified in F. Where the ship's speed exceeds 12 kn, the design yield moment need only be calculated for a stock diameter based on a speed $\mathbf{v}_0$ = 12 [kn].

3. Regarding stopper and locking device see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.14.

H. Propeller Nozzles

1. General

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.

1.2 Special attention is to be given to the support of fixed nozzles at the hull structure.

2. Design pressure

The design pressure for propeller nozzles is to be determined by the following formula :

p_d = $c \cdot p_{d0}$ [kN/m^2]

p_{do} = $\varepsilon \cdot \dfrac{N}{A_p}$ [kN/m^2]

N = maximum shaft power [kW]

A_p = propeller disc area [m^2]

= $\dfrac{\pi}{4} \cdot D^2$

D = propeller diameter [m]

ε = factor according to the following formula:

= $0{,}21 \cdot 2 \cdot 10^{-4} \cdot \dfrac{N}{A_p}$

ε_{min} = 0,10

c = 1,0 in zone 2 (propeller zone),

= 0,5 in zones 1 and 3

= 0,35 in zone 4

see Fig. 14.16

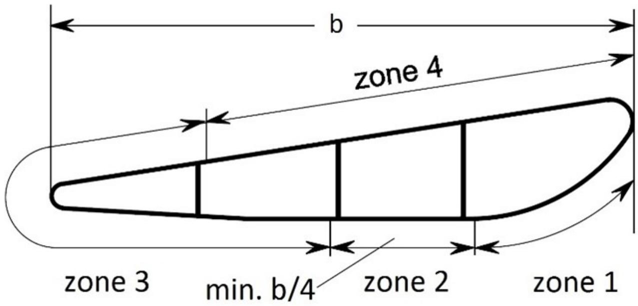


Fig. 14.16 Zone 1 to 4 of propeller nozzle

3. Plate thickness

3.1 The thickness of the nozzle shell plating is not to be less than:

t = $5.a.\sqrt{p_d} + t_k$ [mm]

t_{min} = 7,5 [mm]

a = spacing of ring stiffeners [m]

3.2 The web thickness of the internal stiffening rings shall not be less than the nozzle plating for zone 3, however, in no case be less than 7,5 mm.

4. Section modulus

The section modulus of the cross section shown in Fig. 14.16 around its neutral axis is not to be less than:

$W = n \cdot d^2 \cdot b \cdot \mathbf{v}_0^2$ [cm^3]

d	=	inner diameter of nozzle [m]	
b	=	length of nozzle [m]	
n	=	1,0	for rudder nozzles
	=	0,7	for fixed nozzles

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.

J. Devices for Improving Propulsion Efficiency

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).

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 BKI.

K. Fin Stabilizers

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.

2. Integration into the hull structure

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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.14.H.

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.

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.

L. Equivalence

1. BKI may accept alternatives to requirements given in this Section, provided that they deemed to be equivalent

(IACS UR S10.1.5.1)

2. Direct analyses adopted to justify an alternative design are to take into consideration all relevant modes of failure, on a case by case basis. These failure modes may include among others: yielding, fatigue, buckling and fracture. Possible damages caused by cavitation are also to be considered.

(IACS UR S10.1.5.2)

3. If deemed necessary: lab tests, or full scale tests may be requested to validate the alternative design approach.

(IACS UR S10.1.5.3)

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Section 15 Strengthening for Navigation in Ice

A. General

1. Ice class notations

1.1 The strengthening for the various ice class notations are recommended for navigation under the following ice conditions:

Ice class notation	Ice conditions
ES	Drift ice in mouths of rivers, and coastal regions
ES1 – ES4	Ice conditions as in the Northern Baltic[1]

[1] See paragraph 1.1 of the Finnish Swedish Ice Class Rules, as ammended

1.2 Ships the ice-strengthening of which complies with the requirements of B. will have the notation **ES1**, **ES2**, **ES3** or **ES4** affixed to their Character of Classification.

1.3 The requirements for the ice class notations **ES1** — **ES4** 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 0.12.2011 TRAFI / 21816 / 3.04.01.01 / 2011)".

The ice class notations mentioned under 1.1 are equivalent to the Finnish-Swedish Ice Class in the following way:

- Ice class notation **ES1** corresponds to ice class **IC**.
- Ice class notation **ES2** corresponds to ice class **IB**.
- Ice class notation **ES3** corresponds to ice class **IA**.
- Ice class notation **ES4** 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 **ES2** and **ES1**, 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 Annex to the Class Certificate.*

1.4 The ice class notations **ES1- ES4** can only be assigned to self-propelled ships when in addition to the requirements of this Section also the relevant Rules for Machinery Installations (Pt.1, Vol.III) Sec.13 are complied with. For example, the Character of Classification then reads: ✠ **A 100** Ⓘ **ES1**; ✠ **SM ES1** . Where the hull only is strengthened for a higher ice class notation, a corresponding entry will be made in the Annex to the Class Certificate.

1.5 Ships the ice strengthening of which complies with the requirements of C. will have the notation **ES** affixed to their Character of Classification.

Upon request, the Notation **ES** may be assigned independently for hull or machinery.

1.6 Ships which beyond the requirements for the ice Class Notations **ES**, **ES1** to **ES4** have been specially designed, dimensioned and/or equipped for ice breaking 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 BKI.

1.7 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.

2. Ice class draught for Ships with Notations ES1-ES4

2.1 The upper ice waterline (UIWL) is to be the highest waterline at which the ship is intended to operate in ice. The lower ice waterline (LIWL) is to be the lowest waterline at which the ship is intended to operate in ice. Both the UIWL and LIWL may be broken lines.

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 maximum ice class draught at the forward perpendicular is not to be less than the maximum draught at amidships. The ice class draughts, the minimum propulsion machinery output, P, according to 3, as well as the corresponding ice class, will be stated in the Annex to the Class Certificate.

If the summer load line in fresh water is 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

2.3 The draught and trim, limited by the UIWL, shall not 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. For ships with the ice class notations **ES1** – **ES4**, 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.

2.4 For ships with the ice class notations **ES1** - **ES4** the minimum draught at the forward perpendicular shall not be less than the smaller of the following values:

$$\mathbf{T}_{min} = h_0 \cdot (2 + 2,5 \cdot 10^{-4} \cdot D) \quad [m] \quad \text{or}$$

$$\mathbf{T}_{min} = 4 \cdot h0 \quad [m]$$

D = displacement of the ship [t] on the maximum ice class draught according to 2.1

h_0 = design ice thickness according to B.2.1.

3. Propulsion machinery output for ships with Notations ES1-ES4

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.

3.2 For ships with the ice class notation **ES1** or **ES2**, the keels of which were laid or which are in a similar stage of construction before September 1^{st}, 2003, the propulsion machinery output is not to be less than:

$$P = f_1 \cdot f_2 \cdot f_3 \, (f_4 \cdot D + P_0) \quad [kW]$$

$$P_{min} = 740 \quad kW$$

f_1 = 1,0 for a fixed pitch propeller

= 0,9 for a controllable pitch propeller

f_2 = $\frac{\varphi 1}{200} + 0,675$ but not more than 1,1

= 1,1 for a bulbous bow

$f_1 \cdot f_2 \geq$ 0,85

$\varphi 1$ = the forward facing angle between the stem and the UIWL. If the stem forms a fair curve within the ice belt as defined in 4.1 it may be presented by a straight line between the points of intersection of the stem and the upper and lower limits of the ice belt. If there are sharp changes in the inclination of the stem the largest n_1 is to be used.

f_3 = $1,2 \cdot \frac{B}{\sqrt[3]{D}}$, but not less than 1,0

f_4 and P_0 are to be taken from Table 15.1 for the respective ice Class Notation and displacement.

Table 15.1 Factor f_4 and power P_0 for the determination of minimum propulsion machinery output for ships of ice classes ES1 and ES2

Ice class notation	ES2	ES1	ES2	ES1
D [t]	< 30000		≥ 30000	
f_4	0,22	0,18	0,13	0,11
P_0	370	0	3070	2100

D = displacement of the ship [t] as per 2.4. D need not to be taken as greater than 80000 t.

For **ES2**, no higher propulsion machinery output, P, than required for **ES3** is necessary.

Note:

The Finnish Administration may in special cases approve an propulsion machinery output below that required in accordance with 3.2 above.

3.3 For ships with the ice Class Notation **ES1** or **ES2**, the keels of which are laid or which are in a similar stage of construction on or after September 1^{st}, 2003, and for ships with the ice class notation **ES3** or **ES4**, the propulsion machinery output is not to be less than :

$$P = K_e \cdot \frac{(R_{CH}/1000)^{3/2}}{D_p} \quad [kW]$$

P_{min} = 2800 kW for ice class notation **ES4**

= 1000 kW for ice class notation **ES1**, **ES2** and **ES3**

The required propulsion machinery output P is to be calculated for ships on both the UIWL and the LIWL.

The propulsion machinery output shall not be less than the greater of these two outputs.

K_e = is be taken from 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 3.4.

Table 15.2 Factor K_e for the determination of minimum propulsion machinery output for ships of ice classes ES3 and ES4

Propeller type or machinery	K_e	
	CP or electric or hydraulic propulsion machinery	FP propeller
1 propeller	2,03	2,26
2 propeller	1,44	1,60
3 propeller	1,18	1,31

D_P = diameter of the propeller(s) [m]

R_{CH} = resistance [N] of the ship in a channel with brash ice and a consolidated layer:

$$R_{CH} = C_1 + C_2 + C_3 \cdot C_\mu \left(H_F + H_M\right)^2 \cdot \left(\mathbf{B} + C_\Psi \cdot H_F\right)^2 + C_4 \cdot L_{PAR} \cdot H_F^2 + C_5 \left(\frac{\mathbf{L_{pp}} \cdot \mathbf{T}}{\mathbf{B}^2}\right)^3 \cdot \frac{A_{wf}}{\mathbf{L_{pp}}} \quad [N]$$

C_1 and C_2 take into account a consolidated upper layer of the brash ice and can be taken as zero for ice Class Notations **ES1**, **ES2** and **ES3**.

For ice class **ES4** :

$$C_1 = f_1 \frac{\mathbf{B} \cdot L_{PAR}}{2 \cdot \frac{\mathbf{T}}{\mathbf{B}} + 1} + (1 + 0,021 \cdot \varphi_1) \cdot (f_2 \cdot \mathbf{B} + f_3 \cdot L_{BOW} + f_4 \cdot \mathbf{B} \cdot L_{BOW})$$

$$C_2 = (1 + 0,063 \cdot \varphi_1) \cdot (g_1 + g_2 \cdot \mathbf{B}) + g_3 \left(1 + 1,2 \cdot \frac{\mathbf{T}}{\mathbf{B}}\right) \cdot \frac{\mathbf{B}^2}{\sqrt{\mathbf{L_{pp}}}}$$

C_3 = 845 [kg/m²/s²]

C_4 = 42 [kg/m²/s²]

C_5 = 825 [kg/s²]

$C_\mu = 0,15 \cdot \cos\varphi_2 + \sin\Psi \cdot \sin\alpha; \quad C_\mu \geq 0,45$

$C_\Psi = 0,047 \cdot \Psi - 2,115; \quad C_\Psi = 0 \text{ for } \Psi \leq 45°$

H_F = thickness of the brash ice layer displaced by the bow [m]

$= 0,26 + \sqrt{H_M \cdot \mathbf{B}}$

= 1,0 for ice class notations **ES3** and **ES4**

= 0,8 for ice class notation **ES2**

= 0,6 for ice class notation **ES1**

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 2.1, and on the LIWL using a horizontal waterline passing through the minimum ice class draught amidships, as defined in 2.3. The ship dimensions $\mathbf{L_{PP}}$ and **B**, however, are always to be calculated on the UIWL. See also Fig. 15.1. The lengths of the bow, L_{BOW}, on the UIWL and LIWL are both to be measured from the fore perpendicular defined on the UIWL. The length of the parallel midship body, L_{PAR}, is to be measured between the aft perpendicular and the flat of side, if the vessel has a full beam between these two points.

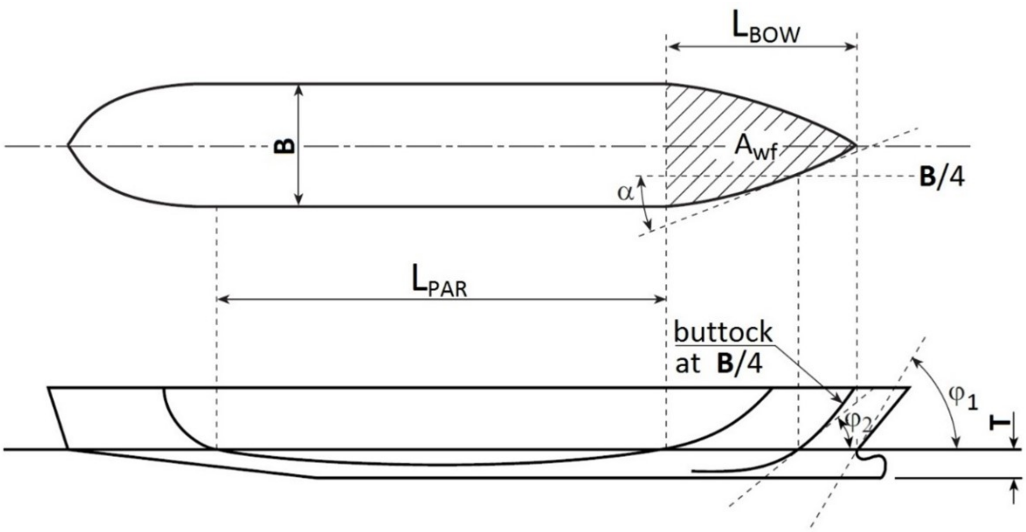


Fig. 15.1 Rake of the stem φ_1 and rake of the bow φ_2 at B/4 from CL

L_{PAR}	=	length of the parallel midship body [m]
$\mathbf{L_{PP}}$	=	length of the ship between perpendiculars [m]
L_{BOW}	=	length of the bow [m]
T	=	maximum and minimum ice class draughts amidship [m] according to 2.1 and 2.3, respectively
A_{wf}	=	area of the waterplane of the bow [m^2]
φ_1	=	the rake of the stem at the centreline [°] For a ship with a bulbous bow, φ_1 shall be taken as 90°.
φ_2	=	the rake, of the bow at **B**/4 [°], φ_{2max} = 90°
α	=	the angle of the waterline at **B**/4 [°]
Ψ	=	$\arctan\left(\frac{\tan\varphi_2}{\sin\alpha}\right)$

The quantity $\left(\frac{\mathbf{L_{pp}} \cdot \mathbf{T}}{\mathbf{B}^2}\right)^3$ is not to be taken less than 5 and not to be taken more than 20.

f_1	=	23	[N/m^2],	g_1 = 1530	[N]
f_2	=	45,8	[N/m],	g_2 = 170	[N/m]
f_3	=	14,7	[N/m],	g_3 = 400	[$N/m^{1,5}$]
f_4	=	29	[N/m^2]		

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 3.4. When calculating the parameter D_P/**T**, **T** shall be measured on the UIWL.

Table 15.3 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
$\mathbf{L}_{PP}$ [m]	65,0	250,0
B [m]	11,0	40,0
T [m]	4,0	15,0
$\mathbf{L}_{BOW}/\mathbf{L}_{PP}$	0,15	0,40
$\mathbf{L}_{PAR}/\mathbf{L}_{PP}$	0,25	0,75
$D_P/\mathbf{T}$	0,45	0,75
$\mathbf{A}_{WF}/\mathbf{L}_{PP} \cdot \mathbf{B})$	0,09	0,27

3.4 For an individual ship, in lieu of the K_e or R_{CH} values defined in 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). If R_{CH} is determined using the rule formulae, then K_e can be determined by using direct calculations or the rule formulae. However, if R_{CH} is determined using model tests, then propeller thrust should be calculated by direct calculations using the actual propeller data.

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 5,0 kn in the following brash ice channels:

ES4 = H_M = 1,0 m and a 0,1 m thick consolidated layer of ice

ES3 = H_M = 1,0 m

ES2 = H_M = 0,8 m

ES1 = H_M = 0,6 m

4. Definitions for ships notations ES1-ES4

4.1 Ice belt

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:

.1 Forward region F

The region from the stem to a line parallel to and at the distance c aft of the borderline between the parallel midship region and the fore ship;

c = 0,04**L**, not exceeding 6,0 m for the ice Class Notation **ES3** and **ES4**, not exceeding 5,0 m for the ice class notations **ES1- ES2**

= 0,02**L**, not exceeding 2,0 m for the ice class notation **ES**.

.2 Midship region M

The region from the aft boundary of the region F, as defined in .1 to a line parallel to and at the distance c aft of the borderline between the parallel midbody region and the aft ship ;

.3 Aft region A

The region from the aft boundary of the region M, as defined in .2 to the stern;

.4 Fore foot FF

(for ice class notation **ES4** 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;

.5 Upper forward ice belt FU

(for ice class notations **ES3** and **ES4** on ships with a speed $\mathbf{v}_0 \geq 18$ kn only)

The region from the upper limit of the ice belt to 2,0 m above it and from the stem to a position 0,2**L** abaft the forward perpendicular.

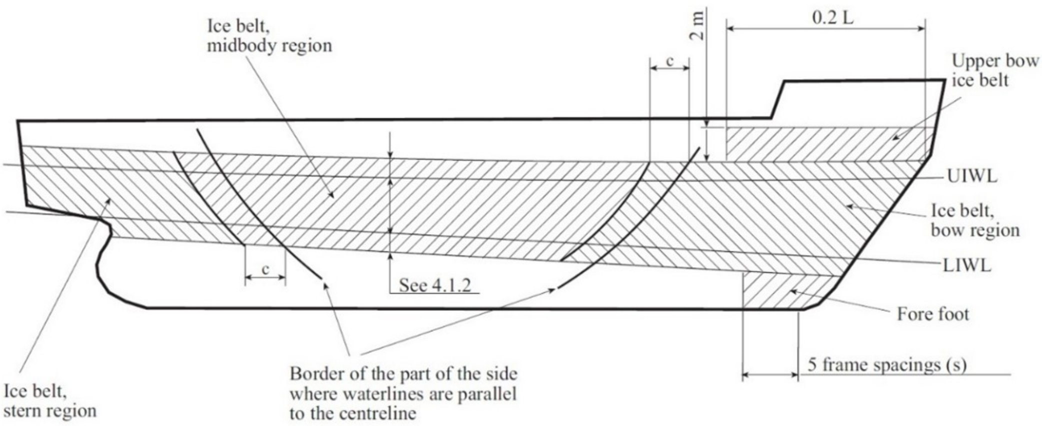


Fig. 15.2 Ice belt

4.1.2 The vertical extension of the regions F, M, and A is to be determined from Table 15.4.

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 regions F, M and A (including FF and FU, if applicable), are to be clearly indicated.

Table 15.4 Vertical extension of the regions F, M and A

Ice class notation	Hull region	Above UIWL [m]	Below LIWL [m]
ES4	F	0,6	1,2
	M		1,00
	A		0,9
ES3	F	0,5	0,9
	M		0,75
	A		
ES,ES1,ES2	F	0,4	0,7
	M		0,6
	A		

4.1.4 The following terms are used in the formulae in B:

a = frame spacing [m], longitudinal or transverse, taking into account the intermediate frames, if fitted

R_{eH} = minimum nominal upper yield point for hull structural steel according to Section 2, B.1

ℓ = unsupported span [m] of frames, web frames, stringer. See also Section 3, C.3

p = design ice pressure [N/mm^2] according to B.2.2

h = design height of ice pressure area [m] according to B.2.1

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 shall be measured along the side of the ship.

B. Requirements for the Notations ES1 – ES4

1. General

1.1 A typical ice load distribution is shown in Fig.15.3. Maximum pressures (p_{max}) occur at the frames, minimum pressures occur between frames, due to different flexural stiffness of frames and shell plating.

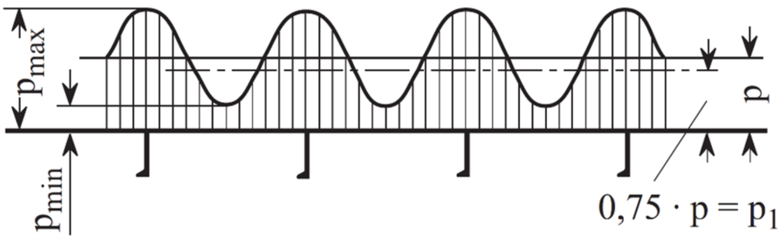


Fig. 15.3 Ice load distribution

The formulae for determining the scantlings used in this Section are based on the following design loads:

for frames :

$$p = \frac{1}{2}(p_{max} + p_{min}) \quad [N/mm^2]$$

for shell plating :

$$p_1 = 0{,}75 \cdot p \quad [N/mm^2]$$

p = design ice pressure as per 2.2.

1.2 The formulae given in this Section may be substituted by direct calculation methods if it is deemed by BKI 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 3. (shell plating) and 4. (frames, ice stringers, web frames).

Direct analyses are to be carried out using the load patch defined in 2 (p, h and ℓ_a). The pressure to be used is 1,8 · p, where p is determined according to 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 · 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 · τ_y , where τ_y = R_{eH} / $\sqrt{3}$.

2. Ice loads

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 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 15.5 Ice thickness h_0 and design height h

Ice class notation	h_0[m]	h [m]
ES, ES1	0,4	0,22
ES2	0,6	0,25
ES3	0,8	0,30
ES4	1,0	0,35

2.2 The design ice pressure is to be determined according to the following formula:

$$p = c_d \cdot c_1 \cdot c_a \cdot p_0 \quad [\mathrm{N/mm^2}]$$

$$c_d = \frac{a \cdot k + b}{1000}$$

$$k = \frac{\sqrt{D \cdot P}}{1000}$$

P_{max} = 740 kW for the ice class notation **ES**

a, b = coefficients in accordance with Table 15.6

Table 15.6 Coefficient c_1

Region	F		M and A	
k	≤ 12	**> 12**	≤ 12	≥ 12
a	30	6	8	2
b	230	518	214	286

D see A.2.4

P = total maximum output the propulsion machinery can continuously deliver to the propeller(s)[kW], see also A.3.1

c_1 = coefficient in accordance with Table 15.7

c_c = $\frac{47 - 5 \cdot \ell_a}{44}$ max. 1,0. min. 0,6

ℓ_a = effective length [m] according to Table 15.8

p_0 = 5,6 N/mm^2 (nominal ice pressure).

Table 15.7 Coefficient c_1

Ice class notation	Region		
	F	M	A
ES	0,3	-	-
ES1	1,0	0,50	0,25
ES2	1,0	0,70	0,45
ES3	1,0	0,85	0,65
ES4	1,0	1,00	0,75

Table 15.8 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

3. Thickness of shell plating in the ice belt

3.1 The thickness of the shell plating is to be determined according to the following formulae:

— transverse framing:

$$t = 667 \cdot \mathbf{a}\sqrt{\frac{f_1 \cdot p_1}{R_{eH}}} + t_c \qquad [mm]$$

— longitudinal framing :

$$t = 667 \cdot \mathbf{a}\sqrt{\frac{p_1}{f_2 \cdot R_{eH}}} + t_c \qquad [mm]$$

p_1 see 1.1

f_1 = $1,3 - \dfrac{4,2}{(1,8 + h/\mathbf{a})^2}$

f_{1max} = 1,0

f_2 = $0,6 + \dfrac{0,4}{h/\mathbf{a}}$, where $h/\mathbf{a} \leq 1$

= $1,4 - \dfrac{0,4\,h}{\mathbf{a}}$, where $1 < h/\mathbf{a} \leq 1{,}8$

t_c = allowance for abrasion and corrosion [mm]. Usually t_c amounts to 2,0 mm. If a special coating is applied and maintained, which by experience is shown to be capable to withstand the abrasion of ice, the allowance may be reduced to 1,0 mm.

3.2 Where the draught (e.g., in the ballast condition) is smaller than 1,5 m, 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 ice belt region F 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%.

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.

3.4 For ships with the ice Class Notation **ES4** the region FF according to A.4.1.1.4 shall have at least the thickness of the region M.

3.5 For ships with the ice Class Notation **ES3** or **ES4** and with a speed $\mathbf{v}_0$ ≥ 18 kn the region FU according to A.4.1.1.5 shall have at least the thickness of the region M.

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.

4. Frames, ice stringers, web frames

4.1 General

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 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 BKI). 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.

4.1.2 For the ice Class Notation **ES4**, for the ice Class Notation **ES3** within the regions F and M and for the ice class notations **ES2** and **ES1** within the region F the following applies:

.1 Frames which are unsymmetrical, or having webs which are not at 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 means at a distance not 'exceeding 1300 mm.

.2 The frames are to be attached to the shell by double continuous welds. No scalloping is allowed except when crossing shell plate butts welds.

.3 The web thickness t_w of the frames is not to be less than determined by the following values:

t_w = max $[t_{w1}; t_{w2}; t_{w3}; t_{w4}]$

t_{w1} = $h_w \sqrt{R_{eH}/C}$ [mm]

t_{w2} = $25 \cdot a$ [mm] for transverse frame

t_{w3} = $0{,}5\ t_s$ [mm]

t_{w4} = 9 [mm]

where

h_w = web height [mm]

t_s = thickness of shell plating [mm]

C = factor to take the section type into account, defined as:

= 805 for profiles

= 282 for flat bars

For the purpose of calculating web thickness of frame, the minimum nominal yield point 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 minimum nominal yield point R_{eH}.

.4 Where there is a deck, tank top (or tank bottom), bulkhead, web frame or stringer in lieu of a frame, its plate thickness of this is to be as required in accordance with .3, to a depth corresponding to the height of adjacent frame. 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.

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 by not more than 250 mm, it may be terminated at that deck or tank top.

For longitudinal framing above UIWL the vertical extension of the ice-strengthening should be extended up to and including the first frame above the upper edge of the ice belt. Additionally, the spacing between the longitudinal frames directly above and below the edge of the ice belt should be the same as the frame spacing in the ice belt. If the first frame above the ice belt is closer than approximately a/2 to the upper edge of the ice belt, then the same frame spacing as in the ice belt should be extended to the second frame above the upper edge of the ice belt.

Table 15.9 Vertical extension b_E of ice strengthened framing

Ice class notation	Region	b_E	
		Above UIWL [m]	Below LIWL [m]
ES	-	1,0	1,0
ES1,ES2,ES3	M		1,6
	A		1,3
	F		1,0
	FU[1)]	Up to top of ice belt	
ES4	M	1,2	To double bottom or below top of floors
	A		2,0
	F		1,6
	FU[1)]	Up to top of ice belt	

[1] if required according to A.4.1.1.5.

4.2 Transverse frames

4.2.1 The section modulus and the effective shear area of a main, 'tweendeck or intermediate transverse frame is to be determined according to the following formula:

1. section modulus:

$$W = \frac{p \cdot a \cdot h \cdot \ell}{m_t \cdot R_{eH}} 10^6 \qquad [cm^3]$$

$$m_t = \frac{7 \cdot m_0}{7 - 5 \cdot \frac{h}{\ell}}$$

2. shear area:

$$A = \frac{\sqrt{3} \cdot f \cdot p \cdot h \cdot a}{2 \cdot R_{eH}} 10^4 \qquad [cm^2]$$

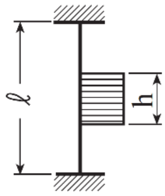
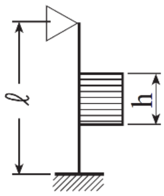
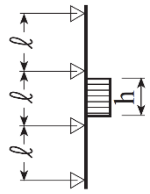
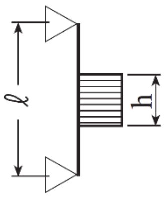
m_0 = coefficient according to Table 15.10.

f = factor which takes into account the maximum shear force versus load location and the shear stress distribution; to be taken as 1,2

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 m0 values. The load centre of the ice load is taken at $\ell/2$.

Where less than 15% of the span ℓ, is situated within the ice-strengthening zone for frames as defined in 4.1.3, ordinary frame scantlings may be used.

Table 15.10 Boundary conditions for transverse frames

Boundary Condition	m_0	Example
	7	Frames in 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

4.2.2 Upper end of transverse framing

4.2.2.1 The upper end of the ice- strengthened part of all frames is to be attached to a deck or an ice stringer as per 4.4.

4.2.2.2 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. Such intermediate frames may also be extended to the deck above and, if this is situated more than 1,8 m above the ice belt, the intermediate frame need not be attached to that deck, except in the forward region F.

4.2.3 Lower end of transverse framing

4.2.3.1 The lower end of the ice strengthened part of all frames is to be attached to a deck, inner bottom, tanktop or ice stringer as per 4.4.

4.2.3.2 Where an intermediate frame terminates below a deck, tanktop 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 respectively main and tweendeck frames, respectively.

4.3 Longitudinal frames

The section modulus and the shear area of the longitudinal frames are to be determined according to the following formulae:

1. section modulus:

$$W = \frac{f_3 \cdot p \cdot h \cdot \ell^2}{m \cdot R_{eH}} 10^6 \qquad [cm^3]$$

2. shear area:

$$A = \frac{\sqrt{3} \cdot f_3 \cdot f_4 \cdot p \cdot h \cdot \ell}{2 \cdot R_{eH}} 10^4 \qquad [cm^2]$$

f_3 = factor which takes account of the load distribution to adjacent frames
= 1-0,2 h/**a**

f_4 = 2,16

m = boundary condition factor
= 13,3 for a continuous beam with double end brackets
= 11,0 for a continuous beam without double end bracket.

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

4.4 Ice stringers

4.4.1 Ice stringers within the ice belt

The section modulus and the shear area of a stringer situated within the ice belt are to be determined according to the following formulae :

1. section modulus:

$$W = \frac{f_5 \cdot f_{5a} \cdot p \cdot h \cdot \ell^2}{m \cdot R_{eH}} \cdot 10^6 \qquad [cm^3]$$

2. shear area:

$$A = \frac{\sqrt{3} \cdot f_5 \cdot f_{5a} \cdot f_{5b} \cdot p \cdot h \cdot \ell}{2 \cdot R_{eH}} \cdot 10^4 \qquad [cm^2]$$

p · h is not to be taken as less than 0,15

m = see 4.3

f_5 = factor which takes account of the distribution of load to the transverse frames; to be taken as 0,9

f_{5a} = safety factor of stringer; to be taken as 1,8

f_{5b} = factor which takes into account the maximum shear force versus load location and the shear stress distribution; to be taken as 1,2

4.4.2 Ice stringers outside the ice belt

The section modulus and the shear area of a stringer situated outside the ice belt, but supporting frames subjected to ice pressure, are to be calculated according to the following formulae:

1. section modulus:

$$W = \frac{f_6 \cdot f_{6a} \cdot p \cdot h \cdot \ell^2}{m \cdot R_{eH}} \cdot \left(1 - \frac{h_s}{\ell_s}\right) \cdot 10^6 \qquad [cm^3]$$

2. shear area:

$$A = \frac{\sqrt{3} \cdot f_6 \cdot f_{6a} \cdot f_{6b} \cdot p \cdot h \cdot \ell}{2 \cdot R_{eH}} \cdot \left(1 - \frac{h_s}{\ell_s}\right) \cdot 10^4 \qquad [cm^2]$$

$p \cdot h$ is not to be taken as less than 0,15

f_6 = factor which takes account of the distribution of load to the transverse frames; to be taken as 0,8

f_{6a} = safety factor of stringer; to be taken as 1,8

f_{6b} = factor which takes into account the maximum shear force versus load location and the shear stress distribution; to be taken as 1,2

m = see 4.3

h_s = distance of the stringer to the ice belt [m]

ℓ_s = distance of the stringer to the adjacent ice stringer or deck or similar structure [m].

4.4.3 Deck strips

4.4.3.1 Narrow deck strips abreast of hatches and serving as ice stringers are to comply with the section modulus and shear area requirements in 4.4.1 and 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.

4.4.3.2 When designing weather deck hatchcovers and their fittings, the deflection of the ship's sides due to ice pressure in way of very long hatch openings (greater than **B**/2) is to be considered.

4.5 Web frames

4.5.1 The load transferred to a web frame from a stringer or from longitudinal framing is to be calculated according to the following formula:

$$P = p \cdot f_7 \cdot h \cdot e \cdot 10^3 \quad [\text{kN}]$$

$p \cdot h$ is not to be taken as less than 0,15

e = web frame spacing [m]

f_7 = safety factor of web frame; to be taken as 1,8

In case the supported stringer is outside the ice belt, the load P may be multiplied by:

$\left(1 - \frac{h_s}{\ell_s}\right)$ where h_s and ℓ_s shall be taken as defined in 4.4.2.

4.5.2 Shear area and section modulus

For the case of simple support at the upper end and constraint at the lower end according to Fig. 15.4, shear area and section modulus can be calculated by the following formulae :

Shear area :

$$A = \frac{\alpha \cdot Q \cdot f_8 \cdot 10 \cdot \sqrt{3}}{R_{eH}} \quad [\text{cm}^2]$$

$$Q = P \cdot k_1 \quad [\text{kN}]$$

$$k_1 = 1,0 + \frac{1}{2} \cdot \left[\frac{\ell_F}{\ell}\right]^3 - \frac{3}{2} \cdot \left[\frac{\ell_F}{\ell}\right]^2 \quad \text{or}$$

$$= \frac{3}{2} \cdot \left[\frac{\ell_f}{\ell}\right]^2 - \frac{1}{2} \cdot \left[\frac{\ell_F}{\ell}\right]^3$$

whichever is greater.

For the lower part of the web frame, the smallest ℓ_F within the ice belt is to be used. For the upper part, the biggest ℓ_F within the ice belt is to be taken.

ℓ, ℓ_F [m] according to Fig. 15.4.

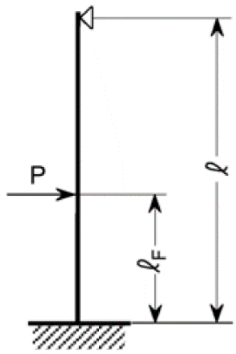


Fig. 15.4 Lengths ℓ and ℓ_F

α	=	see Table 15.11
P	=	as in 4.5.1
f_8	=	factor which takes into account the shear force distribution; to be taken as 1,1

Section modulus :

$$W = \frac{M}{R_{eH}} \cdot \sqrt{\frac{1,0}{1 - \left[\gamma \cdot \frac{A}{A_a}\right]^2}} \cdot 10^3 \quad [\mathrm{cm}^3]$$

M	=	$P \cdot \ell \cdot 0{,}193$ [kNm]
A_a	=	actual shear area
	=	$A_f + A_w$
A_f	=	actual cross sectional area of free flange
A_w	=	actual effective cross sectional area of web plate
A	=	required shear area as above, but by using
k_1	=	$1 + \frac{1}{2}\left[\frac{\ell_F}{\ell}\right]^3 - \frac{3}{2}\left[\frac{\ell_F}{\ell}\right]^2$
γ	=	see Table 15.11

5. Stem

5.1 The stem may be made of rolled, cast or forged steel or of shaped steel plates (see Fig. 15.5).

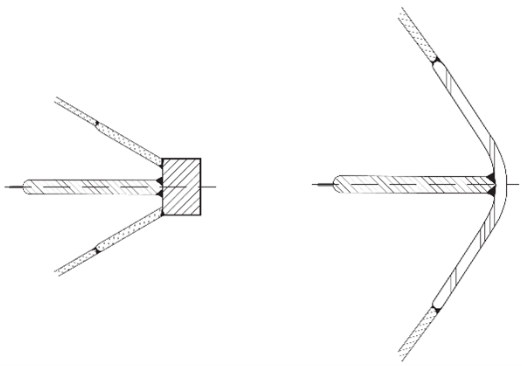


Fig. 15.5 Stem

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.3.3 for definitions), is to be calculated according to the formulae in 3.1 observing that

p_1 = p

a = smaller of the two unsupported widths of plate panel [m]

ℓ_a = spacing of vertical supporting elements [m] (see also Table 15.8)

5.3 The stem and the part of a blunt bow defined in 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 5.2. The reinforcement of the stem shall extend from the keel to a point 0,75 m above UIWL or, in case an upper forward ice belt is required (see also A.4.1.1) to the upper limit of the region **FU**.

Table 15.11 Coefficient 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

A_f = cross sectional area of free flange
A_w = cross sectional area of web plate

6. Arrangements for towing

6.1 A mooring pipe with an opening not less than stated below is to be fitted in the bow bulwark at the centreline.

size of opening	:	250 x 300	[mm]
length	:	150	[mm]
inner surface radius	:	100	[mm]

6.2 A bitt or other means for securing a towline, dimensioned to withstand the breaking force of the towline of the ship, is to be fitted. Alternatively, two fairleads can be fitted symmetrically off the centreline with one bitt each. The bitts shall be aligned with the fairleads allowing the towlines to be fastened straight onto them. The installation of a centreline fairlead is still recommended, since it remains useful for many open water operations as well as some operations in ice.

6.3 On ships with a displacement not exceeding 30000 t the part of the bow which extends to a height of a least 5,0 m above the UIWL and at least 3,0 m aft of the stem, is to be strengthened for the loads caused by fork towing. For this purpose intermediate frames and additional stringers or decks are to be fitted.

Note:

Fork towing in ice is often the most efficient way of assisting ships of moderate size (as defined in 6.3). Ships with a bulb protruding more than 2,5 m forward of the forward perpendicular are often difficult to tow in this way. Some national authorities may deny assistance to such ships if the circumstances so warrant.

7. Stern

7.1 An extremely narrow clearance between the propeller blade tip and the stern frame is to be avoided as a small clearance would cause very high loads on the blade tips.

7.2 On twin and triple screw ships the ice strengthening of the shell and framing shall be extended to the double bottom to an extent of 1,5 m forward and aft of the side propellers.

7.3 Shafting and stern tubes of side propellers are normally to be enclosed within plated bossing. If detached struts are used, their design, strength and attachment to the hull are to be duly considered.

7.4 A wide transom stern extending below the UIWL will seriously impede the capability of the ship to back in ice, which is most essential. Therefore, a transom stern is not to extend below the UIWL if this can be avoided. If unavoidable, the part of the transom below the UIWL is to be kept as narrow was possible. The part of a transom stern situated within the ice belt shall be strengthened as for the midship region M.

7.5 Propulsion arrangements with azimuthing thrusters or "podded" propellers, which provide an improved manoeuvrability, result in increased ice loading of the aft region and stern structure.

Due consideration is to be given to this increased ice loading in the design and dimensioning of the aft region and stern structure.

8. Bilge keels

To limit damage to the shell when a bilge keel is partly ripped off in ice, it is recommended that bilge keels are divided into several shorter independent lengths.

9. Rudder and steering gear

9.1 When calculating the rudder force and torsional moment according to Section 14, B.1 the ship's speed $\mathbf{v}_0$ is not to be taken less than 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, B.1.1 need not be taken greater than κ_2 = 1,1 in connection with the speed values given in Table 15.12.

Table 15.12 Minimum speed for the dimensioning of rudder

Ice class notation	v_0 [kn]
ES1	14
ES2	16
ES3	18
ES4	20

The factor κ_3 according to Section 14, B.1.1 need not be taken greater than 1,0 for rudders situated behind a nozzle.

9.2 Within the ice belt (as per A.4.1) the thickness of the rudder plating is to be determined as of the shell plating within the region A. The thickness of webs shall not to be less than half the rudder plating thickness.

9.3 For the ice Class Notations **ES3** and **ES4**, the rudder stock and the upper edge of the rudder are to be protected against ice pressure by an ice knife or equivalent means. Special consideration shall be given to the design of the rudder and the ice knife for vessels with a flap-type rudder.

9.4 For ships with the ice Class Notations **ES3** and **ES4** due regard is to be paid to the excessive arising when the rudder is forced out of the midship position while backing into an ice ridge. A locking device according to Section 14, G.2 is regarded sufficient 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.

10. Lateral thruster grids

10.1 The following requirements apply in case ice-strengthening of lateral thruster grids is required (see Rules for Machinery Installations (Pt.1, Vol.III) Sec.13.C.13).

In general, lateral thruster tunnels are to be located outside the icebelt defined in A.4.1 by the bow, midbody, 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 10.2 and 10.3 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.

10.2 For a grid of standard construction, intercostal bars are to be fitted perpendicular to continuous bars (see Fig. 15.6). 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. 15.6).

Grids of non-standard construction are to have an equivalent strength to that of the standard configuration described in 10.3.

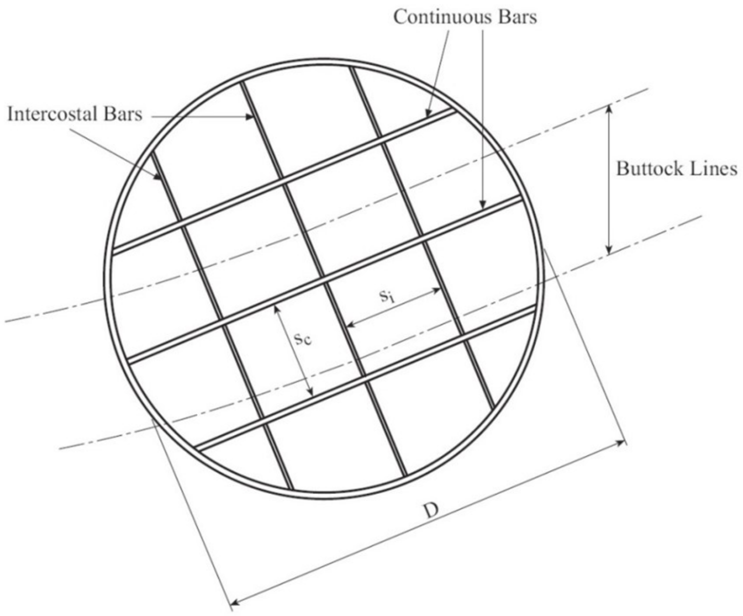


Fig. 15.6 Standard construction of lateral thruster grid

10.3 The section modulus W_c of continuous bars, is not to be less than determined by the following formula:

$$W_c = \frac{s_c \cdot D^2}{4 \cdot R_{eH}} \cdot (1 - \varkappa) \cdot 10^{-4} \quad [cm^3] \qquad W_c \geq 35\ cm^3$$

s_c = spacing [mm] of continuous bars

D = diameter [mm] of thruster tunnel

κ = coefficient, defined as:

$$= 0,4 \cdot \frac{I_i}{I_c} \cdot \frac{s_c}{s_i} \qquad \kappa \leq 0,5$$

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

C. Requirements for the Ice Class Notation ES

1. Shell plating within the ice belt

1.1 Within the ice belt the shell plating shall have a strengthened strake extending over the forward region F the thickness of which is to be determined according to B.3.

1.2 The midship thickness of the side shell plating is to be maintained forward of amidships up to the strengthened plating.

2. Frames

2.1 In the forward region F the section modulus of the frames is to comply with the requirements given in B.4.

2.2 Tripping brackets spaces 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, A.5 in order to prevent tripping of the frames. The tripping brackets are to be extended over the forward region F.

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

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

IACS UR S3 Rev.2

IACS UR S21 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.

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.

1. Definitions

1.1 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**B**.

1.2 A deckhouse is a decked structure above the strength deck the side plating being inboard of the shell plating more than 0,04**B**.

1.3 A long deckhouse is a deckhouse the length of which within 0,4**L** amidships exceeds 0,2**L** or 12 m, where the greater value is decisive. The strength of a long deckhouse is to be specially considered.

1.4 A short deckhouse is a deckhouse not covered by the definition given in 1.3.

1.5 Superstructures extending into the range of 0,4**L** amidships and the length of which exceeds 0,15**L** are defined as effective superstructures. Their side plating is to be treated as shell plating and their deck as strength deck (see Sections 6 and 7).

1.6 All superstructures being located beyond 0,4**L** amidships or having a length of less than 0,15**L** or less than 12 metres are, for the purpose of this Section, considered as non-effective superstructures.

1.7 For deckhouses of aluminium, Section 2, D is to be observed.

1.8 Scantlings of external funnels are to be determined as for deckhouses.

1.9 Throughout this Section the following definitions apply:

k = material factor according to Section 2, B

p_s = load according to Section 4, B.2.1

p_e = load according to Section 4, B.2.2

p_D = load according to Section 4, B.1

p_{DA} = load according to Section 4, B.5

p_L = load according to Section 4, C.1

t_K = corrosion addition according to Section 3, K

2. Arrangement of superstructure

2.1 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.

2.2 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.

3. Strengthening at the ends of superstructures and Deckhouses

3.1 At the ends of superstructures 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 side plating are to be strengthened as specified in Table 16.1. The strengthening shall extend over a region from 4 frame spacing abaft the end bulkhead to 4 frame spacing 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 according to 1.5	30	20
non effective according to 1.6	20	10

3.2 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 spacing beyond the end points of the longitudinal walls. The girders are to overlap with the longitudinal walls by at least 2 frame spacing.

4. 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.

5. Openings in closed superstructures

For opening in closed superstructures see Section 21, S.

6. Recommendations regarding deckhouse vibration

6.1 *The natural frequencies of the basic global deckhouse vibration modes (longitudinal, transverse, and 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.*

6.2 *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.*

6.3 *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 shall be ensured.*

6.4 *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.*

6.5 *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, and 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.*

B. Side Plating and Decks of Non-Effective Superstructures

1. Side plating

1.1 The thickness of the side plating above the strength deck is not to be less than the greater of the following values:

$$t = 1,21 \cdot \mathbf{a} \cdot \sqrt{p \cdot k} + t_k \text{ [mm] or}$$

$$t = 0,8 \cdot t_{min} \quad \text{[mm]}$$

where

p = p_s or p_e, as the case may be

t_{min} = see Section 6, B.3

1.2 The thickness of the side plating of upper-tier superstructures may be reduced if the stress level permits such reduction.

2. Deck plating

2.1 The thickness of deck plating is not to be less than the greater of the following values:

$$t = C \cdot \mathbf{a} \cdot \sqrt{p \cdot k} + t_k \quad \text{[mm] or}$$

$$t = (5,5 + 0,02 \cdot \mathbf{L})\sqrt{k} \quad \text{[mm]}$$

where

p = p_{DA} or p_L, the greater value is to be taken.

C = 1,21 if $p = p_{DA}$

= 1,1 if $p = p_L$

L need not be taken greater than 200 m.

2.2 Where additional superstructures are arranged on non-effective superstructures located on the strength deck, the thickness required by 2.1 may be reduced by 10%.

2.3 Where plated decks are protected by sheathing, the thickness of the deck plating according to 2.1 and 2.2 may be reduced by t_K, however, it is not to be less than 5,0 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.

3. Deck beams, supporting deck structure, frames

3.1 The scantlings of the deck beams and the supporting deck structure are to be determined in accordance with Section 10.

3.2 The scantlings of superstructure frames are given in Section 9, A.3.

C. Superstructure End Bulkheads and Deckhouse Walls

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. These requirements also apply to breakwaters, see also F.

(IACS UR S3.1)

2. Definitions

The design load for determining the scantlings is:

$$p_A = n \cdot c\,(b \cdot f - z) \qquad [kN/m^2]$$

for weather deck hatch cover and of hatch coamings:

f = $c_L \cdot c_0$

for superstructure end bulkheads and deckhouse walls:

f = $\frac{\mathbf{L}}{10} e^{-L/300} - \left[1 - \left(\frac{\mathbf{L}}{150}\right)^2\right]$ for **L** < 150 m

= $\frac{\mathbf{L}}{10} e^{-L/300}$ for 150 m < **L** < 300 m

= 11,03 for **L** > 300 m

$p_{A,min}$ = minimum design load according to Table 16.2

c_L, c_0 = see Section 4, A.2.2

h_N = standard superstructure height

= 1,05 + 0,01 **L** [m] with $1{,}8 \le h_N \le 2{,}3$

n = $20 + \frac{\mathbf{L}}{12}$ for the lowest tier of unprotected fronts. The lowest tier is normally that tier which is directly situated above the uppermost continuous deck to which the Rule depth **H** is to be measured. However, where the actual distance **H - 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

= $10 + \frac{\mathbf{L}}{12}$ for 2^{nd} tier unprotected fronts of superstructures and deckhouses walls; and for unprotected front coaming 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

= $5 + \frac{\mathbf{L}}{15}$ for 3^{rd} tier and tiers above of unprotected fronts, for sides and protected fronts of superstructures and deckhouses walls; and for unprotected front coaming and hatch cover skirt plates

= $7 + \frac{\mathbf{L}}{100} - 8\,\frac{x}{\mathbf{L}}$ for aft ends of superstructures and deckhouses walls abaft of amidships

= $5 + \frac{\mathbf{L}}{100} - 4\,\frac{x}{\mathbf{L}}$ for aft ends of superstructures and deckhouses walls forward of amidships; and for aft ends of coamings and aft hatch cover skirt plates forward of amidships

L need not be taken greater than 300 m.

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

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

$0,60 \leq C_B \leq 0,80$; when determining scantlings of aft ends forward of amidships, C_B need not be taken less than 0,8.

x = distance [m] between the bulkhead considered or the breakwater and the aft end of the length **L**. When determining sides of a deckhouse, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding 0,15**L** each, and x is to be taken as the distance between aft end of the length **L** and the centre of each part considered.

z = vertical distance [m] from the summer load line to the midpoint of stiffener span, or to the middle of the plate field.

c = 0,3 + 0,7 · b’/**B**’

Table 16.2 Minimum design load p_{Amin}

L	p_{Amin} [kN/m²] for				
	Unprotected fronts		Other area		
	lowest tier	higher tier	tier ≤ 3rd	4th tier	tier ≥ 5th
≤ 50	30	12,5 but not less than in other area	15	12,5	8,5
> 50 ≤ 250	$25 + \frac{L}{10}$		$12,5 + \frac{L}{20}$		
> 250	50		25		

For exposed parts of machinery casings and breakwaters, c is not to be taken less than 1,0.

b’ = breadth of deckhouse at the position considered

B′ = actual maximum breadth of ship on the exposed weather deck at the position considered.
b’/**B**’ is not to be taken less than 0,25

a = spacing of stiffeners [m]

ℓ = unsupported span [m]; for superstructure end bulkheads and deckhouse walls, R is to be taken as the superstructure height or deckhouse height respectively, however, not less than 2,0 m

(IACS UR S3.2 and IACS UR S21.2.2)

(IACS UR S3 Table 1 and IACS UR S21 Table 2)

3. Scantlings

3.1 Stiffeners

The section modulus of the stiffeners is to be determined according to the following formula:

$$W = 0,35 \cdot \mathbf{a} \cdot \ell^2 \cdot p_A \cdot k \qquad [cm^3]$$

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

The section modulus of house side stiffeners needs not be greater than that of side frames on the deck situated directly below; taking account of spacing a and unsupported span ℓ.

(IACS UR S3.3)

3.2 Plate thickness

The thickness of the plating is to be determined according to the greater values of the following formula:

$$t = 0,9 \cdot \mathbf{a} \sqrt{p_a \cdot k} + t_k \quad \text{[mm]}$$

$$t_{min} = \left(5,0 + \frac{\mathbf{L}}{100}\right)\sqrt{k} \quad \text{[mm]} \quad \text{for the lowest tier}$$

$$= \left(4,0 + \frac{\mathbf{L}}{100}\right)\sqrt{k} \quad \text{[mm]} \quad \text{for the upper tiers, however not less than 5,0 mm}$$

For ships with **L** < 65 m, the minimum thickness of plating should be as follows:

$$t_{min} = 5 \quad \text{[mm]} \quad \text{for the lowest unprotected front}$$

$$= 4 \quad \text{[mm]} \quad \text{for all other cases}$$

L need not be taken greater than 300 m.

(IACS UR S3.4)

D. Decks of Short Deckhouses

1. Plating

The thickness of deck plating exposed to weather but not protected by sheathing is not to be less than:

$$t = 8,0 \cdot \mathbf{a} \sqrt{k} + t_K \quad \text{[mm]}$$

For weather decks protected by sheathing and for decks within deckhouses the thickness may be reduced by t_K. In no case the thickness is to be less than the minimum thickness t_{min} = 5,0 mm.

2. Deck beams

The deck beams and the supporting deck structure are to be determined according to Section 10.

E. Elastic Mounting of Deckhouses

1. General

1.1 The elastic mountings are to be type approved by BKI. 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.

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 shall normally not be less than 600 mm.

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.

1.4 For pipelines, see Rules for Machinery Installations (Pt.1, Vol.III) Sec.11.

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 Rules for Electrical Installations (Pt.1, Vol. IV).

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.

2. Design loads

For scantling purposes the following design loads apply:

2.1 Weight

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.

The individual dimension less accelerations a_z (vertically), a_y (transversely) and a_x (longitudinally) and the dimension less resultant acceleration a_β, are to be determined according to Section 4, E for k=1,0 and f =1,0. Due to the resultant acceleration a_β the following load is acting:

$P = G \cdot a_\beta \cdot g$ [kN] acting in the y-z plane

$P_x = G \cdot a_x \cdot g$ [kN] acting in longitudinal direction

$P_y = G \cdot a_y \cdot g$ [kN] acting in transverse direction

$P_z = G \cdot a_z \cdot g$ [kN] acting vertically to the baseline

G = mass of the fully equipped deckhouse [t]

g = 9,81 m/s^2

2.1.2 The support forces in the vertical and horizontal directions are to be determined for the various angles β. The scantlings are to be determined for the respective maximum values (see also Fig. 16.1).

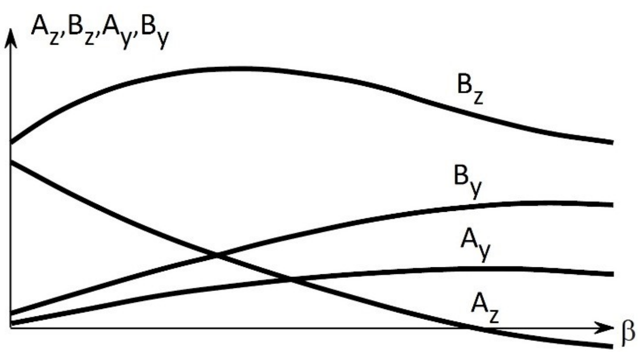


Fig. 16.1 Support forces

2.2 Water pressure and wind pressure

2.2.1 The water load due to the wash of the sea is assumed to be acting on the front wall in the longitudinal direction only.

The design load is:

p_{wa} = $0{,}5 \cdot p_A$ [kN/m^2]

p_A = see C.2

The water pressure is not to be less than:

p_{wa} = 25 [kN/m^2] at the lower edge of the front wall

= 0 at the level of the first tier above the deckhouse bottom

P_{wa} = $p_{wa} \cdot A_f$ [kN]

A_f = loaded part of deckhouse front wall [m^2]

2.2.2 The design wind load acting on the front wall and on the side walls is:

P_{wi} = $A_D \cdot p_{wi}$ [kN]

A_D = area of wall [m^2]

p_{wi} = 1,0 [kN/m^2]

2.3 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 2.1 and 2.2 are to be taken into account.

2.4 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:

1) 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].
2) Outside the deckhouse: Load p_D.
3) Bearing forces in accordance with the load assumptions 2.1 and 2.2.

3. Load cases

3.1 For design purposes the following load cases are to be investigated separately (see also Fig. 16.2)

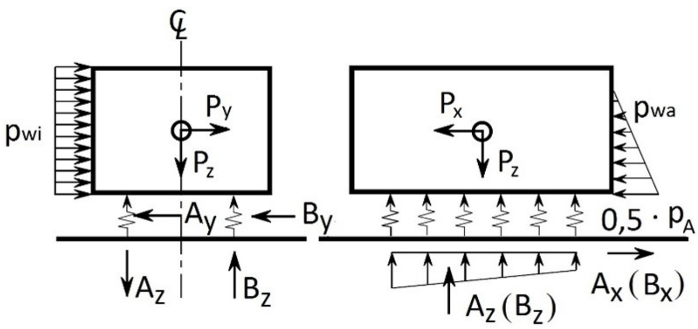


Fig. 16.2 Design loads due to wind and water pressure

3.2 Service load cases

Forces due to external loads:

3.2.1 Transverse direction (z-y-plane)

$$P_{y1} = G \cdot a_{\beta(y)} \cdot g + P_{wi} \quad [kN]$$

acting in transverse direction

$$P_{z1} = G \cdot a_{\beta(z)} \cdot g \quad [kN]$$

acting vertically to the baseline

P_{wi} = wind load as per 2.2.2

$a_{\beta(y)}$ = horizontal acceleration component of a_β

$a_{\beta(z)}$ = vertical acceleration component of a_β

3.2.2 Longitudinal direction (z-x-plane)

$$P_{x1} = G \cdot a_{\beta(x)} \cdot g + P_{wa} + P_{wi} \quad [kN]$$

acting in longitudinal direction

$$P_{z1} = G \cdot a_{\beta(z)} \cdot g \quad [kN]$$

acting vertically to the baseline

$a_{\beta(x)}$ = horizontal acceleration component in the longitudinal plane.

3.2.3 For designing the securing devices to prevent the deckhouse from being lifted, the force (in upward direction) is not to be taken less than determined from the following formula:

$$P_{zmin} = 0{,}5 \cdot g \cdot G \quad [kN]$$

3.3 Extraordinary load cases

3.3.1 Collision force in longitudinal direction:

$$P_{x2} = 0{,}5 \cdot g \cdot G \quad [kN]$$

3.3.2 Forces due to static heel of 45°

$$P_{z2}, P_{y2} = 0{,}71 \cdot g \cdot G \quad [kN]$$

P_{z2} = force acting vertically to the baseline

P_{y2} = force acting in transverse direction.

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 shall be capable of withstanding the horizontal force P_{y2} as per 3.3.2 in transverse direction.

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 2,0 m above the freeboard deck is to be taken.

4. Scantlings of rails, mounting elements and substructures

4.1 General

4.1.1 The scantlings of those elements are to be determined in accordance with the load cases stipulated under 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.

4.1.2 Strength calculations for the structural elements with information regarding acting forces are to be submitted for approval.

4.2 Permissible stresses

4.2.1 The permissible stresses given in Table 16.3 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).

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.

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 4.2.1.

Table 16.3 Permissible stress in the rails and the steel structures at mounting elements and in the substructures [N/mm²]

Type of stress	service load cases	extraordinary 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 $\sigma_v = \sqrt{\sigma_n^2 + 3 \cdot \tau^2}$	$0{,}75 \cdot R_{eH}$	$0{,}9 \cdot R_{eH}$
R_{eH} = minimum nominal upper yield point R_m = tensile strength		

4.2.4 In screwed connections, the permissible stresses given in Table 16.4 are not to be exceeded.

4.2.5 Where turnbuckles in accordance with DIN 82008 are used for securing devices, the load per bolt under load conditions 3.2.3 and 3.3.4 may be equal to the proof load (2 times safe working load).

Table 16.4 Permissible stress in screwed connections [N/mm²]

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 $\sigma_v = \sqrt{\sigma_n^2 + 3(\tau^2 + \tau_t^2)}$	$0{,}6 \cdot R_{eH}$	$1{,}0 \cdot R_{eH}$

5. Corrosion Addition

For the deck plating below elastically mounted deckhouse a minimum corrosion addition of t_K = 3,0 mm applies.

F. Breakwater

1. Arrangement

If cargo is intended to be carried on deck forward of x/**L** ≥ 0,85, a breakwater or an equivalent protecting structure (e.g. whaleback or turtle deck) is to be installed.

2. Dimensions of the breakwater

2.1 The recommended height of the breakwater is

$$h_W = 0,8(b \cdot c_L \cdot c_0 - z) \quad [mm]$$

but shall not be less than

$$h_{Wmin} = 0,6(b \cdot c_L \cdot c_0 - z) \quad [mm]$$

However, the minimum required average height hWmin need not to be more than the maximum height of the deck cargo stowed between the breakwater and 15 m aft of it.

where z is to be the vertical distance [m] between the summer load line and the bottom line of the breakwater.

The average height of whalebacks or turtle decks has to be determined analogously according to Fig.16.3.

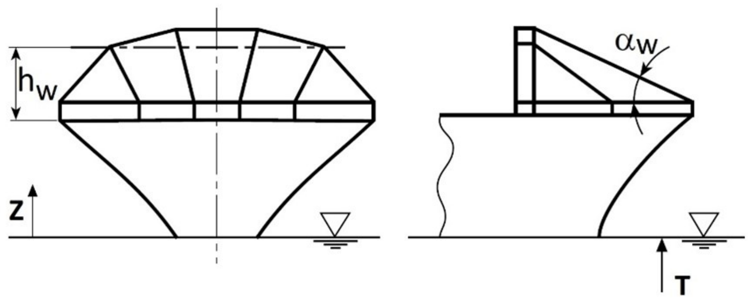


Fig. 16.3 Whaleback

However, IMO requirements regarding navigation bridge visibility are to be considered

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.

3. Scantlings

3.1 Plate thickness

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:

$$t = 0,9 \cdot \mathbf{a} \cdot \sqrt{p_{BW} \cdot k} + t_k \quad [mm] \text{ with } \quad t \geq t_{min}$$

t_{min} = minimum plate thickness [mm], defined as:

$$= \left(5,0 + \frac{\mathbf{L}}{100}\right) \cdot \sqrt{k}$$

However **L** need not be taken greater than 300 m

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 B.2.1.

3.2 Stiffeners

3.2.1 General

Stiffeners are to be connected on both ends to the structural members supporting them.

3.2.2 Breakwaters with α_W ≤ 90 ° and whalebacks with α_W > 20 °

The section modulus W of the stiffeners is to be determined by the following formula:

$$W = 0{,}35 \cdot \mathbf{a} \cdot \ell^2 \cdot p_{BW} \cdot k \text{ [cm}^3\text{]}$$

3.2.3 Whalebacks with α_W < 20 °

The scantlings of stiffeners are to be the same as for deck beams of non-effective superstructures according to B.3.

3.3 Primary supporting structure

3.3.1 General

Sufficient supporting structures are to be provided.

3.3.2 Breakwaters with α_W ≤ 90 ° and whalebacks with α_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}:

$$\sigma_{perm} = \frac{230}{k} \quad \text{[N / mm]}$$

3.3.3 Whalebacks with α_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 B.3.

4. Cut-outs

Cut-outs in the webs of primary supporting members of the breakwater are to be reduced to their necessary minimum. Free edges of the cut-outs are to be reinforced by stiffeners.

If cut-outs in the plating are provided to reduce the load on the breakwater, the area of single cut-outs should not exceed 0,2 m^2 and the sum of the cut-out areas not

5. Loads on breakwaters and whalebacks

5.1 Breakwaters with α_W ≤ 90 ° and whalebacks with α_W > 20 °

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

$$P_{BW} = n \cdot d\,(b \cdot c_L \cdot c_0 - z) \quad \text{[kN/m}^2\text{]}$$

$p_{BW,min}$ = the minimum design load is to be the same as p_A,min for the lowest tier of unprotected fronts according to Table 16.2

n = distribution factor, defined as:

$$= 10 + \frac{\mathbf{L}}{20}$$

L need not be taken greater than 300 m.

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

= $\sin \alpha_W$

α_W = inclining angle [°], determined on centre line, see Fig. 16.3

b = distribution factor, defined as:

$$= 1{,}0 + 2{,}75 \left(\frac{\frac{x}{\mathbf{L}} - 0{,}45}{\mathbf{C_B} + 0{,}2} \right)^2$$

5.2 Whalebacks with α_W < 20 °

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

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

p_D = load on forecastle decks according to Section 4, B.1

6. Proof of buckling strength

Structural members' buckling strength has to be proved according to Section 3, F.

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Section 17 Cargo Hatchways

A. General

1. Application

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 S21.1.1)

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 BKI.

(IACS UR S21.1.1)

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 S21.1.1)

1.4 These requirements are in addition to the requirements of the ICLL.

(IACS UR S21.1.1)

1.5 References

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

IACS UR S14 Rev.6

IACS UR S21 Rev.6

IACS UR S26 Rev.5

IACS UR S30 Rev.1.Corr.1

ICLL containing all amendments up to 1st July 2010

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.

2. Hatchways on freeboard and superstructure decks

2.1 The hatchways are classified according to their position as defined in Section 1, H.6.7.

2.2 Hatchways 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

2.3 A deviation from the requirements under 2.2 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.

2.4 Where an increased freeboard is assigned, the height of hatchway coamings according to 2.2 and 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 below the actual freeboard deck.

2.5 For corrosion protection for all hatch coamings and all hatch covers of bulk carriers, ore carriers and combination carriers, see Section 38, G.

Note:

Special requirements of National Administrations regarding hatchways, hatch covers, tightening and securing arrangements are to be observed.

3. Hatchways on lower decks and within superstructures

3.1 Coamings are not required for hatchways below the freeboard deck or within weathertight closed superstructures unless they are required for strength purposes.

3.2 Where within hatch casings no hatch covers are arranged at the deck level, the next covers and their supports below are to be strengthened corresponding to the greater load.

4. 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 S21.1.2.1)

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 S21.1.2.1)

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 S21.1.2.1)

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 S21.1.2.1)

Symbols

p	=	design load [kN/m^2] for hatch covers of respective load cases A to D according to B.
	=	p_H for vertical loading on hatch covers according to Table 17.2
	=	p_A for horizontal loading on edge girders of hatch covers and on coamings according to Section 16, C.2
	=	p_D, for load on weather decks according to Section 4, B.1
	=	design pressure p_d, for partially filled tanks according to Section 4, D.2
	=	liquid pressure p_1, p_2 according to Section 4, D.1
	=	p_L, for load on cargo decks according to Section 4, C.1
R_{eH}	=	minimum nominal upper yield point of the steel used [N/mm^2] according to Section 2, B
R_m	=	tensile strength of the steel used [N/mm^2]

For normal strength hull structural steel:

R_m = 400 N/mm^2 with R_{eH} = 235 N/mm^2

For higher strength hull structural steel:

R_m = 440 N/mm^2 with R_{eH} = 315 N/mm^2

= 490 N/mm^2 with R_{eH} = 355 N/mm^2

ℓ	=	unsupported span of stiffener [m]
a	=	spacing of hatchway beams or stiffeners [m]
t	=	thickness of structural member [mm]
	=	$t_{net} + t_K$
t_{net}	=	net thickness [mm]
t_K	=	corrosion addition according to Table 17.1.
x	=	distance of mid point of the assessed hatch cover from aft end of length **L** or $\mathbf{L}_C$, as applicable
h_N	=	superstructure standard height [m] according to ICCL, see also Section 16, C.2

5. Corrosion Addition

For the scantlings of hatch covers and coamings the corrosion additions t_K according to Table 17.1 are to be applied.

(IACS UR S21.7.1)

Table 17.1 Corrosion addition 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, K.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 (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, K.1
	Coaming stays and stiffners	1,5 (1,5)
Hatches within enclosed spaces	Hatch covers :	
	- top plating	1,2
	- remaining structures	1,0
	Hatch coamings	according to Section 3, K.1 to K.3

(IACS UR S21 Table 8)

B. Hatch Covers

1. General

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 4.4, this requirement can be waived.

(IACS UR S21.1.4)

1.2 For hatch covers the application of steel with R_{eH} > 355 N/mm^2 is to be agreed with BKI.

2. Design loads

Structural assessment of hatch covers and hatch coamings is to be carried out according to the following design loads:

(IACS UR S21.2)

2.1 Load case A: Vertical and horizontal weather design load

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, H.6.7 and Fig. 17.1 for definitions of Position 1 and 2.

(IACS UR S21.2.1)

2.1.2 In general, the vertical design load p_H needs not to be combined with load cases B and C according to 2.2 and 2.3.

(IACS UR S21.2.1)

Table 17.2 Design load of weather deck hatches

<table>
<tr><th rowspan="2">Position</th><th colspan="2">Design load p_H [kN/m^2]</th></tr>
<tr><th>$\frac{x}{L_C} \le 0,75$</th><th>$0,75 < \frac{x}{L_C} \le 1,0$</th></tr>
<tr><td rowspan="8">1</td><td colspan="2">for 24 m ≤ L_C ≤ 100 m</td></tr>
<tr><td rowspan="2">$\frac{9.81}{76} \cdot (1,5 \cdot L_C + 116)$</td><td>On freeboard deck
$\frac{9,81}{76} \cdot \left[(4,28 \cdot L_C + 28) \cdot \frac{x}{L_C} - 1,71 \cdot L_C + 95\right]$</td></tr>
<tr><td>upon exposed superstructure decks located at least one superstructure standard height h_N above the freeboard deck
$\frac{9,81}{76} \cdot (1,5 \cdot L_C + 116)$</td></tr>
<tr><td colspan="2">for L_C > 100 m</td></tr>
<tr><td rowspan="4">9.81 · 3,5</td><td>On freeboard deck for type B ships according to ICLL
$9,81 \cdot \left[(0,0296 \cdot L_1 + 3,04) \cdot \frac{x}{L_C} - 0,0222 \cdot L_1 + 1,22\right]$</td></tr>
<tr><td>On freeboard deck for ships with less freeboard then type B ships according to ICLL
$9,81 \cdot \left[(0,1452 \cdot L_1 + 8,52) \cdot \frac{x}{L_C} - 0,1089 \cdot L_1 + 9,89\right]$</td></tr>
<tr><td>upon exposed superstructure decks located at least one superstructure standard height h_N above the freeboard deck
9.81 · 3,5</td></tr>
<tr><td>L_1 = L_C, but not more than 340 m</td></tr>
<tr><td rowspan="5">2</td><td colspan="2">for 24 m ≤ L_C ≤ 100 m</td></tr>
<tr><td colspan="2">$\frac{9,81}{76} \cdot (1,1 \cdot L_C + 87,6)$</td></tr>
<tr><td colspan="2">for L_C > 100 m</td></tr>
<tr><td colspan="2">9,81 · 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
9,81 · 2,1</td></tr>
</table>

(IACS UR S21 Table 1)

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 S21.2.1)

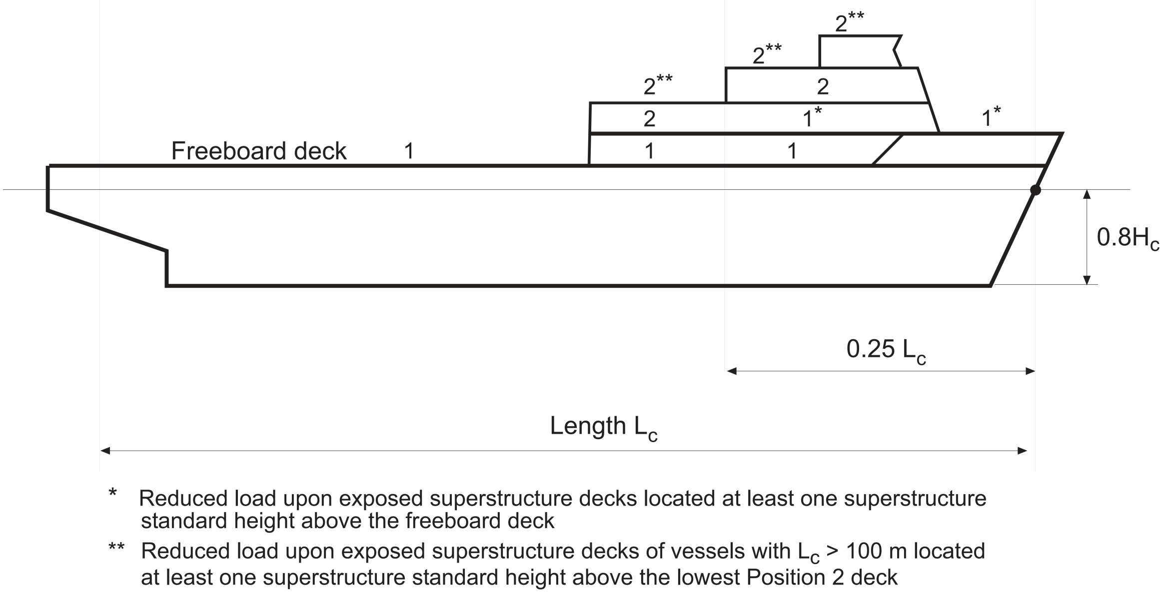


Fig. 17.1 Positions 1 and 2

(IACS UR S21 Figure 1)

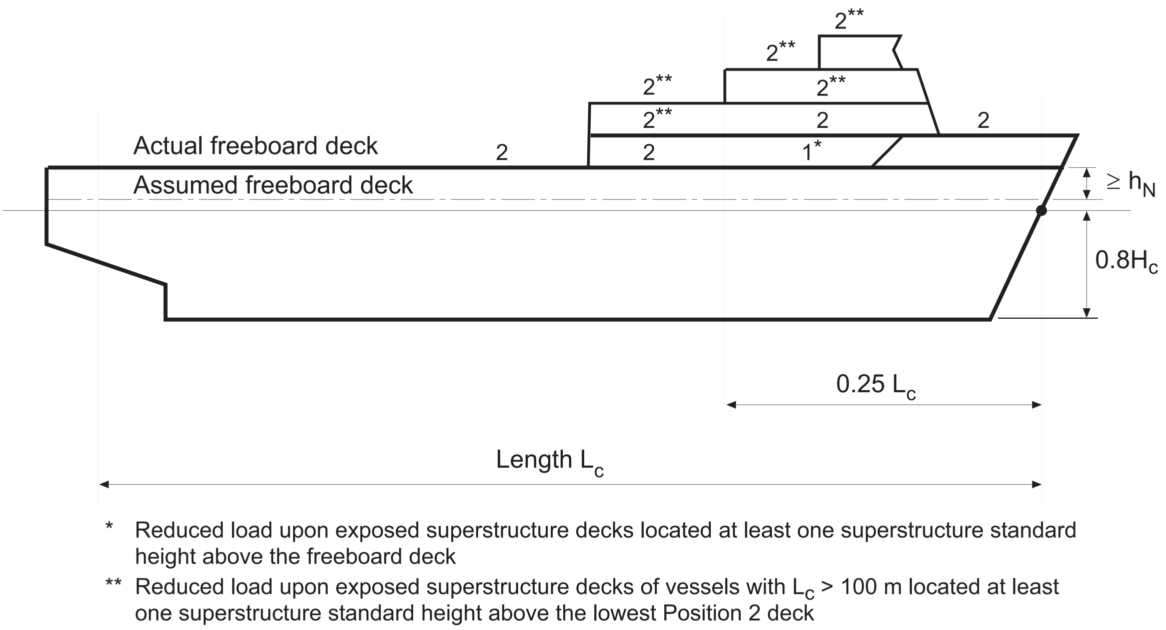


Fig. 17.2 Positions 1 and 2 for an increased freeboard

(IACS UR S21 Figure 2)

2.1.4 The vertical design load p_H shall in no case be less than the deck design load 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.

2.1.5 The horizontal design load p_A for the outer edge girders of weather deck hatch covers and of hatch coamings is to be determined analogously as for superstructure walls in the respective position (see Section 16, C.2).

(IACS UR S21.2.2.1)

For bulk carriers according to Section 23 the horizontal load shall not be less than:

P_{Amin}	=	175	kN/m^2	in general for outer edge girders of hatch covers
	=	220	kN/m^2	in general for hatch coamings or when a forecastle is fitted in accordance with Section 23, G
	=	230	kN/m^2	for the forward edge girder of the hatch 1 cover, if no forecastle according to Section 23, D is arranged
	=	290	kN/m^2	for the forward transverse coaming of hatch 1, if no forecastle according to Section 23, D is arranged

(IACS UR S21.2.2.2)

2.2 Load case B: Cargo loads

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, P_z is carried on weather deck hatch covers Section 4, B.1 is to be observed.

(IACS UR S21.2.3.1)

2.3 Load case C: Container loads

2.3.1 The loads defined in 2.3.2 to 2.3.4 shall be applied where containers are stowed on the hatch covers.

(IACS UR S21 2.4.1)

2.3.2 The load, P [kN], applied at each corner of container stack and resulting from heave and pitch, i.e ship in upright condition shall be determined by the following formulae:

$$P = 9,81 \frac{M}{4}(1 + a_v) \quad [kN]$$

where:

M = maximum designed mass of container stack [t]

(IACS UR S21 2.4.2)

2.3.3 Where containers are stowed on hatch covers the following support forces A_z, B_z and B_y in z- and y 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.

$$A_z = 9,81 \cdot \frac{M}{2} \cdot (1 + a_v) \cdot \left[0,45 - 0,42 \cdot \frac{h_m}{b}\right] \quad [kN]$$

$$B_z = 9,81 \cdot \frac{M}{2} \cdot (1 + a_v) \cdot \left[0,45 + 0,42 \cdot \frac{h_m}{b}\right] \quad [kN]$$

$$B_y = 2,4 \cdot M \quad [kN]$$

where:

a_v = acceleration factor according to Section 4, C.1

M = maximum designed mass of container stack [t]

= $\sum W_i$

h_m = height of centre of gravity of stack above hatch cover top [m], may be calculated as weighted mean value of the stack, where the centre of gravity of each tier Is assumed to be located at the centre of each container

= $\dfrac{\sum (z_i \cdot W_i)}{M}$

z_i = distance [m], from hatch cover top to the centre of i^{th} container

W_i = weight [t], of i-th container

b = distance between midpoint of foot points [m]

When strength of the hatch cover structure is assessed by FE analysis according to 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 A_z and B_z applied for the assessment of hatch cover strength are to be shown in the drawings of the hatch covers.

Note:

It is recommended that container loads as calculated above are considered as limit for foot point loads of container stacks in the calculations of cargo securing (container lashing)

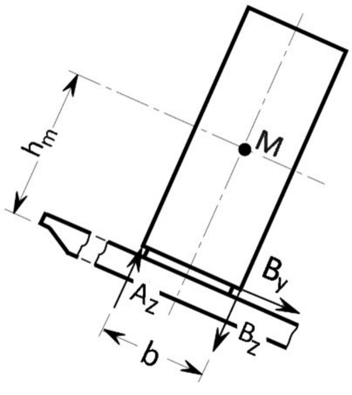


Fig. 17.3 Forces due to load case C acting on hatch cover

(IACS UR S21.2.4.3)

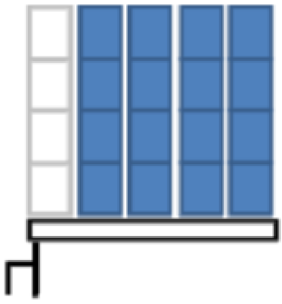
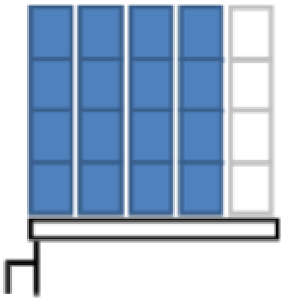
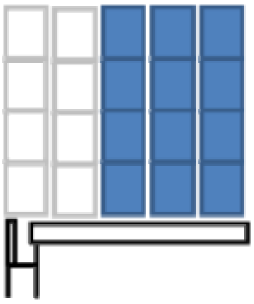
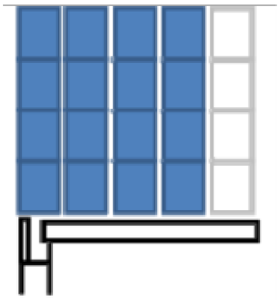
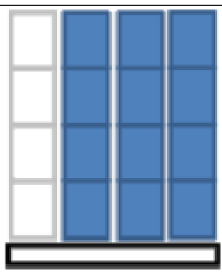
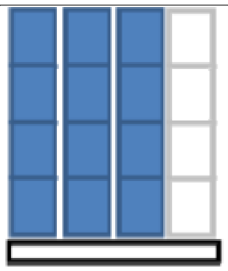
2.3.4 Load cases with partial loading

The load cases in 2.3.2 and 2.3.3 are also to be considered for partial loading which may occur in practice, e.g. where specified container stack places are empty. For each hatch cover, the heel directions, as shown in Table 17.3, are to be considered.

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, that are located completely on the hatch cover. If there are additional stacks that are supported partially by the hatch cover and partially by container stanchions then the loads from these stacks are also to be neglected, refer to Table 17.3. In addition, the case where only the stack places supported partially by the hatch cover and partially by container stanchions are left empty is to be assessed in order to consider the maximum loads in the vertical hatch cover supports.

(IACS UR S21.2.4.4)

Table 17.3 Partial loading of container hatch covers

Heel direction	←	→
Hatch covers supported by the longitudinal hatch coaming with all container stacks located completely on the hatch cover.		
Hatch covers supported by the longitudinal hatch coaming with the outermost container stack supported partially by the hatch cover and partially by container stanchions.		
Hatch covers not supported by the longitudinal hatch coaming (center hatch covers)		

(IACS UR S21 Table 3)

2.3.5 Mixed stowage of 20’ and 40’ containers on hatch cover

In the case of mixed stowage (20’ and 40’ container combined stack), the foot point forces at the fore and aft end of the hatch cover are not to be higher than resulting from the design stack weight for 40’ containers, and the foot point forces at the middle of the cover are not to be higher than resulting from the design stack weight for 20’ containers.

(IACS UR S21.2.4.5)

The design load for other cargo than containers subject to lifting forces is to be determined separately.

2.4 Load case D: Loads due to liquid in hold

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 D.2 irrespective of the filling height of hold spaces.

2.5 Load case E: Loads due to elastic deformations of the ship’s hull

Hatch covers, which in addition to the loads according to above are loaded in the ship’s transverse direction by forces due to elastic deformations of the ship’s hull, are to be so designed that the sum of stresses does not exceed the permissible values given in 3.

(IACS UR S21.2.5)

2.6 Horizontal mass forces

For the design of hatch cover support according to 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:
	=	$0{,}2 \cdot g$ [m/s²] for longitudinal direction
	=	$0{,}5 \cdot g$ [m/s²] for transverse direction

The accelerations in longitudinal direction and in transverse direction do not need to be considered as acting simultaneously.

(IACS UR S21.6.2.1)

3. Permissible stresses and deflections

3.1 The equivalent stress σ_v in steel hatch cover structures related to the net thickness shall not exceed $0{,}8 \cdot R_{eH}$ for load case A as defined in 2.1.

For load cases B to E according to 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 4.4.

For steels with R_{eH} > 355 N/mm², the value of R_{eH} to be applied throughout this Section is to be agreed with BKI but is not to be more than the minimum yield strength of the material.

For grillage analysis, the equivalent stress σ_v may be taken as follows:

$$\sigma_v = \sqrt{\sigma^2 + 3 \cdot \tau^2} \quad [\mathrm{N/mm^2}]$$

σ	=	stress component	[N/mm²]
	=	$\sigma_b + \sigma_n$	
σ_b	=	bending stress	[N/mm²]
σ_n	=	normal stress	[N/mm²]
τ	=	shear stress	[N/mm²]

For FEM calculations, the equivalent stress σ_v may be taken as follows:

$$\sigma_v = \sqrt{\sigma_x^2 - \sigma_x \cdot \sigma_y + \sigma_y^2 + 3 \cdot \tau^2} \quad [\mathrm{N/mm^2}]$$

σ_x	=	normal stress in x-direction	[N/mm²]
σ_y	=	normal stress in y-direction	[N/mm²]
τ	=	shear stress in x-y plane	[N/mm²]

Indices x and y denominate axes of a two-dimensional cartesian coordinate system in the plane of the considered structural element.

In case of FEM calculations using shell or plane stress elements, the stresses are to be read from the centre of the individual element. It is to be observed that, in particular, at flanges of unsymmetrical girders, the evaluation of stress from element centre may lead to non-conservative results. Thus, a sufficiently fine mesh is to be applied in these cases or, the stress at the element edges shall not exceed the allowable stress. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

Stress concentrations shall be assessed on case-by-case basis.

(IACS UR S21.3.1.1)

The deflection f of weather deck hatch covers under the design load p_H shall not exceed

$$f = 0{,}0056 \cdot \ell_g \quad [m]$$

ℓ_g = largest span of girders [m]

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.

(IACS UR S21.3.1.2)

3.2 Where hatch covers are made of aluminium alloys. Section 2, D is to be observed. For permissible deflections 3.1 applies.

3.3 The permissible stresses specified under 3.1 apply to primary girders of symmetrical cross section. For unsymmetrical cross sections, e.g. sections, equivalence in regard to strength and safety is to be proved, see also Section 3, L.

4. Strength calculation for hatch covers

4.1 General

4.1.1 Strength calculation for hatch covers may be carried out by either grillage analysis or FEM. Double skin hatch covers or hatch covers with box girders are to be assessed using FEM, refer to 4.4.

Strength Calculations are to be based on net thickness:

$$t_{net} = t - t_K$$

The corrosion addition t_K used for calculation have to be indicated in the drawings.

(IACS UR S21.1.5 and S21.3.5)

4.1.2 For all structural components of hatch covers for spaces in which liquids are carried, the minimum thickness for tanks according to Section 12, A.7 is to be observed.

4.2 Hatch cover supports

Supports and stoppers of hatch covers are 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 2.5.

Deformations due to the design loads according to 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 6.

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.

4.3 Strength calculations for beam and girder grillages

Cross-sectional properties are to be determined considering the effective breadth according to Section 3, E. Cross sectional areas of profiles parallel to the girder web within the effective breadth can be included, see Section 3, F.5.2.3.5.

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, F.5.2.3.5.

In way of larger cutouts in girder webs it may be required to consider second order bending moments.

4.4 FEM calculations

For strength calculations of hatch covers by means of finite elements, the cover geometry shall be idealised built as realistically as possible. Element size shall be appropriate to account for effective breadth. In no case element width shall be larger than stiffener spacing. In way of force transfer points and cutouts the mesh has to be refined where applicable.

The ratio of element length to width shall not exceed 3. The element height of girder webs shall not exceed one third of the web height. Stiffeners, supporting plates against lateral loads, have to be included in the idealization. Stiffeners may be modelled by using beam elements, or shell/plate elements. Buckling stiffeners may be disregarded for the stress calculation.

Hatch covers fitted with U-type stiffeners as shown in Fig. 17.4 are to be assessed by means of FE analysis. The geometry of the U-type stiffeners is to be accurately modelled using shell/plate elements. Nodal points are to be properly placed on the intersections between the webs of a U-type stiffener and the hatch cover plate, and between the webs and flange of the U-type stiffener.

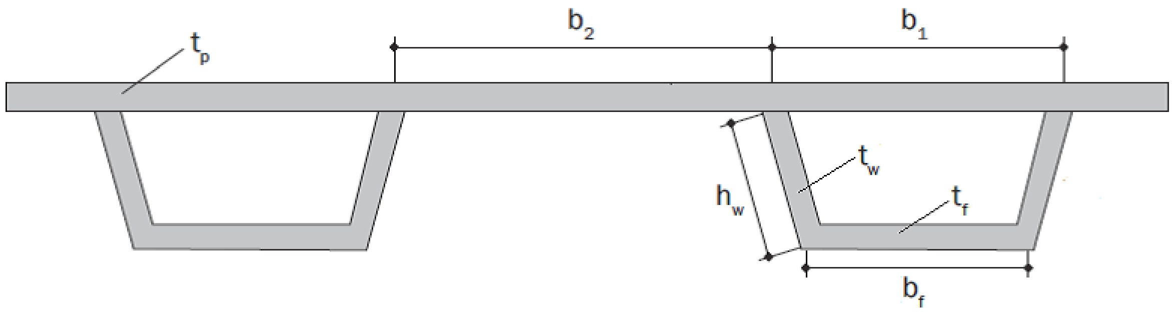


Fig. 17.4 Example of hatch cover fitted with U-type stiffeners

Wherever applicable the following boundary conditions are to be applied to the FE model:

- Boundary nodes in way of a bearing pad on the hatch coamings are to be fixed against displacement in the direction perpendicular to the pad.
- Lifting stoppers are to be fixed against displacements in the direction determined by the stoppers.
- For a folding type hatch cover, the FE nodes connected through a hinge are to have the same translational displacement in the direction perpendicular to the hatch cover top plating

(IACS UR S21.3.5.1)

4.5 Buckling strength of hatch cover structures

4.5.1 General

Buckling strength of all hatch cover structures is to be checked. Buckling assessments are to be performed in compliance with the requirements in Section 3, F for the conditions specified in 4.5.2 and 4.5.3.

The net scantlings as defined in 4.1.1 are to be used for buckling check.

(IACS UR S21.3.6.1)

4.5.2 Slenderness requirements

The slenderness requirements are to be in accordance with Section 3, F.2. The slenderness requirements need not be applied to the lower boundary of double skin hatch covers unless the cargo hold is designed for carriage of ballast or liquid cargo.

The breadth of the primary supporting member flange is to be not less than 40% of their depth for laterally unsupported spans greater than 3,0 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

(IACS UR S21.3.6.2)

4.5.3 Buckling requirements

.1 Application

These requirements apply to the buckling assessment of hatch cover structures subjected to compressive and shear stresses and lateral pressures. The buckling assessment is to be performed for the following structural elements:

- Stiffened and unstiffened panels, including curved panels and panels stiffened with U-type stiffeners.
- Web panels of primary supporting members in way of openings.

For rule application, the panel types and assessment methods, the applied lateral pressure and stresses, safety factors and buckling check criteria are defined in 4.5.3.2, 4.5.3.3, 4.5.3.4 and 4.5.3.5, respectively. The procedure and detailed requirements for buckling assessment are given in Section 3, F.4, including idealization of irregular plate panels, definition of reference stresses and buckling criteria.

Unless otherwise specified, the symbols used in 4.5.3 are defined in Section 3, F.

(IACS UR S21.3.6.3.1)

.2 Panel types and assessment methods

The plate panel of a hatch cover structure is to be modelled as stiffened panel (SP) or unstiffened panel (UP) as defined in Section 3, F.1.3.7. Assessment Method A (-A) and Method B (-B) as defined in Section 3, F.1.3.8 are to be used in accordance with Table 17.4, Fig. 17.5 and Fig. 17.6. For a web panel with opening, the procedure for opening should be used for its buckling assessment.

For a hatch cover fitted with U-type stiffeners, the additional buckling assessment requirements specific for panels with U-type stiffeners in Section 3, F.5.2.5 are also to be followed.

(IACS UR S21.3.6.3.2)

Table 17.4 Structural members and assessment methods

Structural elements	Assessment method [1, 2]	Normal panel definition
Hatch cover top/bottom plating structures, see Fig. 17.5		
Hatch cover top/bottom plating	SP-A	Length: between transverse girders Width: between longitudinal girders
Irregularly stiffened panels	UP-B	Plate between local stiffeners/PSM
Hatch cover web panels of primary supporting members, see Fig. 17.6		
Web of transverse/longitudinal girder (single skin type)	UP-B	Plate between local stiffeners/face plate/PSM
Web of transverse/longitudinal girder (double skin type)	SP-B[3]	Length: between PSM Width: full web depth
Web panel with opening	Procedure for opening	Plate between local stiffeners/face plate/PSM
Irregularly stiffened panels	UP-B	Plate between local stiffeners/face plate/PSM

Notes:
1: SP and UP stand for stiffened and unstiffened panel respectively.
2: A and B stand for Method A and Method B respectively.
3: In case that the that the buckling carlings/brackets are irregularly arranged in the web of transverse/longitudinal girder, UP-B method may be used.

(IACS UR S21.Table 5)

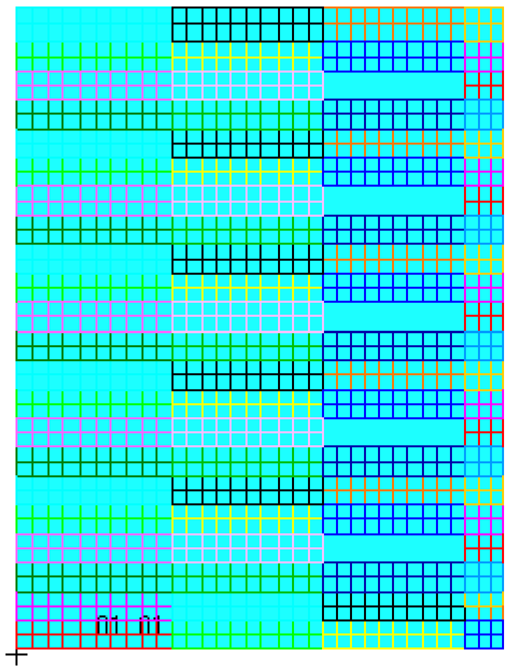


Fig. 17.5 Example of hatch cover fitted with U-type stiffeners

(IACS UR S21.Figure 6)

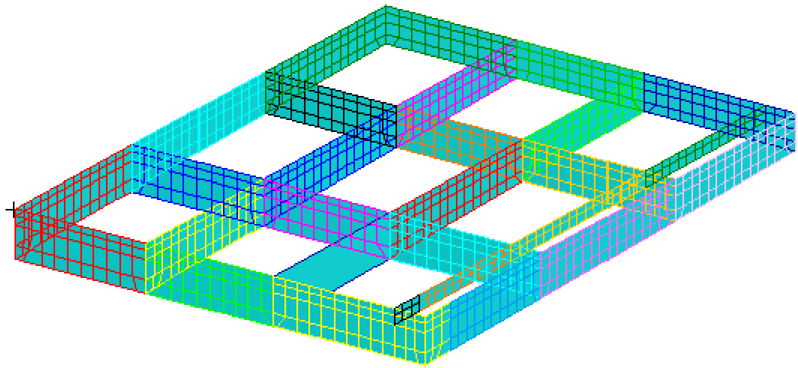


Fig. 17.6 Example of hatch cover fitted with U-type stiffeners

(IACS UR S21.Figure 7)

.3 Applied lateral pressure and stresses

The buckling assessment of hatch covers is based on the lateral pressure as defined in 2.1 and stresses obtained from FE analysis, refer to 4.4.

(IACS UR S21.3.6.3.3)

.4 Safety factors

For all hatch cover structural members, safety factor (S) = 1,0 is to be applied to both of the plating and stiffener buckling capacity formulas as defined in Section 3, F.5.2.2 and Section 3, F.5.2.3, respectively.

(IACS UR S21.3.6.3.4)

.5 Buckling acceptance criteria

A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$$\eta_{act} \leq \eta_{all}$$

where:

η_{act} = buckling utilisation factor based on the applied stress, as defined in Section 3, F.1.3.9 and Section 3, F.4, and calculated per Section 3, F.5.

η_{all} = allowable buckling utilisation factor for plate and stiffener and web of primary structural member (PSM), taken as:.

— for external pressure, as defined in 2.1:

= 0,80

— for other loads, as defined in 2.2 to 2.5:

= 0,90 Static (S) and Dynamic (D)

= 0,72 Static (S)

(IACS UR S21.3.6.3.5)

5. Scantlings

5.1 Hatch cover plating

5.1.1 Top plating

The thickness of the hatch cover top plating is to be obtained from the calculation according to 4. under consideration of permissible stresses according to 3.1.

However, the thickness shall not be less than the largest of the following values :

t = max $[t_1 ; t_2]$ [mm]

$t_1 = c_p \cdot 16,2 \cdot a \cdot \sqrt{\frac{p}{R_{eH}}} + t_K$ [mm]

$t_2 = 10 \cdot a + t_K$ [mm]

$t_{min} = 6,0 + t_K$ [mm]

$c_p = 1,5 + 2,5\left(\frac{|\sigma_x|}{R_{eH}} - 0,64\right) \geq 1,5$ for p_H or p_L

$= 1,0 + 2,5\left(\frac{|\sigma_x|}{R_{eH}} - 0,64\right) \geq 1,0$ for p_D; p_d; p_1; p_2

σ_x = maximum normal stress [N/mm^2] of hatch cover plating, determined according to Fig. 17.7

p = design load [kN/m^2], defined as:

= max $[p_D ; p_H ; p_L ; p_1 ; p_2 ; p_d]$as applicable

For flange plates under compression sufficient buckling strength according to Section 3, F is to be verified.

For hatch covers subject to wheel loading plate thickness shall not be less than according to Section 7, B.2.

(IACS UR S21.3.2)

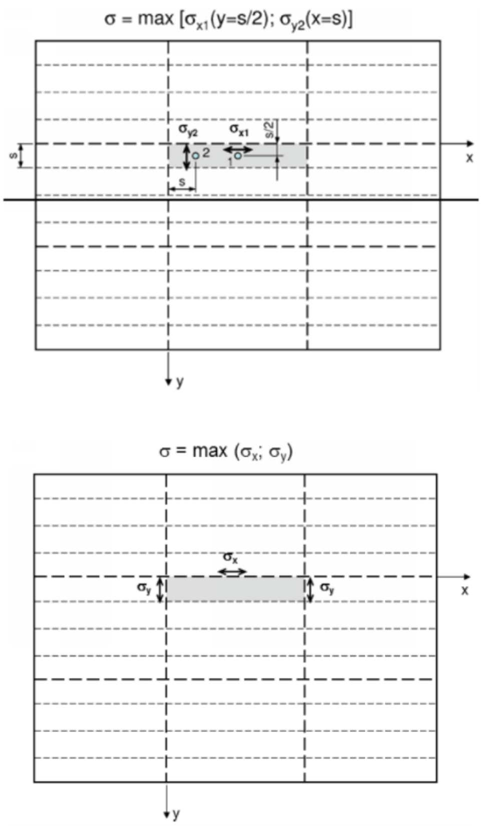


Fig. 17.7 Determination of normal stress of the hatch cover plating

(IACS UR S21 Figure 4)

5.1.2 Lower plating of double skin hatch covers and box girders

The thickness is to be obtained from the calculation according to 4. under consideration of permissible stresses according to 3.1.

The thickness shall not be less than the larger of the following values:

$t = 6{,}5 \cdot \mathbf{a} + t_K$ [mm] If project cargo is intended to be carried on a hatch cover

$t_{min} = 5{,}0 + t_K$ [mm]

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 5.1.1.

Note:

Project cargo means especially large or bulky cargo lashed to the hatch cover. Examples are parts of cranes or wind power stations, turbines, etc. Cargoes that can be considered as uniformly distributed over the hatch cover, e.g., timber, pipes or steel coils need not to be considered as project cargo.

(IACS UR S21.3.2.2)

5.2 Main girders

Scantlings of main girders are obtained from the calculation according to 4. under consideration of permissible stresses according to 3.1.

For all components of main girders sufficient safety against buckling shall be verified according to 4.5.

The thickness of main girder webs shall not be less than :

$t = 6{,}5 \cdot a + t_K$ [mm]

$t_{min} = 5{,}0 + t_K$ [mm]

(IACS UR S21.3.4.1)

At intersections of flanges from two girders, notch stresses have to be observed.

5.3 Edge girders (Skirt plates)

5.3.1 Scantlings of edge girders are obtained from the calculations according to 4. under consideration of permissible stresses according 3. The thickness of the outer edge girders exposed to wash of sea shall not be less than the largest of the following values:

$$t = 16{,}2 \cdot a \cdot \sqrt{\frac{p_A}{R_{eH}}} + t_K \quad [\text{mm}]$$

$$t = 8{,}5 \cdot a + t_k \quad [\text{mm}]$$

$$t_{min} = 5{,}0 + t_K \quad [\text{mm}]$$

where:

p_A = horizontal design load [kN/m^2], as defined in 2.1.5

(IACS UR S21.3.4.2)

5.3.2 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 elements is not to be less than determined by the following formula:

$$I = 6{,}0 \cdot q \cdot s^4 \quad [\text{cm}^4]$$

q = packing line pressure [N/mm], minimum 5,0 N/mm

s = spacing [m] of securing devices, not to be taken less than 2 m

(IACS UR S21.6.1.4)

5.3.3 For hatch covers of spaces in which liquids are carried, the packing line pressure shall also be ensured in case of hatch cover loading due to liquid pressure.

5.3.4 For all components of edge girders sufficient safety against buckling is to be verified according to 4.5.3.

5.4 Hatch cover stiffeners

The section modules W_{net} and shear area A_{net} of uniformly loaded hatch cover stiffeners constraint at both ends shall not be less than by the following formulae:

$$W_{net} = \frac{1000 \cdot p \cdot a \cdot \ell^2}{f_{bc} \cdot \sigma_a} \quad [cm^3]$$

$$A_{net} = \frac{8.7 \cdot p \cdot a \cdot \ell}{\sigma_a} \quad [cm^2]$$

where:

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

σ_a = allowable stress [N/mm^2], as given:

— for external pressure, as defined in 2.1:

= $0{,}8 \cdot R_{eH}$ [N/mm^2]

— for other loads, as defined in 2.2 to 2.5:

= $0{,}90 \cdot R_{eH}$ [N/mm^2] Static (S) and Dynamic (D)

= $0{,}72 \cdot R_{eH}$ [N/mm^2] Static (S)

p = design load [kN/m^2], defined as:

= max [p_D; p_H; p_L; p_1; p_2; p_d] as applicable

f_{bc} = boundary coefficient:

= 8 in the case of stiffener simply supported at both ends or simply supported at one end and clamped at the other end

= 12 in the case of stiffener clamped at both ends

For stiffeners of lower plating of double skin hatch covers, requirements mentioned above are not applicable due to the absence of lateral loads. For double skin hatch covers of holds designed for ballast or liquid cargo, the stiffeners on lower plating are to be strengthened on case-by-case basis.

The net thickness [mm] of the stiffener (except u-beams/trapeze stiffeners) web is to be taken not less than 4,0 mm.

The net section modulus of the stiffeners is to be determined based on an attached plate width assumed equal to the stiffener spacing.

Stiffeners parallel to main girder webs and arranged within the effective breadth according to Section 3, E shall be continuous at 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 3. The requirements of this paragraph are not applied to stiffeners of lower plating of double skin hatch covers if the lower plating is not considered as strength member.

For hatch cover stiffeners under compression sufficient safety against lateral and torsional buckling according to 4.5.3 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 3.

(IACS UR S21.3.3)

5.5 Hatch cover supports

5.5.1 For the transmission of the support forces resulting from the load cases specified in 2.1 - 2.6, supports are to be provided which are to be designed such that the nominal surface pressures in general do not exceed the following values:

$$p_{n,max} = d \cdot p_n \quad [N/mm^2]$$

d = 3,75 – 0,015 · **L**

d_{max} = 3,0

d_{min} = 1,0 in general

= 2,0 for partial loading conditions (see 2.3.4)

p_n = permissible nominal surface pressure as defined in Table 17.5

Table 17.5 Permissible nominal surface pressure p_n

Support material	p_n [N/mm^2] when loaded by	
	Vertical force	Horizontal force (on stoppers)
hull structural steels	25	40
hardened steels	35	50
lower friction materials	50	-

(IACS UR S21 Table 9)

For metallic supporting surfaces not subjected to relative displacements the following applies:

$$p_{n,max} = 3 \cdot p_n \quad [N/mm^2]$$

Note:

When the maker of vertical hatch cover support material can provide proof that the material is sufficient for the increased surface pressure, not only statically but under dynamic conditions including relative motion for adequate number of cycles, permissible nominal surface pressure may be increased in such a case, long term distribution of spectra for vertical loads and relative horizontal motion should specified and accepted by BKI in connection with relevant drawing approval.

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 S21.6.2.2)

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 S21.6.2.2)

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 15000 m/year.

(IACS UR S21.6.2.2)

5.5.4 The substructures of the supports have to be of such a design, that a uniform pressure distribution is achieved.

(IACS UR S21.6.2.2)

5.5.5 Irrespective of the arrangement of stoppers, the supports shall be able to transmit the following force Ph in the longitudinal and transverse direction:

$$P_h = \mu . \frac{P_v}{\sqrt{d}} \quad [kN]$$

P_v	=	vertical supporting force [kN].
μ	=	frictional coefficient:
	=	0,5 for steel on steel
	=	0,35 for non-metallic, low-friction support materials on steel
d	=	factor according to 5.5.1

(IACS UR S21.6.2.2)

5.5.6 Supports, as well as the adjacent structures and substructures are to be designed such that the permissibel stresses according to 3. are not exceeded.

(IACS UR S21.6.2.2)

5.5.7 For substructures and adjacent constructions 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 S21.6.2.2)

5.6 Securing of weather deck hatch covers

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 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 S21.6.1.1)

5.6.2 Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

(IACS UR S21.6.1.2)

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 S21.6.1.3)

5.6.4 The net cross-sectional area of the securing devices is not to be less than determined by the following formula:

$$A = 0{,}28 \cdot q \cdot s \cdot k_\ell \quad [cm^2]$$

q	=	packing line pressure [N/mm], minimum 5,0 N/mm
s	=	spacing between securing devices [m], not to be taken less than 2,0 m
k_ℓ	=	$\left(\frac{235}{R_{eH}}\right)^e$

R_{eH} is not to be taken greater than $0{,}70 \cdot R_m$.

e	=	0,75	for	$R_{eH} > 235$	$[N/mm^2]$
	=	1,00	for	$R_{eH} \le 235$	$[N/mm^2]$

Rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5,0 m^2 in area.

Securing devices of special design in which significant bending or shear stresses occur may be designed according to 5.6.5. As load the packing line pressure q multiplied by the spacing between securing devices s is to be applied.

(IACS UR S21.6.1.4)

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 2, load case C, refer to Fig. 17.8. 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:

$$\sigma_v \le \frac{150}{k_\ell} \quad [N/mm^2]$$

Note:

The partial load cases given in Table 17.3 may not cover all unsymmetrical loadings, critical for hatch cover lifting.

(IACS UR S21.6.1.5)

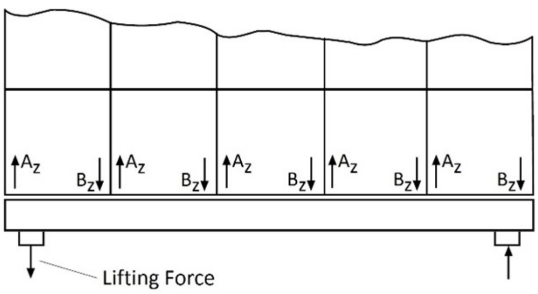


Fig. 17.8 Lifting forces at a hatch cover

(IACS UR S21 Figure 10)

5.6.6 Securing devices of hatch covers for spaces in which liquids are carried shall be designed for the lifting forces according to load case D in 2.4.

5.6.7 Cargo deck hatch covers consisting of several parts have to be secured against accidental lifting.

5.7 Hatch cover stoppers

5.7.1 General

Hatch covers shall 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 2.1.5.

Design forces for the stoppers are obtained from the loads according to 2.1.5 and 2.6.

The permissible stress in stoppers and their substructures in the cover and of the coamings is to be determined according to 3. The provisions in 5.5 are to be observed.

(IACS UR S21.6.2.3)

5.7.2 Additional requirements for Bulk carriers according to Section 23

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.

With the exclusion of No. 1 hatch covers, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2.

This pressure may be reduced to 175 kN/m^2 if a forecastle is fitted in accordance with Section 23, G.

The equivalent stress:

1) in stoppers and their supporting structures, and
2) calculated in the throat of the stopper welds is not to exceed the allowable value of $0{,}8 \cdot R_{eH}$ [N/mm^2]

(IACS UR S21.6.2.3)

5.8 Cantilevers, load transmitting elements

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 3.1 are not to be exceeded.

5.8.2 Structural members subjected to compressive stresses are to be examined for sufficient safety against buckling, according to 4.5.

5.8.3 Particular attention is to be paid to the structural design in way of locations where loads are introduced into the structure.

5.9 Container foundations on hatch covers

Container foundations and their substructures are to be designed for the loads according to 2, load case B and C, respectively, applying the permissible stresses according to 3.1.

(IACS UR S21.4.1)

6. Weathertightness of hatch covers

For weather deck hatch covers packings are to be provided, exception see 6.2. Further to the following requirements Rules for Classification and Surveys (Pt. 1, Vol. I) Annex A.6 is applicable to hatch covers.

(IACS UR S21.4.2)

6.1 Packing material

6.1.1 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 shall be given to the packing arrangement in ships with large relative movements between hatch covers and coamings or between hatch cover sections.

(IACS UR S21.4.2.1)

6.1.2 If the requirements in 6.2 are fulfilled the weather tightness can be dispensed with.

6.2 Non-weathertightness hatch covers

6.2.1 Upon request and subject to compliance with the following conditions the fitting of weather tight gaskets according to 6.1 may be dispensed with for hatch covers of cargo holds solely for the transport of containers:

.1 The hatchway coamings shall be not less than 600 mm in height.

.2 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:

$$\mathbf{H}(x) \geq \mathbf{T}_{fb} + f_b + h \quad [m]$$

$\mathbf{T}_{fb}$ = draught corresponding to the assigned summer load line

f_b = freeboard determined in accordance with ICLL

h = height [m], defined as:

= 4,6 for $\frac{x}{\mathbf{L}} \leq 0{,}75$ [m]

= 6,9 for $\frac{x}{\mathbf{L}} > 0{,}75$ [m]

.3 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.

.4 Where a hatch is covered by several hatch cover panels the clear opening of the gap in between the panels shall be not wider than 50 mm.

.5 The labyrinths and gaps between hatch cover panels shall be considered as unprotected openings with respect to the requirements of intact and damage stability calculations.

.6 With regard to drainage of cargo holds and the necessary fire-fighting system reference is made to Rules for Machinery Installations (Pt.1, Vol.III) Sec. 11 and 12.

.7 Bilge alarms should be provided in each hold fitted with non-weathertight covers.

.8 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 S21.4.2.2)

6.2.2 Securing devices

In the context of paragraph 6.2 an equivalence to 5.6 can be considered subject to:

- the proof that in accordance with 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. 17.9. The height h_E shall not be less than the greater of the following formulae:

$$h_E = 1,75 \cdot \sqrt{2 \cdot e \cdot s} \quad [mm]$$

$$h_{Emin} = h_F + 150 \quad [mm]$$

where

h_F = height of the face plate [mm]

e = largest distance of the cover guides from the longitudinal face plate [mm]

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 2.6 acting at the position h_E using the equivalent stress level $\sigma_V = R_{eH}$ [N/mm^2].

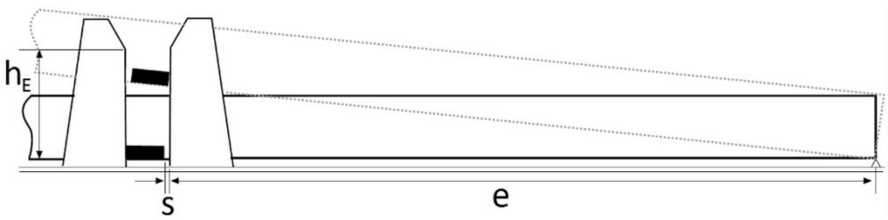


Fig. 17.9 Height of transverse cover guides

6.3 Drainage arrangements

6.3.1 Drainage arrangement at hatch covers

Cross-joints of multi-panel covers are to be provided with efficient drainage arrangements.

(IACS UR S21.4.2.3)

6.3.2 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 S21.5.4.5)

6.4 Tightness test, trials

6.4.1 The self-tightening steel hatch covers on weather decks and within open superstructures are to be hose tested. The water pressure should not be less than 2 bar and the hose nozzle should be held at a distance of not more than 1,5 m from the hatch cover to be tested. The nozzle diameter should not 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)

6.4.2 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)

C. Hatch Coamings and Girders

1. General

1.1 Hatch coamings which are part of the longitudinal hull structure are to be designed according to Section 5.

For hatchway coamings which are designed on the basis of strength calculations as well as for hatch girders, cantilevers and pillars, see Section 10.

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.

In case of transverse coamings of ships with large deck openings Section 5, F is to be observed.

(IACS UR S21.5.4.1)

Secondary stiffeners of hatch coamings are to be continuous over the breadth and length of hatch coamings.

(IACS UR S21.1.4)

1.2 Coamings which are 600 mm or more in height are to be stiffened in their upper part by a horizontal stiffener.

Where the unsupported height of a coaming exceeds 1,2 m additional stiffeners is 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).

Hatchway coamings are to be adequately supported by stays.

Adequate safety against buckling according to Section 3, F is to be proved for longitudinal coamings which are part of the longitudinal hull structure.

1.3 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 S21.5.3.1 and S21.5.4.2)

1.4 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.

(IACS UR S21.5.4.3)

1.5 Coaming girder 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, Fig.17.10 gives an example.

(IACS UR S21.5.4.4)

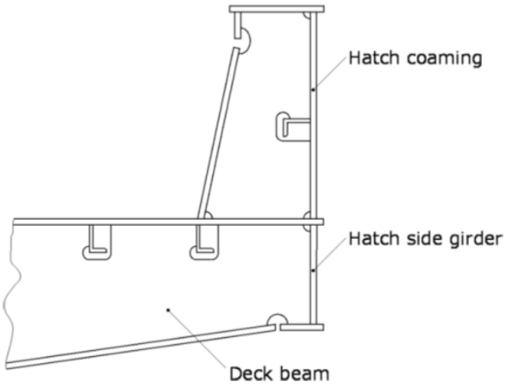


Fig. 17.10 Example for a hatch side girder

(IACS UR S21 Figure 9)

1.6 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, B.9.

For rounding of hatchway corners, see also Section 7, A.3.

1.7 Longitudinal hatch coamings with a length exceeding 0,1**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 S21.5.4.1)

2. Scantlings

2.1 Plating

The thickness t of weather deck hatch coamings shall not be less than the larger of the following values:

$$t = c \cdot a \cdot \sqrt{\frac{p_A}{R_{eH}}} + t_K \quad [mm]$$

$$t_{min} = 6,0 + \frac{\mathbf{L}}{100} + t_K \quad [mm],$$ **L** need not be taken greater than 300 m

$$= 9,5 + t_K \quad [mm],$$ for bulk carrier according to Section 23

p_A = horizontal design load [kN/m^2], as defined in B.2.1.5

c = coefficient, defined as:

= 16,4 for bulk carrier according to Section 23

= 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 S21.5.1)

For grab operation see also Section 23, B.9.1.

2.2 Coaming stays

2.2.1 Coaming stays are to be designed for the loads and permissible stresses according to B.

(IACS UR S21.5.3)

2.2.2 At the connection with deck, the net section modulus W_{net}, in cm^3, and the gross thickness t_w, in mm, of the coaming stays designed as beams with flange (examples 1 and 2 are shown in Fig. 17.11) are to be taken not less than:

$$W_{net} = \frac{526}{R_{eH}} \cdot e \cdot h_s^2 \cdot p_A \quad [cm^3]$$

$$t_w = \frac{2}{R_{eH}} \frac{e \cdot h_s \cdot p_A}{h_w} + t_K \quad [mm]$$

p_A = horizontal design load [kN/m^2], as defined in B.2.1.5

e = spacing of coaming stays [m]

h_s = height [m] of coaming stays

h_w = web height [m] of coaming stay at its lower end

For the calculation of W_{net} the effective breadth of the coaming plate shall not be larger than the effective plate width according to Section 3, F.5.2.3.5 and their face plate area is to be taken into account only when it is welded with full penetration welds to the deck plating and adequate underdeck structure is fitted to support the stresses transmitted by it.

Face plates may only be included in the calculation if an appropriate substructure is provided and welding ensures an adequate joint.

For other designs of coaming stays, such as those shown in Fig. 17.11, examples 3 and 4, the stresses are to be determined through a grillage analysis or FEM. The calculated stresses are to comply with the permissible stresses according to B.3.

Webs are to be connected to the decks by fillet welds on both sides with a = 0,44 · t_w.

For toes of stay webs within 0,15 · h_w the throat thickness is to be increased to a = 0,7 · t_w for t_w ≤ 10 mm.

For t_w > 10 mm deep penetration double bevel welds are to be provided in this area.

(IACS UR S21.5.3.1)

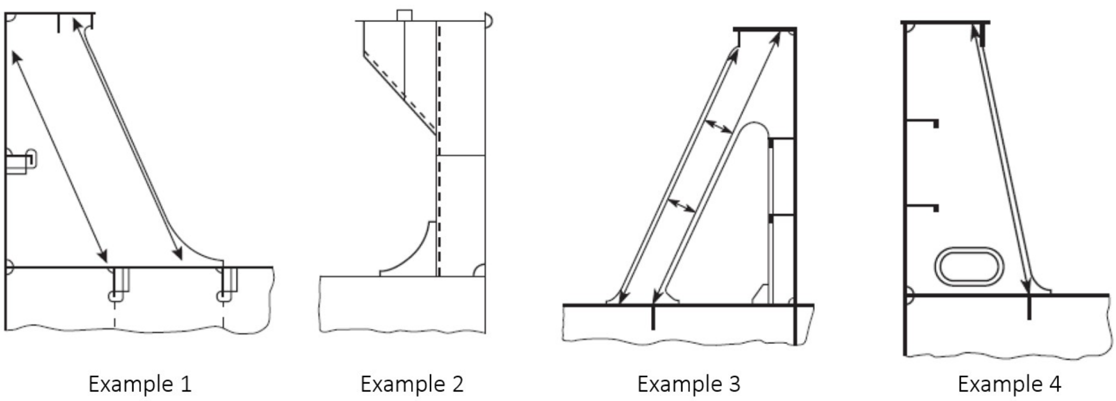


Fig. 17.11 Examples of coaming stays

(IACS UR S21 Figure 8)

2.2.3 For coaming stays, which transfer friction forces at hatch cover supports, sufficient fatigue strength according to Section 20 is to be considered, refer also to B.5.5.

(IACS UR S21A.5.3.2)

2.3 Horizontal stiffeners

The stiffeners shall be continuous at the coaming stays.

For stiffeners with both ends constraint the elastic section modulus W_{net} and shear area A_{net}, calculated on the basis of net thickness, shall not be less than:

$$W_{net} = \frac{c \cdot a \cdot \ell^2 \cdot p_A}{f_{bc} \cdot f_p \cdot R_{eH}} \quad [cm^3]$$

$$A_{net} = \frac{10 \cdot a \cdot \ell \cdot p_A}{R_{eH}} \quad [cm^2]$$

where:

p_A = horizontal design load [kN/m^2], as defined in B.2.1.5

c = coefficient, defined as:

= 1043 for bulk carrier according to Section 23

= 1000 for all other ships

f_p = ratio of plastic and elastic section modulus, defined as:

= $\frac{W_{p\ell}}{W_{e\ell}} \leq \frac{R_m}{R_{eH}}$ for bulk carrier according to Section 23

= 1,16 can be used in the absence of more precise evaluation

= 1,0 for ships other than bulk carrier according to Section 23

$W_{p\ell}$ = plastic section modulus

$W_{e\ell}$ = elastic section modulus

f_{bc} = boundary coefficient:

— for other ships:

= 8 for the end spans of stiffeners sniped at the coaming corners

= 12 in general

— for bulk carriers according to Section 23:

= 12 for the end spans of stiffeners sniped at the coaming corners

= 16 in general

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 shall not be less than according to Section 3, D.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 S21.5.2)

D. Smaller Opening and Hatches

1. Miscellaneous openings in freeboard and superstructure decks

1.1 Manholes and small flush deck hatches in decks in position 1 and 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))

1.2 Openings in freeboard decks other than hatchways and 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 Section 21, S.1. Alternatively, if stairways within a deckhouse are enclosed within properly constructed companionways fitted with doors complying with Section 21, S.1, the external door need not be weathertight.

(ICLL Annex I, II, 18(2))

1.3 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))

1.4 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))

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))

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))

1.7 Where the closing appliances of access openings in superstructures and deckhouses are not in accordance with Section 21, S.1, interior deck openings are to be considered exposed (i.e. situated in the open deck).

(ICLL Annex I, II, 18(7))

1.8 The doors of the companionways are to be capable of being operated and secured from both sides. They are to be closed weathertight by rubber sealings and toggles.

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.

1.10 Access hatchways shall have a clear width of at least 600 x 600 mm.

1.11 For special requirements for strength and securing of small hatches on the exposed fore deck, see 2.

1.12 According to the Guidance for Code and Convention Interpretations (Pt.1, Vol.Y), Section 11, 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.

2. Strength and securing of small hatches on the exposed fore deck

2.1 General

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)

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 m^2 or less.

(IACS UR S26.1.2)

2.1.3 Hatches designed for emergency escape need not comply with the requirements according methods A and B in 2.4.1, 2.5.3 and 2.6. For securing devices of hatches designed for emergency escape hatches are to be of a quick-acting type (e.g. one action wheel handles are provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover.

(IACS UR S26.1.3 and 1.4)

2.2 Application[1)]

2.2.1 For ships that are contracted for construction on or after 1^{st} January 2004 on the exposed deck over the forward 0,25**L**, applicable to all types of sea going ships:

— 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.

2.2.2 For ships that are contracted for construction prior to 1^{st} January 2004 only for hatches on the exposed deck giving access to spaces forward of the collision bulkhead, and to spaces which extend over this line aft-wards, applicable to:

— Bulk carriers, ore carriers, and combination carriers (as defined in Rules for Classification and Surveys (Pt. 1 Vol. I) Annex A.7) and general dry cargo ships (excluding container vessels, vehicle carriers, Ro-Ro ships and woodchip carriers), of length 100 m or more.

2.2.3 These requirements do not apply to small hatches on container ship giving access to a cargo hold which comply with Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Section 7, LL64 except the requirement of clause 4 and 5. Such hatch covers are considered non-weathertight regardless of whether it is actually weathertight or not. However, for scantlings of small hatches, the strength requirements in 2.3 should be applied instead of clause 6 of Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Section 7, LL64.

(IACS UR S26.2.1, 2.2 and 2.5)

2.3 Strength

2.3.1 For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with Table 17.6 and Fig. 17.12. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in 2.5.1, see Fig. 17.12. Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener, see Fig. 17.13.

(IACS UR S26.4.1)

[1)] For ships contracted for construction prior to 1^{st} January 2004 refer to IACS UR S26, para. 3.

Table 17.6 Scantlings for small steel hatch covers on the fore deck

Nominal size [mm x mm]	Cover plate thickness [mm]	Primary stiffeners	Secondary stiffeners
		Flat bar [mm x mm]; number	
630 x 630	8,0	–	–
630 x 830	8,0	100 x 8; 1	–
830 x 630	8,0	100 x 8; 1	–
830 x 830	8,0	100 x 10; 1	–
1030 x 1030	8,0	120 x 12; 1	80 x 8; 2
1330 x 1330	8,0	150 x 12; 2	100 x 10; 2
For ships with **L** < 80 m the cover scantlings may be reduced by the factor : $0,11.\sqrt{\mathbf{L}} \geq 0,75$			

(IACS UR S26.Table 1)

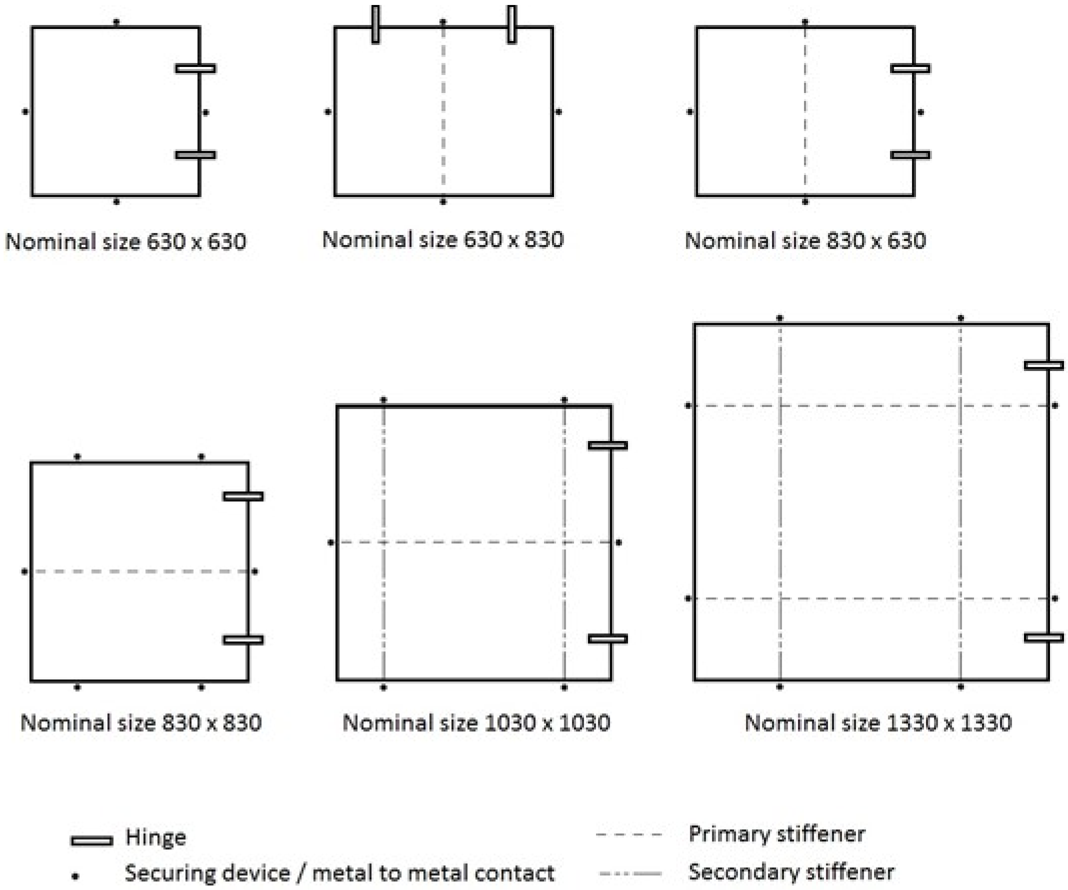


Fig. 17.12 Arrangement of stiffeners

(IACS UR S26. Figure 1)

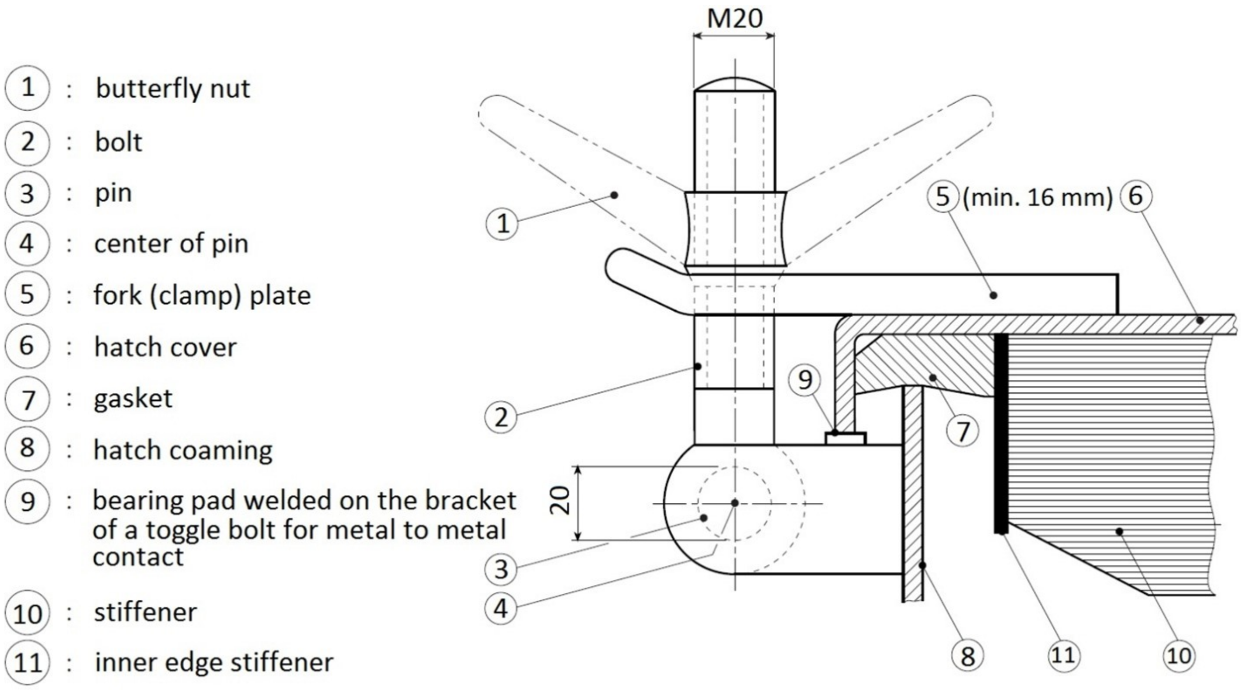


Fig. 17.13 Example of a primary securing method

(IACS UR S26.Figure 2)

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)

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)

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)

2.4 Primary securing devices

2.4.1 Small hatches located on exposed fore deck subject to the application according to 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

2.4.2 Dogs (twist tightening handles) with wedges are not acceptable.

(IACS UR S26.5)

2.5 Requirements for primary securing

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. 17.12 and of sufficient capacity to withstand the bearing force.

(IACS UR S26.6.1)

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)

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. 17.13.

(IACS UR S26.6.3)

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)

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)

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)

E. Engine and Boiler Room Hatchways

1. Deck openings

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.

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, A.3.

2. Engine and boiler room casings

2.1 Engine and boiler room openings on weather decks and inside open superstructures are to be protected by casings of sufficient height.

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 **L** does not exceed 75 m, and not less than 2,3 m where **L** is 125 m or more. Intermediate values are to be determined by interpolation.

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.

2.4 Inside open superstructures the casings are to be stiffened and plated according to Section 16 ,C, as for an aft end bulkhead.

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 D.2.3, and the stiffeners are to have the same thickness and a depth of web of 75 mm, being spaced at 750 mm.

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.

2.7 The coaming plates are to be extended to the lower edge of the deck beams.

3. Doors in engine and boiler room casings

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.

3.2 The doors are to be at least of the same strength as the casing walls in which they are fitted.

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.

F. Cargo Hatch Cover Securing Arrangements for Bulk Carriers not Built in accordance with UR S21 (Rev.3)

1. Application and Implementation

1.1 These requirements apply to all bulk carriers, as defined in Rules for Classification and Survey (Pt.1, Vol.I) Annex A.7, which were not built in accordance with UR S21(Rev.3) and are for steel hatch cover securing devices and stoppers for cargo hold hatchways No.1 and No.2 which are wholly or partially within 0,25**L** of the fore perpendicular, except pontoon type hatch cover.

1.2 All bulk carriers not built in accordance with UR S21 (Rev.3) are to comply with the requirements of this UR in accordance with the following schedule:

1) For ships which will be 15 years of age or more on 1 January 2004 by the due date of the first intermediate or class renewal survey after that date;
2) For ships which will be 10 years of age or more on 1 January 2004 by the due date of the first class renewal survey after that date;
3) For ships which will be less than 10 years of age on 1 January 2004 by the date on which the ship reaches 10 years of age.

1.3 Completion prior to 1 January 2004 of an intermediate or special survey class renewal survey with a due date after 1 January 2004 cannot be used to postpone compliance. However, completion prior to 1 January 2004 of an intermediate survey the window for which straddles 1 January 2004 can be accepted.

1.4 This subsection is not applicable to self-unloading bulk carriers (SUBC).

2. Securing Devices

The strength of securing devices is to comply with the requirements given in B.5.6.1 to B.5.6.4 and B.5.3.2.

3. Stoppers

3.1 No. 1 and 2 hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.

3.2 No. 2 hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

3.3 No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2.

This pressure may be reduced to 175 kN/m^2 if a forecastle is fitted.

3.4 The equivalent stress:

1) in stoppers and their supporting structures, and
2) calculated in the throat of the stopper welds is not to exceed the allowable value of 0,8 · R_{eH}.

(IACS UR S30)

4. Materials and Welding

Where stoppers or securing devices are fitted to comply with this sub-section, they are to be manufactured of materials, including welding electrodes, meeting relevant requirements in Rules for Materials (Pt.1, Vol. V) Sec. 4 or 7 and Rules for Welding (Pt.1, Vol. VI) Sec. 5 respectively.

(IACS UR S30.1.4)

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Section 18 Equipment

A. General

1. Every ship is to be equipped with at least one anchor windlass.

Windlass and chain stopper, if fitted, are to comply with Rules for Machinery Installations (Pt.1, Vol.III) Sec. 14.D.

2. The equipment of anchors, chain cables, wires and ropes is to be determined from Table 18.2 in accordance with the equipment numeral Z.

3. For ships having the navigation Notation "**L**" (Coasting Service) 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.

4. Design of the anchoring equipment

4.1 The anchoring equipment required by this Section is intended of temporary mooring of a ship within a harbour or sheltered area when the ship is awaiting berth, tide, etc. Guidance for Marine Industry (Pt.1, Vol.AC) Sec.1, R-10 "Anchoring, Mooring and Towing Equipment" may be referred to for recommendations concerning anchoring equipment for ships in deep and unsheltered water.

4.2 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.

4.3 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.

4.4 The equipment numeral (Z) formula for anchoring equipment as given in B. is based on an assumed maximum current speed of 2,5 m/s, maximum wind speed of 25 m/s and a minimum scope of chain cable of 6, the scope being the ratio between length of chain paid out and water depth. For ships with L greater than 135 m, alternatively the required anchoring equipment can be considered applicable to a maximum current speed of 1,54 m/s, a maximum wind speed of 11 m/s and waves with maximum significant height of 2,0 m.

4.5 It is assumed that under normal circumstances a ship will use only one bow anchor and chain cable at a time.

4.6 Manufacture of anchors and anchor chain cables is to be in accordance with Rules for Materials (Pt.1, Vol.V) Sec.12 and 13.

4.7 In addition to planned anchoring for normal operations, anchoring equipment is also important for ship safety in emergency situations such as loss of manoeuvrability unscheduled repairs and other unexpected situations

4.8 The anchoring equipment required herewith applies to self-propelled ships over 100GT, except for:

1) inland navigation ships, see Rules for Hull – Inland Waterways (Pt.2, Vol.II) Sec.7.D.
2) military ships, see Guidelines for Hull Structures and Ship Equipment (Pt.9, Vol.2) Sec.18.
3) government ships operated for non-commercial purposes, subject to the regulation of flag state administration.
4) high speed and light crafts, see Rules for High Speed Craft (Pt.3, Vol.III) Sec.6.
5) yachts, see Rules for Yacth (Pt.3, Vol.IX) Sec.2.K.

(IACS UR A1.1)

5. Ships built under survey of BKI and which are to have the mark ✠ stated in their Certificate and in the Register Book must be equipped with anchors and chain cables complying with the Rules for Materials (Pt.1, Vol.V), and having been tested on approved machines in the presence of Surveyor.

6. Structural requirements associated with towing and mooring on conventional ships

6.1 Conventional ships shall be provided with arrangements, equipment and fittings of sufficient safe working load to enable the safe conduct of all towing and mooring operations associated with the normal operations of the ship.

Conventional ships means displacement-type ships of 500 GT and above, excluding high speed craft, special purpose ships and offshore units of all types. As per MSC.266(84), 'Special purpose ship' means a mechanically self-propelled ship which by reason of its function carries on board more than 12 special personnel

6.2 These requirements applies to design and construction of shipboard fittings and supporting structures used for the normal towing and mooring operations. Normal towing means towing operations necessary for manoeuvring in ports and sheltered waters associated with the normal operations of the ship.

6.3 For ships, not subject to SOLAS Reg. II-1/3-4 Par. 1, but intended to be fitted with equipment for towing by another ship or a tug, e.g. such as to assist the ship in case of emergency as given in SOLAS Reg. II-1/3-4 Par. 2, the requirements designated as 'other towing' in this Section shall be applied to design and construction of those shipboard fittings and supporting hull structures.

6.4 These requirements is not applicable to design and construction of shipboard fittings and supporting hull structures used for special towing services defined as:

— **Canal transit towing**: Towing service for ships transiting canals, e.g. the Panama Canal. It shall be referred to local canal transit requirements.
— **Emergency towing for tankers**: Towing service to assist tankers in case of emergency. For the emergency towing arrangements, ships subject to SOLAS Reg. II-1/3-4 Par. 1 shall comply with that regulation and resolution MSC.35 (63) as may be amended.
— **Escort towing**: Towing service, in particular, for laden oil tankers or LNG carriers, required in specific estuaries. It shall be referred to local escort requirements and guidance given by, e.g., the Oil Companies International Marine Forum (OCIMF).

(IACS UR A2.0)

6.5 These requirements are to be applied as applicable in F., G. and H

7. References

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

IACS UR A1 Rev.8

IACS UR A2 Rev.5

IACS UR L4 Rev.3 Corr.2

IACS Rec. 10 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.

7.2 For the substructures of windlasses and chain stoppers, see Section 10, B.5.

7.3 For the location of windlasses on tankers, see Section 24, A.9.

7.4 When determining the equipment for ships having the navigation notation "**T**" (Shelter Water Service) affixed to their Character of Classification, the provisions of Section 30, E are to be observed.

7.5 When determining the equipment for tugs, Section 27, E is to be observed.

7.6 When determining the equipment of barges and pontoons, Section 31, G is to be observed.

7.7 For Seagoing ships navigating on inland waters and rivers are to have anchor equipment also complying with the Regulations of the competent authorities.

8. 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 = 205.

Shipboard fitting

Shipboard fittings mean those components limited to the following: bollards and bitts, fairleads, stand rollers, chocks used for the normal mooring of the ship and the similar components used normal for the towing of the ship. Other components such as capstans, winches, etc. are not covered by this Section. Any weld or bolt or equivalent device connecting the shipboard fitting to the supporting structure is part of the shipboard fitting and if selected from an industry standard subject to that standard.

(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 The supporting hull structure of capstans, winches, etc. used for normal or other towing and mooring operations mentioned above is also subject to this Section.

(IACS UR A2.0)

Nominal capacity condition

The nominal capacity condition is defined as the theoretical condition where the maximum possible deck cargoes are included in the ship arrangement in their respective positions. For container ships the nominal capacity condition represents the theoretical condition where the maximum possible number of containers is included in the ship arrangement in their respective positions.

(IACS UR A2.0)

Ship Design Minimum Breaking Load (MBL_{SD})

Ship Design Minimum Breaking Load (MBLSD) means the minimum breaking load of new, dry mooring lines or tow line for which shipboard fittings and supporting hull structures are designed in order to meet mooring restraint requirements or the towing requirements of other towing service.

(IACS UR A2.0)

Line Design Break Force (LDBF)

Line Design Break Force (LDBF) means the minimum force that a new, dry, spliced, mooring line will break at. This is for all synthetic cordage materials.

(IACS UR A2.0)

B. Equipment Numeral

1. The equipment numeral Z for anchors and chain cables is to be calculated as follows:

$$Z = D^{2/3} + 2 \cdot (h \cdot \mathbf{B} + S_{fun}) + \frac{A}{10}$$

D	=	moulded displacement [t] (in sea water having a density of 1,025 t/m^3) to the summer load waterline
h	=	effective height [m], from the summer load waterline to the top of the uppermost house
	=	$a + \Sigma h_i$
a	=	vertical distance at hull side [m], from the summer load water-line, amidships, to the upper deck
h_i	=	height [m] on the centreline of each tier of houses having a breadth greater than **B**/4. For the lowest tier, "h_1" 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, see Fig.18.1a below for an example.
S_{fun}	=	effective front projected area of the funnel [m²], defined as:
	=	A_{FS} - S_{shield} [m^2]
A_{FS}	=	front projected area of the funnel [m²], calculated between the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, and the effective height hF. A_{FS} is taken equal to zero if the funnel breadth is less than or equal to **B**/4 at all elevations along the funnel height. When several funnels are fitted on the ship, A_{FS} shall be taken as the sum of the front projected area of each tunnel. A_{FS} shall be taken equal to zero if the sum of each funnel breadth is less than or equal to **B**/4 at all evaluations along the funnels height.
h_F	=	effective height of the funnel [m], measured from the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, and the top of the funnel. The top of the funnel may be taken at the level where the funnel breadth reaches **B**/4. When several funnels are fitted on the ship, the top may be taken at the level where the sum of each funnel breadth reaches **B**/4.
S_{shield}	=	the section of front projected area A_{FS} [m²], which is shielded by all deck houses having breadth greater than **B**/4. If there are more than one shielded section, the individual shielded sections i.e $S_{shield1}$, $S_{shield2}$, etc as shown in Fig. 18.1b to be added together. To determine S_{shield}, the deckhouse breadth is assumed B for all deck houses having breadth greater than **B**/4 as shown for $S_{shield1}$, $S_{shield2}$ in Fig. 18.1b.
A	=	side projected area [m^2], of the hull, superstructures, houses and funnels above the summer load waterline, which is within the length **L** of the ship have a breadth greater than **B**/4. The side projected area of the funnel is considered in A when A_{FS} is greater than zero. In this case, the side projected area of the funnel should be calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F. When several funnels are fitted on the ship the shielding effect of funnels in transverse direction may be considered in the total side projected area, i.e. when the side projected areas of two or more funnels fully or partially overlap the overlapped area shall only be counted once.

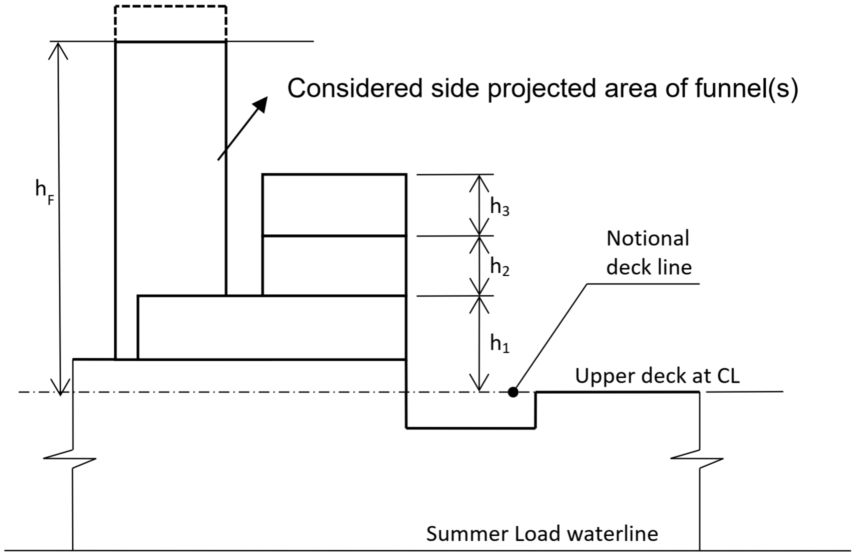

Fig. 18.1a Side Projected Area

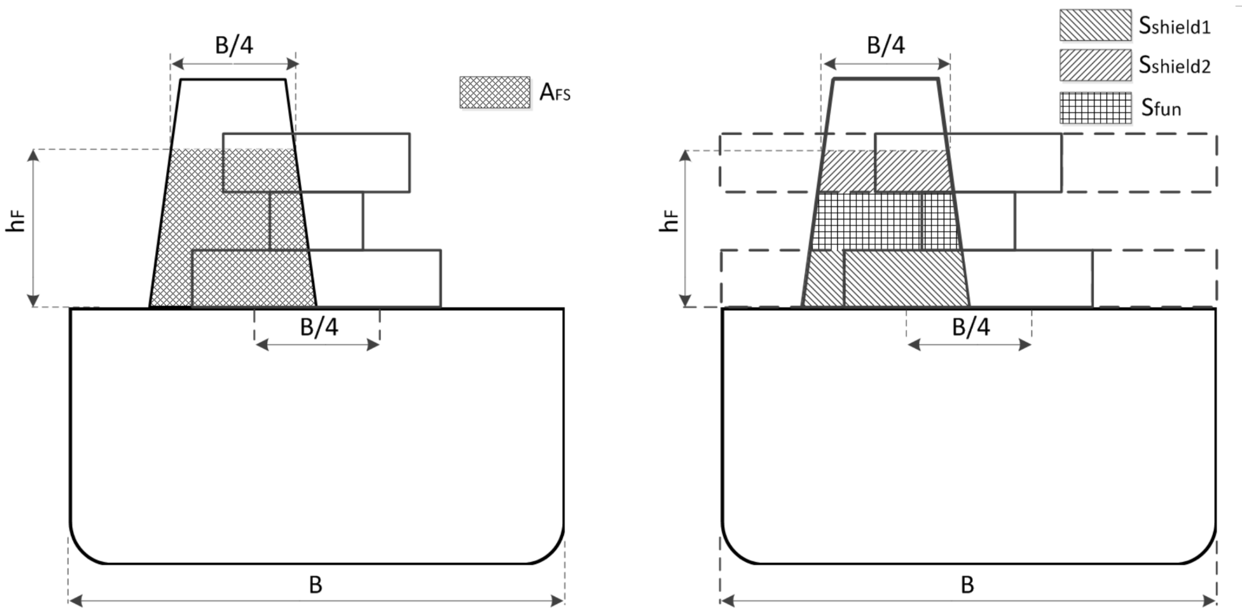

Fig. 18.1b Front projected area

Notes:

1 *When calculating h, sheer and trim are to be ignored, i.e. h is the sum of freeboard amidships plus the height (at centreline) of each tier of houses having a breadth greater than* ***B****/4.*

2 *Where a deckhouse having a breadth greater than* ***B****/4 is located above a deckhouse having a breadth of* ***B****/4 or less, the wide house is to be included and the narrow house ignored.*

3 *Screens of bulwarks 1,5 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. 18.2 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. With regard to determining A, when a bulwark is more than 1,5 m high, the area shown below as A_1 is to be included in A.*

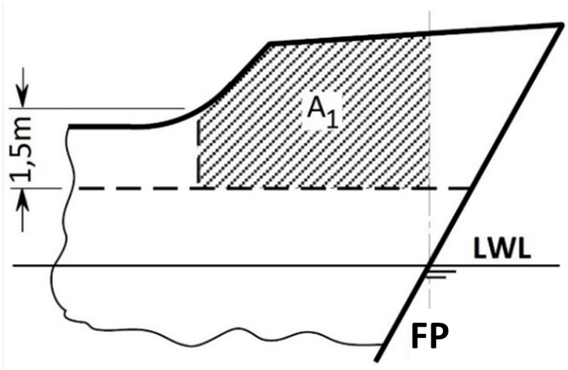

Fig. 18.2 Effective area A_1 of bulwark

(IACS UR A1.2)

For ships of length less than 90m, alternative methodology using direct force calculation for anchoring equipment described in Guidance for Marine Industry (Pt.1, Vol.AC) Sec.1, R-10, Appendix B may be used.

(IACS UR A1.2.4)

2. The mooring lines for ships with Equipment Numeral Z of less than or equal to 2000 are given in F.4.1. For other ships the mooring lines are given in F.4.2.

The equipment numeral for the recommended selection of towing and mooring line should be calculated in compliance with 1. Deck cargoes at the ship's nominal capacity condition should be included for the determination of side-projected area A. The nominal capacity condition is defined in A.8.

The minimum recommended number and minimum strength of mooring lines are specified in F.4.1 and F.4.2. As an alternative to F.4.1 and F.4.2, the minimum recommendation for mooring lines may be determined by direct mooring analysis in line with the procedure given in Guidance for Marine Industry (Pt.1, Vol.AC) Sec.1, R-10, Appendix A.

The designer should consider verifying the adequacy of mooring lines based on assessments carried out for the individual mooring arrangement, expected shore-side mooring facilities and design environmental conditions for the berth.

The definition of line design break force (LDBF) is given in A.8.

This value is declared by the manufacturer on each line's mooring line certificate and is stated on a manufacturer's line data sheet. LDBF of a line should be 100%-105% of the ship design minimum breaking load defined in F.4.2.1.

The LDBF for nylon (polyamide) mooring lines should be specified as break tested wet, because nylon lines change strength characteristics once exposed to water and generally do not fully dry to their original construction state.

(IACS Rec. 10 2.1)

C. Anchors

1. General

The equipment of anchors is to be determined according to Table 18.2 and is to be based on equipment number in B.1.

The bower anchors are to be connected to their cables and positioned on board ready for use. When the stream anchor is required, see 6.

(IACS UR A1.4.3)

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.

National regulations concerning the provision of a spare anchor, stream anchor or a stern anchor may need to be observed.

2. Stock anchors

When equipment numeral (Z) less than 205, the mass of stocked anchors, when used, and mass of stream anchors, excluding the stock should be 80% and the mass of the stock should be 20% of the mass as given in Table 18.2 for stockless bower anchors.

(IACS Rec. 10, 1.1.2.1.1(a))

3. Ordinary (stockless) anchors

Ordinary anchors of “stockless” type are to be generally adopted and they are to be of approved design.

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.

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)

4. High Holding Power (HHP) Anchors

A ‘high holding power’ anchor is an anchor with a holding power of at least twice that of an ordinary stockless anchor of the same mass. A HHP anchor is to be suitable for ship’s use and is not to require prior adjustment or special placement on the sea bottom.

When special type of anchors designated ”high holding power anchor” of proven superior holding ability are used as bower anchors, the mass of each anchor may be 75% of the mass required for ordinary stockless bower anchors in the Table 18.2.

For approval and/or acceptance as a HHP anchor satisfactory full scale tests according to 7. are to be made confirming that the anchor has a holding power of at least twice that of an ordinary stockless anchor of the same mass.

(IACS UR A1.4.1.2)

The dimensioning of the chain cable and of the windlass is to be based on the undiminished anchor mass according to Tables 18.2.

5. Very High Holding Power (VHHP) anchors

A ‘very high holding power’ anchor is an anchor with a holding power of at least four times that of an ordinary stockless anchor of the same mass. A VHHP anchor is suitable for restricted service ships’ use and does not require prior adjustment or special placement on the sea bottom.

The use of VHHP anchors is limited to restricted service ships as defined by BKI.

The VHHP anchor mass is generally not to exceed 1500 kg.

When very high holding power anchors of the proven holding power are used as bower anchors, the mass of each such anchor may be reduced to not less than 50% of the mass required for ordinary stockless anchors in Table 18.2.

For approval and/or acceptance as a VHHP anchor satisfactory full scale tests according to 7. are to be made confirming that the anchor has a holding power of at least four times that of an ordinary stockless anchor or at least twice that of a previously approved HHP anchor of the same mass.

(IACS UR A1.4.1.3)

6. Stern anchor

Where stern anchor or stream anchor equipment is fitted, the diameter of the chain cables are to be determined from the Tables in accordance with the anchor mass. The stern anchor should be ready to be connected with its cable. 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 Rules for Machinery Installations (Pt.1, Vol.III) Sec. 14.D are to be observed.

Where a steel wire rope is to be used for the stern anchor instead of a chain cable the following has to be observed:

- The steel wire rope shall at least be as long as the required chain cable in Table 18.2. The strength of the steel wire rope shall at least be of the value for the required chain of grade K1.
- A short length of chain cable should be fitted between the wire rope and bower or stream anchor having a length of 12,5 m or the distance between anchor in stowed position and winch, whichever is less.
- All surfaces being in contact with the wire need to be rounded with a radius of not less than 10 times the wire rope diameter (including stem).
- A cable winch must be provided according to the requirements for windlasses in Rules for Machinery Installations (Pt.1, Vol.III) Sec.14.D.

(IACS Rec. 10, 1.1.3.3)

See also 2.

7. Anchor holding power tests for HHP and VHHP anchors

7.1 Full scale tests are to be carried out at sea on various types of bottom, normally, soft mud or silt, sand or gravel and hard clay or similar compounded material. The tests are to be applied to anchors of mass which are as far as possible representative of the full range of sizes proposed.

7.2 For a definite group within the range, the two anchors selected for testing (ordinary stockless anchor and HHP anchor, or ordinary stockless anchor and VHHP anchor, respectively) are to be of approximately the same mass and tested in association with the size of chain required for that anchor mass. Where an ordinary stockless anchor is not available, for testing of HHP anchors a previously approved HHP anchor may be used in its place. For testing of VHHP anchors, a previously approved HHP or VHHP anchor may be used in place of an ordinary stockless anchor. The length of the cable with each anchor is to be such that the pull on the shank remains horizontal. For this purpose a scope of 10 is considered normal but a scope of not less than 6 may be accepted. Scope is defined as the ratio of length of cable to depth of water.

7.3 Three tests are to be taken for each anchor and each type of bottom. The stability of the anchor and ease of breaking out are to be noted where possible. Tests are to be carried out from a tug but alternatively shore based tests may be accepted. The pull is to be measured by dynamometer. Measurements of pull, based on the RPM/bollard pull curve of the tug may be accepted as an alternative to a dynamometer.

7.4 For approval and/or acceptance for a range of HHP anchor sizes, tests are to be carried out for at least two anchor sizes. The mass of the maximum size approved is not to be more than 10 times the mass of the largest size tested.

7.5 For approval and/or acceptance for a range of VHHP anchor sizes, at least three anchor sizes are to be tested, indicative of the bottom, middle and top of the mass range.

7.6 The holding power test load is not to exceed the proof load of the anchor.

(IACS UR A1.4.2)

8. Testing of anchors

The testing of all type of anchor shall be accordance with Rules of Materials (Pt.1, Vol.V) Sec.12. F.

9. Securing of stowed anchors

To hold the anchor tight in against the hull or the anchor pocket, respectively, it is recommended to fit anchor lashings, e.g., a ‘devil’s claw’.

Anchor lashings should be designed to resist a load at least corresponding to twice the anchor mass plus 10 m of cable without exceeding 40% of the yield strength of the material.

(IACS Rec. 10 1.3.2)

D. Chain Cables

1. The chain cable is to be as required by Tables 18.2 for the calculated equipment numeral for the ship apply to chain cables made of chain cable materials specified in the requirements of Rules for Materials (Pt.1, Vol.V), for the following grades:

Grade KI-K1 (ordinary quality)

Grade KI-K2 (special quality)

Grade KI-K3 (extra special quality)

(IACS UR A1.5.1.1)

2. Grade K-1 material used for chain cables in conjunction with ”High Holding Power Anchors” shall have a tensile strength R_m of not less than 400 N/mm^2.

Grade K-2 and K-3 chain cables shall be post production quenched and tempered and purchased from recognized manufacturers only.

3. The total length of chain given in the Table 18.2 is to be divided in approximately equal parts between the two bower anchors.

4. Either stud link or short link chain cables may be used for stream anchors.

5. Bower anchors are to be associated with stud link chain cables for one of the grades listed under Rules for Materials (Pt.1, Vol.V) Sec.13, Table 13.2.

(IACS UR A1.5.2)

6. The design and/or standard breaking loads (BL) and proof loads (PL) values of stud link chain cables to be used for testing and acceptance of chain cables, are given in the Rules for Materials (Pt.1,Vol.V) Sec.13, Table 13.7.

(IACS UR A1.5.3)

7. For equipment numerals Z up to 90, as an alternative to studlink chain cables, short link chain cables may be used.

(IACS Rec. 10 1.1.3.1)

8. 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.

9. The attachment of the inboard ends of the chain cables to the ship's structure is to be provided with a mean 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.

(IACS Rec.10 1.3.2)

10. Wire rope may be used in place of chain cable on ships:

— with less than 90 m in length and which will need an anchor for emergency purposes, i.e., not intended to use their anchor in normal temporary anchoring operation, or

— with the anchoring equipment used for positioning with a minimum of 4 points anchoring, e.g., for cable or pipe laying.

(IACS UR A1.5.1.2)

11. Used of wire rope is subject to the following conditions:

— The length of the wire rope is to be equal to 1,5 times the corresponding tabular length of chain cable (Table 18.2) and their strength is to be equal to that of tabular chain cable of Grade 1 (Rules for Materials (Pt.1,Vol.V) Sec.13, Table 13.7).

— The anchor weight shall be increased by 25% compared to anchor associated with chain cable according to Table 18.2.

— A short length of chain cable is to be fitted between the wire rope and anchor having a length of 12,5 m or the distance between anchor in stowed position and winch, whichever is less.

— All surfaces being in contact with the wire need to be rounded with a radius of not less than 10 times the wire rope diameter (including stem).

— Steel wire shall be selected to fit for purpose based on the manufacturer's recommendation and shall be provided with guidance for maintenance and inspection.

(IACS UR A1.5.1.3)

For stern anchor, C.6 should be observed.

12. For restricted services the use of steel wire rope may be accepted in place of chain cable at the discretion of BKI.

(IACS UR A1.5.1.4)

13. The permissible of wear down of stud link chain cable for bower anchors following Rules for Classification and Surveys (Pt.1, Vol.I) Annex A.3.

(IACS UR A1.6)

E. Chain Locker

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 (spurling pipe) and self-stowing of the cables. The chain locker should be provided with an internal division so that the port and starboard chain cables may be fully and separately stowed.

(IACS Rec. 10 1.3.1 (a))

The minimum required stowage capacity without mud box for the two bow anchor chains is as follows:

$$S = 1,1 \cdot d^2 \cdot \frac{\ell}{10^5} \quad [m^3]$$

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 shall as far as possible be quadratic with a maximum edge length of $33 \cdot d$. As an alternative, circular base areas may be selected, the diameter of which shall not exceed $(30 \text{ to } 35) \cdot d$.

Above the stowage of each chain locker sufficient free depth is to be provided, which is to be determined by the following formula:

$$h = 1500 \quad [mm]$$

2. The chain locker boundaries and their access openings should be watertight as necessary to prevent accidental flooding of the chain locker and damaging essential auxiliaries or equipment or affecting the proper operation of the ship.

(IACS Rec. 10 1.3.1 (b))

3. Special requirements to minimize the ingress of water

3.1 Spurling pipes and cable lockers are to be watertight up to the weather deck. Bulkheads between separate cable lockers (see arrangement 1 in Fig. 18.3), or which form a common boundary of cable lockers (see arrangement 2 in Fig. 18.3), need not however be watertight.

(IACS UR L4.1)

Fig. 18.3 Chain locker arrangement

3.2 Where means of access is provided, it is to be closed by a substantial cover and secured by closely spaced bolts.

(IACS UR L4.2)

3.3 Where a means of access to spurling pipes or cable lockers is located below the weather deck, the access cover and its securing arrangements are to be in accordance with recognized standards (see Notes) or equivalent for watertight manhole covers. Butterfly nuts and/or hinged bolts are prohibited as the securing mechanism for the access cover.

(IACS UR L4.3)

Notes:

Examples of the recognized standards are such as:

a) *ISO 5894:2018*
b) *China: CB/T4392-2014 "Marine manhole cover"*
c) *India: IS 15876-2009 "Ships and Marine Technology manholes with bolted covers"*
d) *Japan: JIS F2304:2015, "Ship's Manholes" and JIS F2329:1975, "Marine Small Size Manhole"*
e) *Korea: KS V ISO 5894:2012*
f) *Norway: NS 6260:1985 "Manhole cover – overview"*
g) *Russia: GOST 2021-90 "Ship's steel manholes. Specifications"*

3.4 Spurling pipes through which anchor cables are led are to be provided with permanently attached closing appliances to minimize water ingress. Examples of acceptable arrangements are such as:

1) Steel plates with cutouts to accommodate chain links or
2) Canvas hoods with a lashing arrangement that maintains the cover in the secured position.

(IACS UR L4.4)

4. Adequate drainage facilities of the chain locker are to be provided.

(IACS Rec. 10 1.3.1 (c))

5. 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.2 and B.3 respectively. The distance from the load centre to the top of the chain locker pipe is to be taken for calculating the load.

6. For the location of chain lockers on tankers Section 24, A.9 is to be observed

F. Mooring Equipment

1. Shipboard fittings and supporting deck structures

1.1 Strength, Arrangement and selection

The strength of shipboard fittings used for mooring operations and their supporting hull structures as well as the strength of supporting hull structures of winches and capstans is to comply with the requirements of this Sub-Section.

For fittings intended to be used for, both, mooring and towing, G. applies to towing.

(IACS UR A2.2.1)

Shipboard fittings, winches, and capstans for mooring are to be located on stiffeners 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 (for chocks in bulwark, etc.) provided the strength is confirmed adequate for the service.

(IACS UR A2.2.2)

Shipboard fittings may be selected from an industry standard accepted by BKI and at least based on the ship design minimum breaking load according to Table 18.2 (see Notes in 2.3).

Mooring bitts (double bollards) are to be chosen for the mooring line attached in figure-of-eight fashion if the industry standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment.

When the shipboard fitting is not selected from an accepted industry standard, the strength of the fitting and of its attachment to the ship is to be in accordance with 2. Mooring bitts (double bollards) are required to resist the loads caused by the mooring line attached in figure-of-eight fashion, see Note. For strength assessment beam theory or finite element analysis using net scantlings is to be applied, as appropriate. Corrosion additions as well as a wear down allowance are to be included as defined in 3. At the discretion of BKI, load tests may be accepted as alternative to strength assessment by calculations.

Note:

With the line attached to a mooring bitt in the usual way (figure-of-eight fashion), either of the two posts of the mooring bitt can be subjected to a force twice as large as that acting on the mooring line. Disregarding this effect, depending on the applied industry standard and fitting size, overload may occur.

(IACS UR A2.2.4)

1.2 Safe working load (SWL)

1) shipboard fittings used for mooring purpose.
2) Unless a greater SWL is requested by the applicant according to 2.3.3), the SWL is not to exceed the ship design minimum breaking load according to Table 18.2, see Notes in 2.3.

3) The SWL [t], of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for mooring. For fittings intended to be used for, both, mooring and towing, TOW [t], according to G.1.2 is to be marked in addition to SWL.

4) The above requirements on SWL apply for the use with no more than one mooring line.

5) The towing and mooring arrangements plan mentioned in H. is to define the method of use of mooring lines.

(IACS UR A2.2.6)

2. Supporting hull structure

2.1 Strength

Strength calculations for supporting hull structures of mooring equipment are to be based on net thicknesses.

$$t_{net} = t - t_K$$

t_K = corrosion addition according to 3.

(IACS UR A2.0)

The design load applied to supporting hull structure is to be in accordance with 2.3.

2.2 Arrangement

The arrangement of reinforced members beneath shipboard fittings, winches and capstans is to consider any variation of direction (horizontally and vertically) of the mooring forces acting upon the shipboard fittings, see Fig. 18.7 for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be ensured.

(IACS UR A2.2.5)

2.3 Load considerations

1) The minimum design load applied to supporting hull structures for shipboard fittings is to be 1,15 times the ship design minimum breaking load according to Table 18.2 for the equipment numeral Z (see Notes)

2) The minimum design load applied to supporting hull structures for winches, etc. is to be 1,25 times the intended maximum brake holding where the maximum brake holding load is to be assumed not less than 80% of the ship design minimum breaking load according Table 18.2, see Notes. For supporting hull structures of capstans, the design load is to be 1,25 times the maximum hauling-in force.

3) When a safe working load SWL greater than that determined according to 1.2 is requested by the applicant, then the design load is to be increased in accordance with the appropriate SWL/design load relationship given by 2.3 and 1.2.

4) The design load is to be applied to fittings in all directions that may occur by taking into account the arrangement shown on the towing and mooring arrangements plan. Where the mooring line takes a turn at a fitting the total design load applied to the fitting is equal to the resultant of the design loads acting on the line, refer to the Fig.18.4. However, in no case does the design load applied to the fitting need to be greater than twice the design load on the line.

Note:

1 *If not otherwise specified by B.1 and F.4, side projected area including that of deck cargoes as given by the ship nominal capacity condition is to be taken into account for selection of mooring lines and the loads applied to shipboard fittings and supporting hull structures. The nominal capacity condition is defined in A.8.*

2 *The increase of the line design break force for synthetic ropes according to F.6.2 needs not to be taken into account for the loads applied to shipboard fittings and supporting hull structures.*

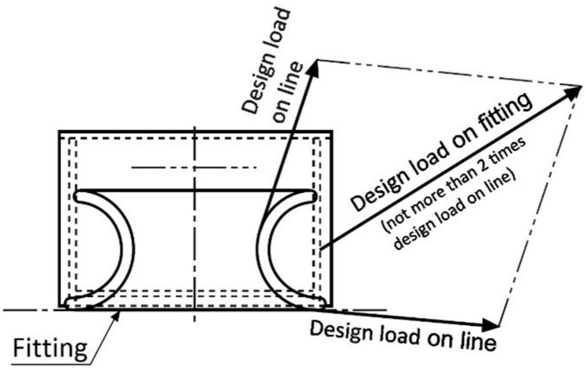

Fig. 18.4 Application of design loads

(IACS UR A2.2.3)

2.4 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 and bitts the attachment point of the mooring line is to be taken not less than 4/5 of the tube height above the base, see a) in Fig.18.5. However, if fins are fitted to the bollard tubes to keep the mooring line as low as possible, the attachment point of the mooring line may be taken at the location of the fins, see b) in Fig.18.5.

(IACS UR A2.2.5)

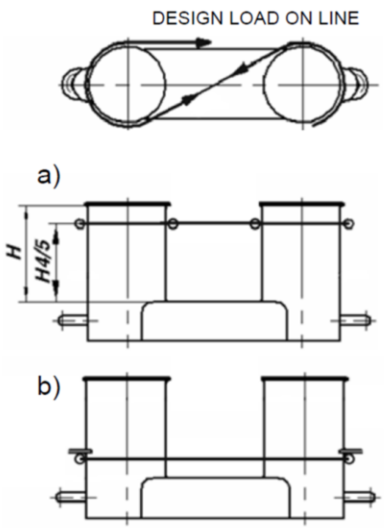

Fig. 18.5 Attachment point of mooring line

(IACS UR A2.2.5)

2.5 Allowable stresses

Allowable stresses under the design load conditions as specified in 2.3 are as follows:

1) For strength assessment by means of beam theory or grillage analysis:

Normal stress : $\sigma_N \leq R_{eH}$

Shear stress : $\tau \leq 0{,}6\ R_{eH}$

Normal stress is the sum of bending stress and axial stress. No stress concentration factors being taken into account.

(IACS UR A2.2.5(1))

2) For strength assessment by means of finite element analysis:

Von Mises stress : $\sigma_V \leq R_{eH}$

For strength assessment by means of finite element analysis the mesh is to be fine enough to represent the geometry as realistically as possible. The aspect ratios of elements are not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs must not exceed one-third of the web height. In way of small openings in girder webs the web thickness is to be reduced to a mean thickness over the web height as requirement of BKI rules. Large openings are to be modelled. Stiffeners may be modelled by using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modelled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element.

Where :

R_{eH} = Nominal upper yield point of the material used [N/mm^2] according to Section 2, B.2

(IACS UR A2.2.5(2))

3. Corrosion addition

The total corrosion addition, t_k, is not to be less than the following values:

— For the supporting hull structure, according to Section 3, K

— For pedestals and foundations on deck which are not part of a fitting according to an accepted industry standard 2,0 mm

— For shipboard fittings not selected from an accepted industry standard 2,0 mm

For Ships subject to IACS CSR Bulk Carriers and Oil Tanker, according to Rules for Bulk Carriers and Oil Tankers (Pt.1, Vol.XVII)

(IACS UR A2.4)

In addition to the corrosion addition given above, the wear allowance, t_w, for shipboard fittings not selected from an accepted industry standard is not to be less than 1,0 mm, added to surfaces which are intended to regularly contact the line.

(IACS UR A2.5)

4. Mooring lines

4.1 Mooring lines for ship with Z $\leq$ 2000

The minimum recommended mooring lines for ships having an Equipment Numeral (Z) of less than or equal to 2000 are given in Table 18.2.

For ships having the ratio A/Z > 0,9 the following number of lines should be added to the number of mooring lines as given by Table 18.2:

1 line where $0,9 < \frac{A}{Z} \leq 1,1$

2 lines where $1,1 < \frac{A}{Z} \leq 1,2$

3 lines where $\frac{A}{Z} > 1,2$

The determination of side projected area (A) is considering with B.2.

(IACS Rec. 10, 2.1.1)

The length of each mooring lines for ships with Z $\leq$ 2000 may be taken from Table 18.2.

(IACS Rec. 10, 2.1.3)

4.2 Mooring lines for ships with Z > 2000

The minimum recommended strength and number of mooring lines for ships with an Equipment Numeral Z > 2000 are given in 4.2.1 and 4.2.2, respectively. The length of mooring lines is given by 4.2.3.

The strength of mooring lines and the number of head, stern, and breast lines (see Note) for ships with an Equipment Numeral Z > 2000 are based on the side-projected area A according to B.1, but considering the following conditions:

1) For ship types having small variation in the draft, like e.g. passenger and RO-RO ship, the side projected area A may be calculated using the summer load waterline.
2) Wind shielding of the pier can be considered for the calculation of the side-projected area A unless the ship is intended to be regularly moored to jetty type piers. A height of the pier surface of 3,0 m over waterline may be assumed, i.e. the lower part of the side-projected area with a height of 3,0 m above the waterline for the considered loading condition may be disregarded for the calculation of the side-projected area A.
3) Deck cargoes at the ship nominal capacity condition should be included for the determination of side-projected area A. For the condition with cargo on deck, the summer load waterline may be considered. Deck cargo may not need to be considered if ballast draft condition generates a larger side-projected area A than the full load condition with cargoes on deck. The larger of both side-projected areas should be chosen as side-projected area A. The nominal capacity condition is defined in A.8.

The mooring lines as given here under are based on a maximum current speed of 1,0 m/s and the following maximum wind speed v_w [m/s]:

v_w	=	25 – 0,002 · (A – 2000)	for passenger ships, ferries and car carriers with 2000 m^2 < A < 4000 m^2
	=	21	for passenger ships, ferries, and car carriers with A > 4000 m^2
	=	25	for other ships

The wind speed is considered representative of a 30 second mean speed from any direction and at a height of 10 m above the ground. The current speed is considered representative of the maximum current speed acting on bow or stern (±10°) and at a depth of one-half of the mean draft. Furthermore, it is considered that ships are moored to solid piers that provide shielding against cross current.

Additional loads caused by, e.g., higher wind or current speeds, cross currents, additional wave loads, or reduced shielding from non-solid piers may need to be particularly considered. Furthermore, it should be observed that unbeneficial mooring layouts can considerably increase the loads on single mooring lines.

Note:

The following is defined with respect to the purpose of mooring lines, see also Fig. 18.6:

Breast line:	*A mooring line that is deployed perpendicular to the ship, restraining the ship in the off-berth direction.*
Spring line:	*A mooring line that is deployed almost parallel to the ship, restraining the ship in fore or aft direction.*
Head/Stern line:	*A mooring line that is oriented between longitudinal and transverse direction, restraining the ship in the off-berth and in fore or aft direction. The amount of restraint in fore or aft and off-berth direction depends on the line angle relative to these directions.*

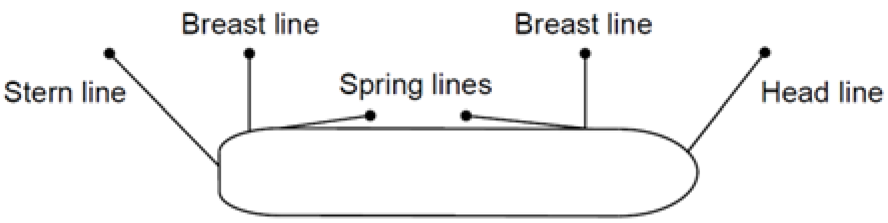

Fig. 18.6 mooring line

(IACS Rec. 10, 2.1.2)

4.2.1 Ship design minimum breaking load

The ship design minimum breaking load MBL_{SD} of the mooring lines should be taken as:

$$MBL_{SD} = 0{,}1 \cdot A_2 + 350 \quad [kN] \quad \text{with } MBL_{SD} \le 1275 \text{ kN}$$

Where:

MBL_{SD} = the ship design minimum breaking load

However, in this case the moorings are to be considered as not sufficient for environmental conditions given by 4.2. For these ships, the acceptable wind speed $v_w{}^*$ can be estimated as follows:

$$v_w{}^* = v_w \cdot \sqrt{\frac{MBL^*_{SD}}{MBL_{SD}}} \quad [m/s]$$

Where:

v_w = the wind speed as per 4.2,

$MBL_{SD}{}^*$ = the ship design minimum breaking load of the mooring lines intended to be supplied with $MBL_{SD}{}^* \ge MBL^*_{SDmin}$

$$\mathrm{MBL}^*_{\mathrm{SDmin}} \geq \left(\frac{21}{\mathrm{v_W}}\right)^2 \cdot \mathrm{MBL_{SD}}$$

$MBL*_{min}$ = ship design minimum breaking load corresponding to an acceptable wind speed $v_W{}^*$ of 21 m/s

if $v_W{}^* > v_W$

$$\mathrm{MBL}^*_{\mathrm{SDmin}} \geq \left(\frac{\mathrm{v}^*_\mathrm{W}}{\mathrm{v_W}}\right)^2 .\mathrm{MBL_{SD}}$$

(IACS Rec. 10 2.1.2.1)

4.2.2 Number of mooring lines

The total number of head, stern and breast lines (see Note in 4.2) should be taken as:

$$n = 8{,}3 \cdot 10^{-4} \cdot A_2 + 6$$

For oil tankers, chemical tankers, bulk carriers, and ore carriers the total number of head, stern and breast lines should be taken as:

$$n = 8{,}3 \cdot 10^{-4} \cdot A_2 + 4$$

The total number of head, stern and breast lines should be rounded to the nearest whole number.

The number of head, stern and breast lines may be increased or decreased in conjunction with an adjustment to the ship design minimum breaking load of the lines. The adjusted ship design minimum breaking load , $MBL_{SD}{}^{**}$, should be taken as:

$$\mathrm{MBL}^{**}_{\mathrm{SD}} = 1,2 \cdot \mathrm{MBL_{SD}} \cdot \frac{n}{n^{**}} \leq \mathrm{MBL_{SD}} \qquad \text{for increased number of lines}$$

$$\mathrm{MBL}^{**}_{\mathrm{SD}} = \mathrm{MBL_{SD}} \cdot \frac{n}{n^{**}} \qquad \text{for reduced number of lines}$$

Where:

MBL_{SD} or $MBL_{SD}{}^*$ as specified in 4.2.1

n^{**} = the increased or decreased total number of head, stern and breast lines

n = the number of lines for the considered ship type as calculated by the above formulas without rounding.

Vice versa, the ship design minimum breaking load of head, stern and breast lines may be increased or decreased in conjunction with an adjustment to the number of lines.

The total number of spring lines (see Note in 4.2) should be taken not less than:

2 lines where $Z < 5000$

4 lines where $Z \geq 5000$

The ship design minimum breaking load of spring lines should be the same as that of the head, stern and breast lines. If the number of head, stern and breast lines is increased in conjunction with an adjustment to the ship design minimum breaking load of the lines, the number of spring lines should be taken as follows, but rounded up to the nearest even number.

$$n_s^* = \frac{MBL_{SD}}{MBL_{SD}^{**}} \cdot n_s$$

Where:

MBL_{SD} or $MBL_{SD}{}^*$ as specified in 4.2.1

n_s = the number of spring lines as given above

n_s^* = the increased number of spring lines.

(IACS Rec. 10, 2.1.2.2)

4.2.3 Length of mooring lines

For ships with Z > 2000 the length of each mooring lines may be taken as 200 m.

The lengths of individual mooring lines may be reduced by up to 7% of the above given lengths, but the total length of mooring lines should not be less than would have resulted had all lines been of equal length.

(IACS Rec. 10 2.1.3)

5. Equipment for mooring at single point moorings

5.1 Upon request from the owner, BKI is prepared to certify that the ship is specially fitted for compliance with Sections 2.1, 4.2 and 6 of the "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".

5.2 For tankers employed in shuttle service using single point moorings (SPM) Section 24, L has to be observed.

6. Ropes

6.1 The following items 6.2 to 6.3 and the Tables 18.1 and 18.2 for tow lines and mooring ropes are recommendations only, a compliance with which is not a condition of Class.

6.2 Tow lines and mooring lines may be of wire, natural fibre or synthetic fibre construction or of a mixture of wire and fibre. For synthetic fibre ropes it is recommended to use lines with reduced risk of recoil (snap-back) to mitigate the risk of injuries or fatalities in the case of breaking mooring lines.

(IACS Rec.10 2.3)

The required diameters of synthetic fibre ropes used in lieu of steel wire ropes may be taken from Table 18.1.

6.3 For wire ropes used as mooring lines, the breaking load test specified in Rules for Materials (Pt.1, Vol.V) Sec.14.D has to be observed.

7. Examination after construction

The condition of deck fittings, their pedestals or foundations, if any, and the hull structures in the vicinity of the fittings are to be examined in accordance with BKI.

(IACS UR A2.6)

Table 18.1 Wire/ fibre ropes diameter

Steel wire ropes[1)]	Synthetic wire ropes	Fibre ropes		
	Polyamide[2)]	Polyamide	Polyester	Polypropylene
dia. [mm]	dia. [mm]	dia. [mm]	dia. [mm]	dia. [mm]
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 equivalent

[2)] Regular laid ropes of refined polyamide monofilaments and filament fiber

G. Towing Equipment

1. Shipboard fittings and supporting hull structures

1.1 Arrangement and strength

Shipboard fittings for towing are to be located on stiffeners, 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 (for chocks in bulwarks, etc.) provided the strength is confirmed adequate for the intended service.

(IACS UR A2.1.2)

Shipboard fittings may be selected from an industry standard accepted by BKI and at least based on the following loads:

1) For normal towing operations, the intended maximum towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangements plan,

2) For other towing service, the ship design minimum breaking load of the tow line according to Table 18.2 (see Notes in 1.1.1),

3) For fittings intended to be used for, both, normal and other towing operations, the greater of the loads according to 1) and 2).

Towing bitts (double bollards) may be chosen for the towing line attached with eye splice if the industry standard distinguishes between different methods to attach the line, i.e. figure-of eight or eye splice attachment.

When the shipboard fitting is not selected from an accepted industry standard, the strength of the fitting and of its attachment to the ship is to be in accordance with 1.1.1 and 1.1.2. Towing bitts (double bollards) are required to resist the loads caused by the towing line attached with eye splice. For strength assessment beam theory or finite element analysis using net scantlings is to be applied, as appropriate. Corrosion additions as well as a wear down allowance are to be included as defined in F.3. At the discretion of the Society, load tests may be accepted as alternative to strength assessment by calculations.

(IACS UR A2.1.4)

The strength of shipboard fittings used for ordinary towing operations at bow, sides and stern and their supporting hull structures are to be determined on the basis of 1.1.1 and 1.1.2.

Where a ship is equipped with shipboard fittings intended to be used for other towing services, the strength of these fittings and their supporting hull structures are to comply with the requirements on this sub-section

For fittings intended to be used for, both, towing and mooring, F. applies to mooring.

(IACS UR A2.1.1)

Strength calculations are to be based on net thicknesses

$t_{net} = t - t_K$

t_K = corrosion addition, see F.3

(IACS UR A2.0)

1.1.1 Load consideration

The minimum design load applied to supporting hull structures for shipboard fittings is to be:

1) For normal towing operations 1,25 times the intended maximum towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangements plan.
2) For other towing service, the ship design minimum breaking load according to Table 18.2. (see Notes),
3) For fittings intended to be used for, both, normal and other towing operations, the greater of the design loads according to 1) and 2).

Note:

1 *Side projected area including that of deck cargoes as given by the ship nominal capacity condition is to be taken into account for selection of towing lines and the loads applied to shipboard fittings and supporting hull structures. The nominal capacity condition is defined in A.8.*

2 *The increase of the line design break force for synthetic ropes according to F.1.2 needs not to be taken into account for the loads applied to shipboard fittings and supporting hull structures.*

When a safe towing load TOW greater than that determined according to 1.2 is requested by the applicant, then the design load is to be increased in accordance with the appropriate TOW/design load relationship given by 1.1.1 and 1.2.

The design load is to be applied to fittings in all directions that may occur by taking into account the arrangement shown on the towing and mooring arrangements plan. Where the towing line takes a turn at a fitting the total design load applied to the fitting is equal to the resultant of the design loads acting on the line, see Fig. 18.7. However, in no case does the design load applied to the fitting need to be greater than twice the design load on the line.

(IACS UR A2.1.3)

1.1.2 Acting point of towing force

The design load applied to supporting hull structure is to be in accordance with 1.1.1.

The reinforced members beneath shipboard fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the towing forces acting upon the shipboard fittings, see Fig. 18.7 for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be ensured.

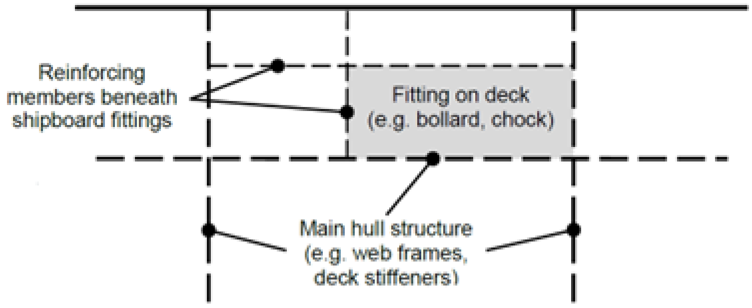

Fig. 18.7 Sample arrangement of reinforced members beneath shipboard fittings

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 and bitts the attachment point of the towing line is to be taken not less than 4/5 of the tube height above the base, see Fig.18.8 below.

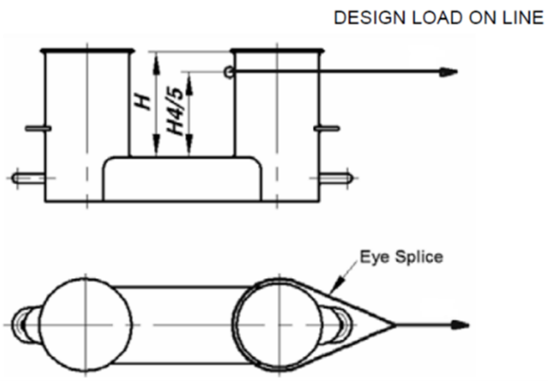

Fig. 18.8 Attachment point of towing line

(IACS UR A2.1.5)

1.1.3 Allowable stresses

Allowable stresses under the design load conditions as specified in 1.1.1 are as follow:

1) For strength assessment by means of beam theory or grillage analysis:

Normal stress : $\sigma_N \leq R_{eH}$

Shear stress : $\tau \leq 0{,}6\ R_{eH}$

(IACS UR A2.1.5(1))

For determining normal stress see F.2.5.1)

2) For strength assessment by means of finite element analysis:

Von Mises stress : $\sigma_V \leq R_{eH}$

(IACS UR A2.1.5(2))

For determining strength assessment by means of finite elements, see F.2.5.2)

Where :

R_{eH} = Nominal upper yield point of the material used [N/mm^2] according to Section 2, B.2

1.2 Safe Towing Load (TOW)

1) The safe towing load (TOW) is safe the load limit of shipboard fittings used for towing purpose.
2) TOW used for normal towing operations is not to exceed the following value:

$$\text{TOW} \leq . \ 0,8 \frac{F_D}{1,25}$$

FD = design load per 1.1.1.1)

(IACS UR A2.1.6.(2))

3) TOW used for other towing operations is not to exceed 80% of the design load according to 1.1.1(2)
4) For fittings used for both normal and other towing operations, the greater of the safe towing loads according to 2) and 3) is to be used.
5) TOW [t], of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for towing. For fittings intended to be used for, both, towing and mooring, SWL [t], according to F.1.2 is to be marked in addition to TOW.
6) The above requirements on TOW apply for the use with no more than one line. If not otherwise chosen, for towing bitts (double bollards) TOW is the load limit for a towing line attached with eye-splice.
7) The towing and mooring arrangements plan mentioned in H.1 is to define the method of use of towing lines.

(IACS UR A2.1.6)

2. Tow line

The tow lines are given in Table 18.2 and are intended as own tow line of a ship to be towed by a tug or other ship. For the selection of the tow line from Table 18.2, the Equipment Numeral Z should be taken according to B.2.

The designer should consider verifying the adequacy of towing lines based on assessments carried out for the individual towing arrangement.

(IACS Rec. 10.2.2)

3. 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 1. as given for other towing services are to be applied analogously.

H. Mooring and Towing Arrangements

1. Mooring and Towing arrangement Plan

The SWL and TOW for the intended use for each shipboard fitting is to be noted in the towing and mooring arrangements plan available on board for the guidance of the Master. It is to be noted that TOW is the load limit for towing purpose and SWL that for mooring purpose. If not otherwise chosen, for towing bitts it is to be noted that TOW is the load limit for a towing line attached with eye-splice.

Information provided on the plan is to include in respect of each shipboard fitting:

1) location on the ship
2) fitting type
3) SWL/TOW
4) purpose (mooring / harbour towing / other towing)

5) manner of applying towing or mooring line load including limiting fleet angles angle i.e. angle of change in direction of a line at the fittings.

Item 3) with respect to items 4) and 5), is subject to approval by BKI.

Furthermore, information provided on the plan is to include:

A) the arrangement of mooring lines showing number of lines (N);

B) ship design minimum breaking load (MBL_{SD});

C) the acceptable environmental conditions as given in F.4.2.1 for the recommended ship design minimum breaking for ships with Equipment Numeral Z > 2000:

- 30 second mean wind speed from any direction (v_W or v_W^* according to F.4.2.1)
- Maximum current speed acting on bow or stern (±10°)

The information as given in above is to be incorporated into the pilot card in order to provide the pilot proper information on harbour and other towing operations.

(IACS UR A2.3)

2. Mooring winches

2.1 Each winch should be fitted with brakes the holding capacity of which is sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80% of the ship design minimum breaking load of the rope as fitted on the first layer.

The winch should be fitted with brakes that will allow for the reliable setting of the brake rendering load.

(IACS Rec. 10.2.4.1)

2.2 For powered winches the maximum hauling tension which can be applied to the mooring line (the reeled first layer) should not be less than 2/9 times, nor be more than 1/3 times the rope's ship design minimum breaking load. For automatic winches these figures apply when the winch is set to the maximum power with automatic control.

(IACS Rec. 10.2.4.2)

2.3 For powered winches on automatic control, the rendering tension which the winch can exert on the mooring line (the reeled first layer) should not exceed 1,5 times, nor be less than 1,05 times the hauling tension for that particular power setting of the winch. The winch should be marked with the range of rope strength for which it is designed.

(IACS Rec. 10.2.4.3)

3. Mooring and towing arrangement

3.1 Mooring arrangement

Mooring lines in the same service (e.g. breast lines, see Note in F.4.2) should be of the same characteristic in terms of strength and elasticity.

As far as possible, sufficient number of mooring winches should be fitted to allow for all mooring lines to be belayed on winches. This allows for an efficient distribution of the load to all mooring lines in the same service and for the mooring lines to shed load before they break. If the mooring arrangement is designed such that mooring lines are partly to be belayed on bitts or bollards, it should be considered that these lines may not be as effective as the mooring lines belayed on winches.

Mooring lines should have as straight a lead as is practicable from the mooring drum to the fairlead.

At points of change in direction sufficiently large radii of the contact surface of a rope on a fitting should be provided to minimize the wear experienced by mooring lines and as recommended by the rope manufacturer for the rope type intended to be used.

(IACS Rec. 10.2.5.1)

3.2 Towing arrangement

Towing lines should be led through a closed chock. The use of open fairleads with rollers or closed roller fairleads should be avoided.

For towing purpose it is recommended to provide at least one chock close to centreline of the ship forward and aft. It is also beneficial to provide additional chocks on port and starboard side at the transom and at the bow.

Towing lines should have a straight lead from the towing bitt or bollard to the chock.

For the purpose of towing, bitts or bollards serving a chock should be located slightly offset and in a distance of at least 2 m away from the chock, see Fig. 18.9:

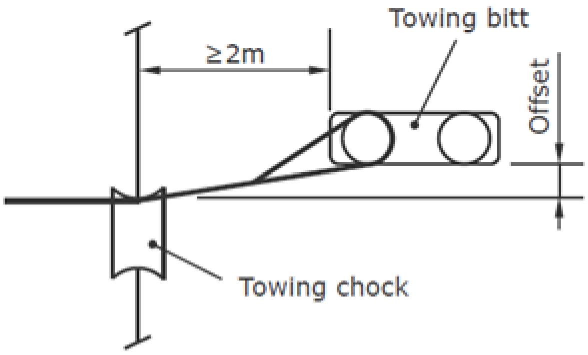

Fig. 18.9 Typical towing arrangement

Warping drums should preferably be positioned not more than 20 m away from the chock, measured along the path of the line.

Attention should be given to the arrangement of the equipment for towing and mooring operations in order to prevent interference of mooring and towing lines as far as practicable. It is beneficial to provide dedicated towing arrangements separate from the mooring equipment.

For emergency towing arrangements for tankers reference should be made to SOLAS Chapter II-1, Regulation 3-4. For all ships other than tankers it is recommended to provide towing arrangements fore and aft of sufficient strength for 'other towing' service as defined in A.6.3.

(IACS Rec. 10.2.5.2)

Table 18.2 Anchor, Chain Cables and Ropes

No. for Reg.	Equipment numeral Z	Stockless anchor			Stud link chain cables						Recommended ropes				
		Bower anchor		Stream anchor	Bower anchors				Stream wire or chain for stream anchor		Towline		Mooring lines		
		Number[1)]	Mass per anchor		Total length	Diameter d_1	Diameter d_2	Diameter d_3	Length	Break load[2)]	Length	Ship Design Minimum Break Load[2)]	Number	Length[3)]	Ship Design Minimum Break Load[2)]
			[kg]	[kg]	[m]	[mm]	[mm]	[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	64,7	180	98	3	80	35
102	50 – 70	2	180	60	220	14	12,5	12,5	80	64,7	180	98	3	80	37
103	70 – 90	2	240	80	220	16	14	14	85	73,5	180	98	3	100	40
104	90 – 110	2	300	100	247,5	17,5	16	16	85	80	180	98	3	110	42
105	110 – 130	2	360	120	247,5	19	17,5	17,5	90	89,2	180	98	3	110	48
106	130 – 150	2	420	140	275	20,5	17,5	17,5	90	98,1	180	98	3	120	53
107	150 – 175	2	480	165	275	22	19	19	90	107,9	180	98	3	120	59
108	175 – 205	2	570	190	302,5	24	20,5	20,5	90	117,7	180	112	3	120	64
109	205 – 240	2	660		302,5	26	22	20,5			180	129	4	120	69
110	240 – 280	2	780		330	28	24	22			180	150	4	120	75
111	280 – 320	2	900		357,5	30	26	24			180	174	4	140	80
112	320 – 360	2	1020		357,5	32	28	24			180	207	4	140	85
113	360 – 400	2	1140		385	34	30	26			180	224	4	140	96
114	400 – 450	2	1290		385	36	32	28			180	250	4	140	107
115	450 – 500	2	1440		412,5	38	34	30			180	277	4	140	117
116	500 – 550	2	1590		412,5	40	34	30			190	306	4	160	134
117	550 – 600	2	1740		440	42	36	32			190	338	4	160	143
118	600 – 660	2	1920		440	44	38	34			190	370	4	160	160
119	660 – 720	2	2100		440	46	40	36			190	406	4	160	171
120	720 – 780	2	2280		467,5	48	42	36			190	441	4	170	187
121	780 – 840	2	2460		467,5	50	44	38			190	479	4	170	202
122	840 – 910	2	2640		467,5	52	46	40			190	518	4	170	218
123	910 – 980	2	2850		495	54	48	42			190	559	4	170	235
124	980 – 1060	2	3060		495	56	50	44			200	603	4	180	250
125	1060 – 1140	2	3300		495	58	50	46			200	647	4	180	272
126	1140 – 1220	2	3540		522,5	60	52	46			200	691	4	180	293
127	1220 – 1300	2	3780		522,5	62	54	48			200	738	4	180	309
128	1300 – 1390	2	4050		522,5	64	56	50			200	786	4	180	336
129	1390 – 1480	2	4320		550	66	58	50			200	836	4	180	352
130	1480 – 1570	2	4590		550	68	60	52			220	888	5	190	352
131	1570 – 1670	2	4890		550	70	62	54			220	941	5	190	362
132	1670 – 1790	2	5250		577,5	73	64	56			220	1024	5	190	384
133	1790 – 1930	2	5610		577,5	76	66	58			220	1109	5	190	411
134	1930 – 2080	2	6000		577,5	78	68	60			220	1168	5[4)]	190[4)]	437[4)]
135	2080 – 2230	2	6450		605	81	70	62			240	1259			
136	2230 – 2380	2	6900		605	84	73	64			240	1356			
137	2380 – 2530	2	7350		605	87	76	66			240	1453			
138	2530 –2700	2	7800		632,5	90	78	68			260	1471			
139	2700 – 2870	2	8300		632,5	92	81	70			260	1471			

Table 18.2 Anchor, Chain Cables and Ropes *(continued)*

No. for Reg.	Equipment numeral Z	Stockless anchor			Stud link chain cables						Recommended ropes				
		Bower anchor		Stream anchor	Bower anchors				Stream wire or chain for stream anchor		Towline		Mooring lines		
		Number[1)]	Mass per anchor		Total length	Diameter d_1	Diameter d_2	Diameter d_3	Length	Break load[2)]	Length	Ship Design Minimum Break Load[2)]	Number	Length[3)]	Ship Design Minimum Break Load[2)]
			[kg]		[m]	[mm]	[mm]	[mm]	[m]	[kN]	[m]	[kN]		[m]	[kN]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
140	2870 – 3040	2	8700		632,5	95	84	73			260	1471			
141	3040 – 3210	2	9300		660	97	84	76			280	1471			
142	3210 – 3400	2	9900		660	100	87	78			280	1471			
143	3400 – 3600	2	10500		660	102	90	78			280	1471			
144	3600 – 3800	2	11100		687,5	105	92	81			300	1471			
145	3800 – 4000	2	11700		687,5	107	95	84			300	1471			
146	4000 – 4200	2	12300		687,5	111	97	87			300	1471			
147	4200 – 4400	2	12900		715	114	100	87			300	1471			
148	4400 – 4600	2	13500		715	117	102	90			300	1471			
149	4600 – 4800	2	14100		715	120	105	92			300	1471			
150	4800 – 5000	2	14700		742,5	122	107	95			300	1471			
151	5000 – 5200	2	15400		742,5	124	111	97			300	1471			
152	5200 – 5500	2	16100		742,5	127	111	97			300	1471			
153	5500 – 5800	2	16900		742,5	130	114	100			300	1471			
154	5800 – 6100	2	17800		742,5	132	117	102			300	1471			
155	6100 – 6500	2	18800		742,5		120	107			300	1471			
156	6500 – 6900	2	20000		770		124	111			300	1471			
157	6900 – 7400	2	21500		770		127	114			300	1471			
158	7400 – 7900	2	23000		770		132	117			300	1471			
159	7900 – 8400	2	24500		770		137	122			300	1471			
160	8400 – 8900	2	26000		770		142	127			300	1471			
161	8900 – 9400	2	27500		770		147	132			300	1471			
162	9400 – 10000	2	29000		770		152	132			300	1471			
163	10000 – 10700	2	31000		770			137			300	1471			
164	10700 – 11500	2	33000		770			142			300	1471			
165	11500 – 12400	2	35500		770			147			300	1471			
166	12400 – 13400	2	38500		770			152			300	1471			
167	13400 – 14600	2	42000		770			157			300	1471			
168	14600 – 16000	2	46000		770			162			300	1471			

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 K3 (extra special quality), see also D

1) see C.1
2) see F.4.2.1
3) see F.4.2.3
4) This value only applied for $z \leq 2000$, for Z > 2000, see F.4.2

(IACS UR A1 Table 1 and Rec. 10 Table 1, 5, 6, 7)

J. Supporting hull structures of anchor windlass and chain stopper

1. General

The supporting hull structure of anchor windlass and chain stopper is to be sufficient to accommodate the design and sea loads.

(IACS UR A1.7)

1.1 Design loads

The design loads are to be taken not less than:

— for chain stoppers, 80% of the chain cable breaking load

— for windlasses, where no chain stopper is fitted or the chain stopper is attached to the windlass, 80% of the chain cable breaking load

— for windlasses, where chain stoppers are fitted but not attached to the windlass, 45% of the chain cable breaking load

The design loads are to be applied in the direction of the chain cable.

(IACS UR A1.7.1)

1.2 Sea loads

The sea loads are to be taken according to Rules for Machinery Installations (Pt.1, Vol.III), Sec. 14, D.4.3.

(IACS UR A1.7.2)

1.3 Allowable stresses

The stresses acting on the supporting hull structures of windlass and chain stopper, based on net thickness obtained by deducting the corrosion addition, t_K, given in 1.4, are not to be greater than the following permissible values:

1) For strength assessment by means of beam theory or grillage analysis:

Normal stress : $\sigma_N \le R_{eH}$

Shear stress : $\tau \le 0{,}6 \cdot R_{eH}$

The normal stress is the sum of bending stress and axial stress. The shear stress to be considered corresponds to the shear stress acting perpendicular to the normal stress. No stress concentration factors are to be taken into account

2) For strength assessment by means of finite element analysis:

Von Mises stress : $\sigma_V \le R_{eH}$

For strength assessment by means of finite element analysis the mesh is to be fine enough to represent the geometry as realistically as possible. The aspect ratios of elements are not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs must not exceed one-third of the web height. In way of small openings in girder webs, the web thickness is to be reduced to a mean thickness over the web height as requirement BKI. Large openings are to be modelled. Stiffeners may be modelled using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modelled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element.

Where:

R_{eH} = nominal upper yield point of the material used [N/mm^2] according to Section 2, B.2

(IACS UR A1.7.3)

1.4 Corrosion addition

The total corrosion addition, t_K, is not to be less than the following values:

— For the supporting hull structure, according to Section 3, K

— For Ships subject to IACS CSR Bulk Carriers and Oil Tanker, according to Rules for Bulk Carriers and Oil Tankers (Pt.1, Vol.XVII)

(IACS UR A1.7.4)

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Section 19 Welded Joints

Preface

The content of this Section is to a large extent identical to that of Rules for Welding (Pt. 1, Vol.VI) Sec.12, G. Because of the reissues of Section 12, G referred to and this Section at different times, some temporary divergences may arise and in such circumstances the more recent Rules shall take precedence.

A. General

1. Information contained in manufacturing documents

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 shall also 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.

1.2 Symbols and signs used to identify welded joints shall 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.

2. Materials, weldability

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.

2.2 For normal strength hull structural steels grades A, B, D and E which have been tested by BKI, weldability normally is considered to have been proven. The suitability of these base materials for high efficiency welding processes with high heat input shall be verified.

2.3 Higher strength hull structural steels grade AH/DH/EH/FH which have been approved by BKI in accordance with the relevant requirements of Rules for Materials (Pt.1, Vol.V), 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 shall be verified.

2.4 High strength (quenched and tempered) fine grain structural steels, low temperature steels, stainless and other (alloyed) structural steels require special approval by BKI. Proof of weldability of the respective steel is to be presented in connection with the welding procedure and welding consumables.

2.5 Cast steel and forged parts require testing by BKI. For castings intended to be used for welded shipbuilding structures the maximum permissible values of the chemical composition according to Rules for Materials (Pt.1, Vol.V) Sec.7.B.4, Table 7.1 have to be observed.

2.6 Aluminium alloys require testing by BKI. Proof of their weldability shall be presented in connection with the welding procedure and welding consumables.

2.7 Welding consumables used are to be suitable for the parent metal to be welded and are to be approved by BKI.

3. Manufacture and testing

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 Rules for Welding (Pt.1, Vol.VI).

3.2 The weld quality grade of welded joints without proof by calculation (see 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 Rules for Welding (Pt.1, Vol.VI) Sec. 12.I. Where proof of fatigue strength is required, in addition the requirements of Section 20 apply.

B. Design

1. General design principles

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.

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 3.3.

1.3 When planning welded joints, it shall first 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 shall be selected and its possibly lower load bearing capacity taken into account when dimensioning the component.

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.

1.5 Special characteristics peculiar to the material, such as the lower strength values of rolled material in the thickness direction (see 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 fillet weld connections are used).

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 shall 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).

2. Design details

2.1 Stress flow, transitions

2.1.1 All welded joints on primary supporting members shall be designed to provide as smooth a stress profile as possible with no major internal or external notches, no discontinuities in rigidity and no obstructions to strains, see Section 3, H.

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.

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.

2.1.4 Wherever possible, joints (especially site joints) in girders and sections shall not be located in areas of high bending stress. Joints at the knuckle of flanges are to be avoided.

2.1.5 The transition between differing component dimensions shall 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.

2.1.6 Where the plate thickness differs at joints perpendicularly to the direction of the main stress, differences in thickness greater than 3,0 mm shall 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 3,0 mm or less may be accommodated within the weld.

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.

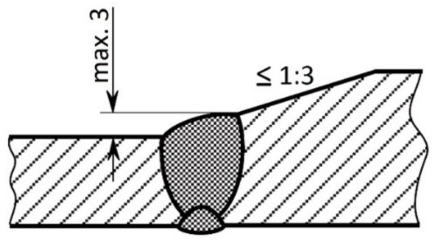


Fig. 19.1 Accommodation of differences of thickness

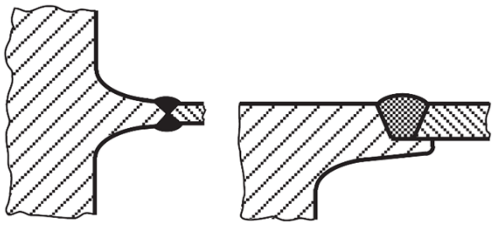


Fig. 19.2 Welding flanges on steel castings or forgings

2.1.8 For the connection of shaft brackets to the boss and shell plating, see 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 2.7 and Section 14, D.2.4. The joint between the rudder-stock and the coupling flange are to be connected by full penetration weld.

2.2 Local clustering of welds, minimum spacing

2.2.1 The local clustering of welds and short distances between welds are to be avoided. Adjacent butt welds should be separated from each other by a distance determined by the following formulae:

$50 + 4 \cdot t$ [mm] between adjacent butt welds

$30 + 2 \cdot t$ [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.

2.2.2 Reinforcing plates, welding flanges, mountings and similar components socket-welded into plating should be of the following minimum size:

$$D_{min} = 170 + 3(t - 10) \geq 170 \quad mm$$

D = diameter of round or length of side of angular weldments [mm]

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.

2.3 Welding cut-outs

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).

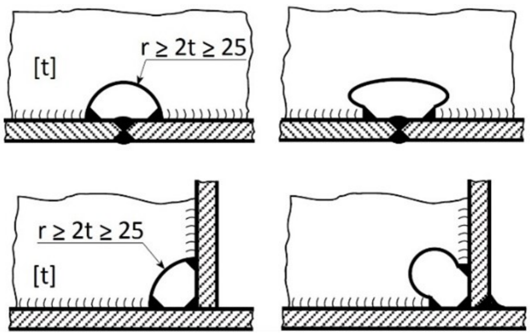


Fig. 19.3 Welding cut-outs

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.

2.4 Local reinforcements, doubling plates

2.4.1 Where plating (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. shall invariably take the form of thicker sections welded into the plating, see 2.2.2.

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 times their thickness shall be slot welded to the underlying plating in accordance with 3.3.11 at intervals not exceeding 30 times the thickness of the doubling plate.

2.4.3 Along their (longitudinal) edges, doubling plates shall 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 shall be increased to 0,5 x the doubling plate thickness but shall not 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.

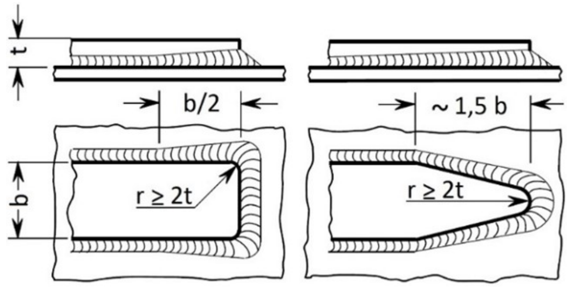


Fig. 19.4 Welding at the ends of doubling plates

2.4.4 Where proof of fatigue strength is required (see Section 20), the configuration of the end of the doubling plate shall conform to the selected detail category.

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 fitting for ladder.

2.5 Intersecting members, stress in the thickness direction

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 shall be taken in the design and fabrication of the structures to prevent lamellar tearing (stratified fractures) due to the anisotropy of the rolled products.

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.

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)[1)] are to be used.

2.6 Welding of cold formed sections, bending radii

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

$$\varepsilon = \frac{100}{1 + 2r/t}\ [\%]$$

r	=	inner bending radius	[mm]
t	=	plate thickness	[mm]

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.

[1)] See Rules for Materials (Pt.1, Vol.V) Sec.4.I

Table 19.1 Minimum inner bending radius r

Plate thickness t [mm]	Minimum inner bending radius r [mm]
≤ 4	1,0 · t
≤ 8	1,5 · t
≤ 12	2,0 · t
≤ 24	3,0 · t
> 24	5,0 · t

Note:

The bending capacity of the material may necessitate a larger bending radius.

2.6.3 For other steels and other materials, where applicable, the necessary minimum bending radius shall, in case of doubt, be established by test. Proof of adequate toughness after welding may be stipulated for steels with minimum nominal upper yield point 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.

2.7 Build - up welds on rudderstocks and pintles

2.7.1 Wear resistance and/or corrosion resistant build-up welds on the bearing surfaces of rudderstocks, pintles etc. shall be applied to a thickened collar exceeding by at least 20 mm the diameter of the adjoining part of the shaft.

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 2.7.3 is possible (leaving an adequate residual diameter).

2.7.3 After welding, the transition areas between the welded and non-welded portions of the shaft shall 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”.

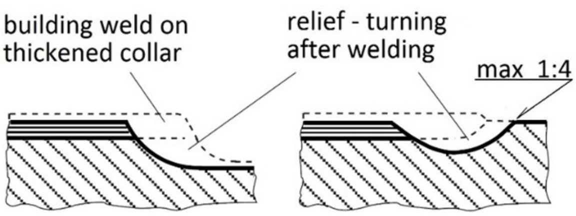


Fig. 19.5 Build-up welds applied to rudderstocks and pintles

3. Weld shapes and dimensions

3.1 Butt joints

3.1.1 Depending on the plate thickness, the welding method and the welding position, butt joints shall 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 shall have been tested and approved in the context of a welding procedure test.

3.1.2 As a matter of principle, the rear sides of butt joints shall 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 3.1.1, require to be tested and approved in connection with a welding procedure test. The effective weld thickness shall 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.

3.1.3 Where the aforementioned conditions cannot be met, e.g. where the welds are accessible from one side only, the joints shall 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.

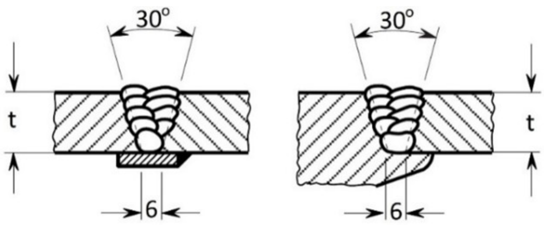


Fig. 19.6 Single-side welds with permanent weld pool support (backings)

3.1.4 The weld shapes illustrated in Fig. 19.7 shall be used for clad plates. These weld shapes shall be used in analogous manner for joining clad plates to (unalloyed and low alloyed) hull structural steels.

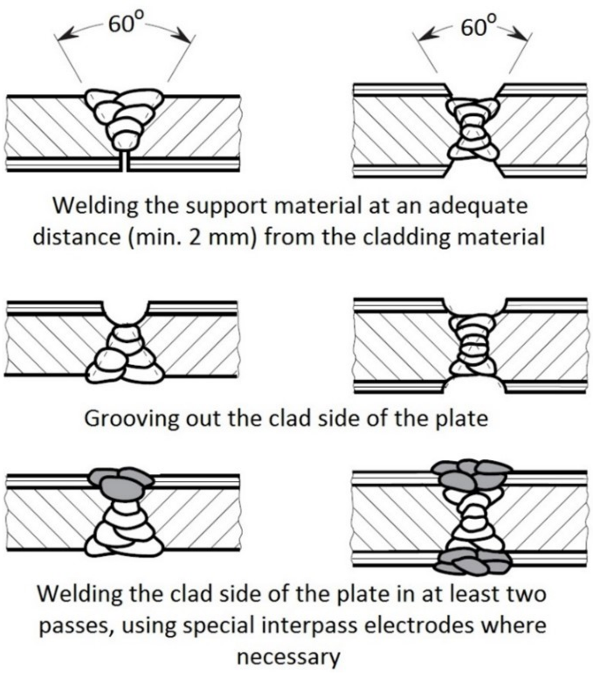


Fig. 19.7 Weld shapes for welding of clad plates

3.2 Corner, T and double-T (cruciform) joints

3.2.1 Corner, T and double-T (cruciform) joints with complete union of the abutting plates shall 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.

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.

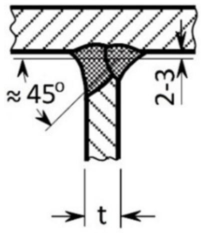


Fig. 19.8 Single and double-bevel welds with full root penetration

3.2.2 Corner, T and double-T (cruciform) joints with a defined incomplete root penetration, as shown in Fig. 19.9, shall be made as single or double-bevel welds, as described in 3.2.1, with a back-up weld but without grooving of the root.

The effective weld thickness may be assumed as the thickness of the abutting plate t minus f, where f is the incomplete root penetration of 0,2 · t with a maximum of 3,0 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.

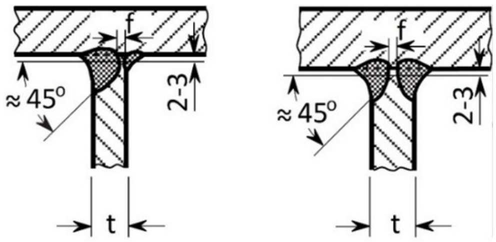


Fig. 19.9 Single and double-bevel welds with defined incomplete root penetration

3.2.3 Corner, T and double-T (cruciform) joints with both an unwelded root face c and a defined incomplete root penetration f shall be made in accordance with Fig. 19.10.

The effective weld thickness shall 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 3,0 mm. Where proof of fatigue strength is required (see Section 20), these welds are to be assigned to types D2 or D3.

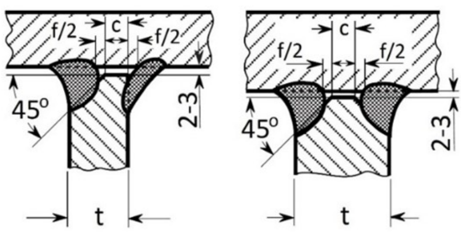


Fig. 19.10 Single and double-bevel welds with unwelded root face and defined incomplete root penetration

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 3.1.3 using a weld pool support (backing), or as single-side, single bevel welds in a manner similar to those prescribed in 3.2.2.

The effective weld thickness shall be determined by analogy with 3.1.3 or 3.2.2, as appropriate. Wherever possible, these joints should not be used where proof of fatigue strength is required (see Section 20).

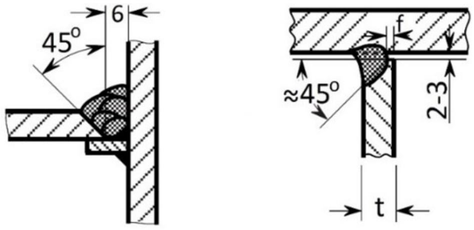


Fig. 19.11 Single-side welded T joints

3.2.5 Where corner joints are flush; the weld shapes shall 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.

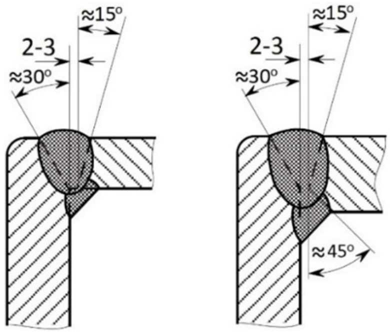


Fig. 19.12 Flush fitted corner joints

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 shall be achieved. Sufficient penetration has to be verified in way of the welding procedure test.

The effective thickness of the weld connecting the horizontal plates shall be determined in accordance with 3.2.2. The requisite "a" dimension is determined by the joint uniting the vertical (web) plates and shall, where necessary, be determined an accordance with Table 19.4 or by calculation as for fillet welds.

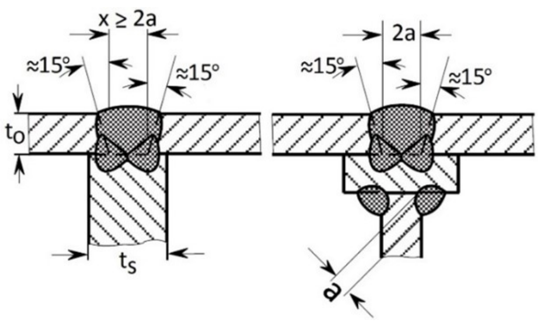


Fig. 19.13 Welding together three plates

The Table 19.2 shows reference values for the design of three plate connections at rudders, steering nozzle, etc.

Table 19.2 Reference value for three plate connections

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

3.3 Fillet weld connections

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) shall be determined in accordance with Table 19.4 or by calculation according to C. The leg length of a fillet weld is to be not less than 1,4 times the throat thickness "a". For fillet welds at doubling plates, see 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.

3.3.2 The relative fillet weld throat thicknesses specified in Table 19.4 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 shall be increased accordingly and the necessary increment shall be established during the welding procedure test (see Rules for Welding (Pt.1, Vol.VI) Sec.12.F). Alternatively proof by calculation taking account of the properties of the weld metal may be presented.

Note:

In case of higher strength aluminium alloys (e.g. AlMg 4,5Mn 0,7), such an increment may be necessary for cruciform joint 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 Rules for Welding (Pt.1, Vol.VI) Sec.12.F .

3.3.3 The throat thickness of fillet welds shall not exceed 0,7 times the lesser thickness of the parts to be connected (generally the web thickness). The minimum throat thickness is defined by the expression:

$$a_{min} = \sqrt{\frac{t_1 + t_2}{3}} \text{ [mm]} \qquad \text{with} \qquad a_{min} \geq 3{,}0 \text{ mm}$$

t_1 = lesser (e.g. the web) plate thickness [mm]

t_2 = greater (e.g. the flange) plate thickness [mm]

3.3.4 It is desirable that the fillet weld section shall 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.

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:

$$a_{deep} = a + \frac{2 \cdot e_{min}}{3} \quad \text{[mm]}$$

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 shall not be less than the minimum throat thickness related to the theoretical root point.

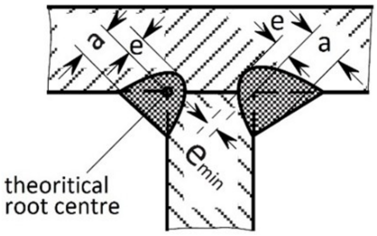


Fig. 19.14 Fillet welds with increased penetration

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 1,0 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 shall 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 Rules for Welding (Pt.1, Vol.VI) Sec.12.F. This applies in analogous manner to welding processes where provision has to be made for inadequate root penetration.

3.3.7 Strengthened fillet 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, C.3.2.5 and Table 19.4), unless single or double bevel welds are stipulated in these locations. In these areas the ”a” dimension shall equal 0,7 x the lesser thickness of the parts to be welded.

3.3.8 Intermittent fillet welds in accordance with Table 19.4 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 shall be used. This applies accordingly also to areas, structures or spaces exposed to extreme environmental conditions or which are exposed to corrosive cargo.

There shall 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.

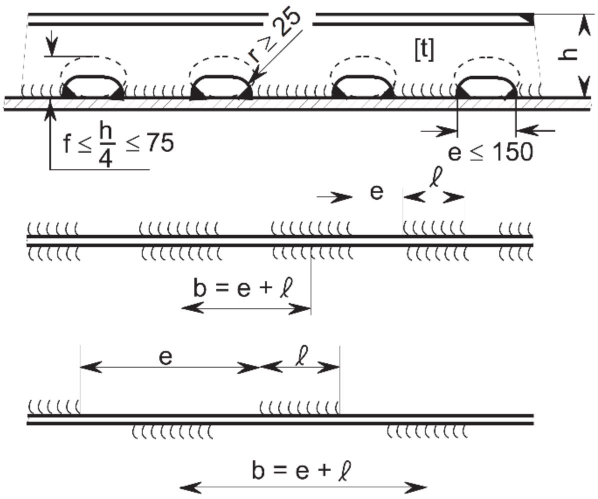


Fig. 19.15 Scallop, chain and staggered welds

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 applying the 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 19.4 or determined by calculation

b = pitch

= $e + \ell$ [mm]

e = interval between the welds [mm]

ℓ = length of fillet weld [mm]

The pitch ratio b/ℓ should not exceed 5,0. The maximum unwelded length ($b - \ell$ with scallop and chain welds, or $b/2 - \ell$ with staggered welds) should not exceed 25 times the lesser thickness of the parts to be welded. The length of scallops should, however, not exceed 150 mm.

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 shall be $1,5 \cdot t + 15$ mm (t = thickness of the thinner plate). Except where another value is determined by calculation, the fillet weld throat thickness "a" shall equal 0,4 times the lesser plate thickness, subject to the requirement that it shall not be less than the minimum throat thickness required by 3.3.3. The fillet weld shall be continuous on both sides and shall meet at the ends.

3.3.11 In the case of plug welding, the plug 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 3.3.8. The fillet weld throat thickness "a_u" may be established in accordance with 3.3.9. The width of the holes shall be equal to at least twice the thickness of the plate and shall not be less than 15 mm. The ends of the holes shall 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 shall be welded, while the remaining void is packed with a suitable filler. In special cases, instead of slot welding, plug weld may be approved by BKI. Lug joint welding is not allowed.

4. Welded joints of particular components

4.1 Welds at the ends of girders and stiffeners

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 19.4.

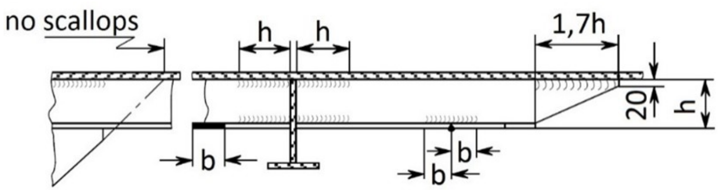


Fig. 19.16 Welds at the ends of girders and stiffeners

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.

4.1.3 Wherever possible, the free ends of stiffeners shall 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.

4.1.4 Where butt joints occur in flange plates, the flange shall be continuously welded to the web on both sides of the joint over a distance at least equal to the width of the flange.

4.2 Joints between section ends and plates

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.

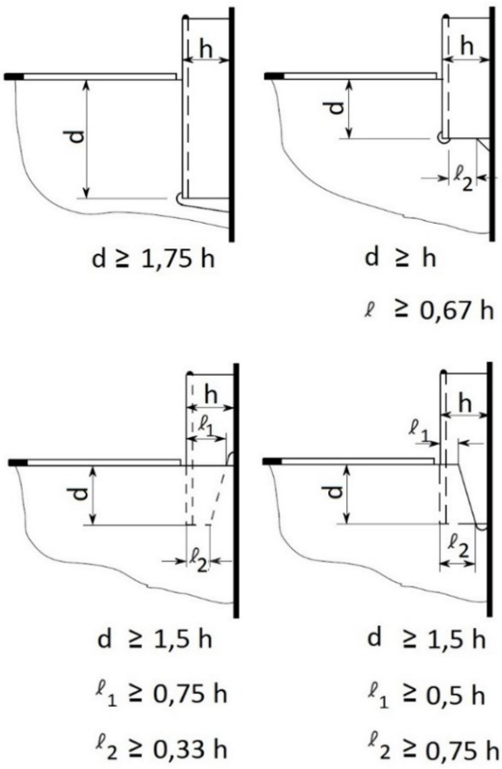


Fig. 19.17 Joints uniting section ends and plates

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 shall be continuous on both sides and shall 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 3.3.3.

4.3 Welded shaft bracket joints

4.3.1 Unless cast in one piece or provided with integrally cast welding flanges analogous to those prescribed in 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.

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 shall be provided with integrally forged or cast welding flanges.

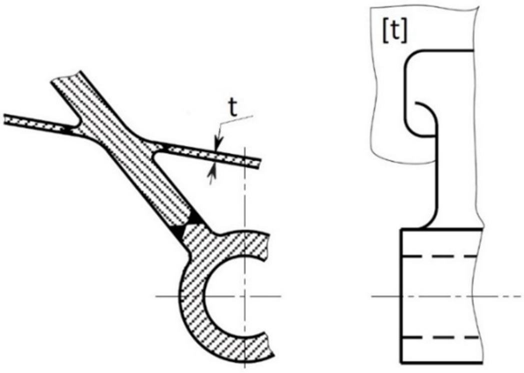
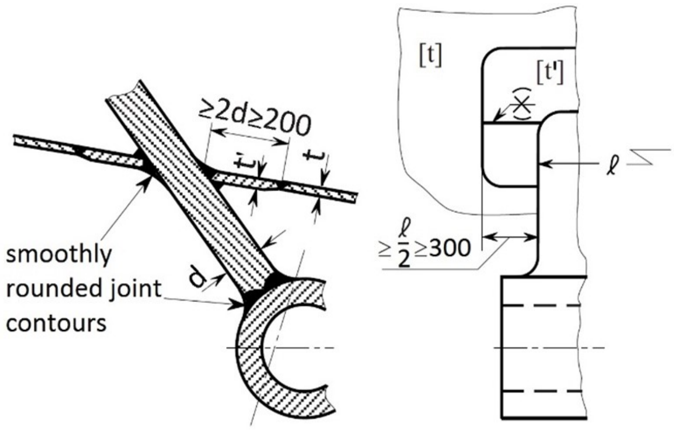


Fig. 19.18 Shaft bracket with integrally cast welding flanges



t = plating thickness in accordance with Section 6, F [mm]

t' = $\frac{d}{3} + 5,0$ [mm] where d < 50 mm

= $3\sqrt{d}$ [mm] where d ≥ 50 mm

For shaft brackets of elliptically shaped cross section d may be substituted by 2/3d in the above formulae.

Fig. 19.19 Shaft bracket without integrally cast welding flanges

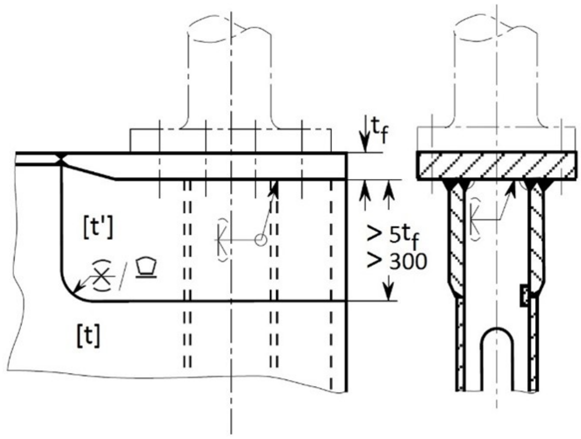
4.4 Rudder coupling flanges

4.4.1 Unless forged or cast steel flanges with integrally forged or cast welding flanges in conformity with 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 3.2.1, see Fig. 19.20. See also Section 14, D.1.4 and D.2.4.

4.4.2 Allowance shall be made for the reduced strength of the coupling flange in the thickness direction, see 1.5 and 2.5. In case of doubt, proof by calculation of the adequacy of the welded connection shall be produced.

4.4.3 The welded joint between the rudder stock (with thickened collar, see 2.1.8) and the flange shall be made in accordance with Fig. 19.21a.

For small stock diameter welded joint in accordance with Fig. 19.21b may be applied.



t	=	plate thickness in accordance with Section 14, E.2 [mm]		
t_f	=	actual flange thickness [mm]		
t'	=	$\frac{t_f}{3} + 5,0$	[mm]	where t_f < 50 mm
	=	$3\sqrt{t_f}$	[mm]	where $t_f \geq 50$ mm

Fig. 19.20 Horizontal rudder coupling flanges

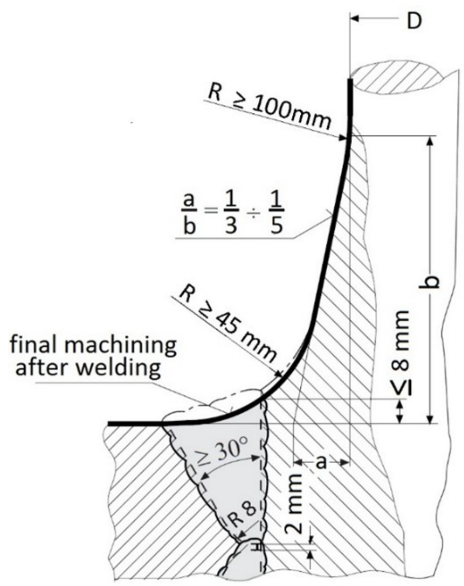


Fig. 19.21a Welded joint between rudder stock and coupling flange

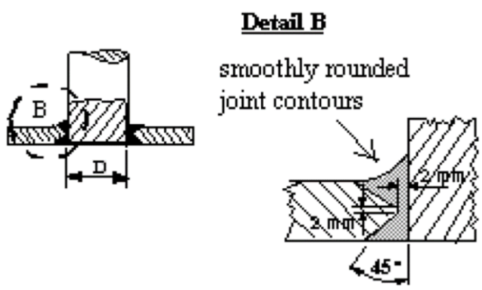


Fig. 19.21b Welded joint between rudder stock and coupling flange for small stock diameter

C. Stress Analysis

1. General analysis of fillet weld stresses

1.1 Definition of stresses

For calculation purposes, the following stresses in a fillet weld are defined (see also Fig. 19.22):

$\sigma_\perp$	=	normal stresses acting vertically to the direction of the weld seam [N/mm^2]
$\tau_\perp$	=	shear stress acting vertically to the direction of the weld seam [N/mm^2]
$\tau_{\|\|}$	=	shear stress acting in the direction of the weld seam [N/mm^2]

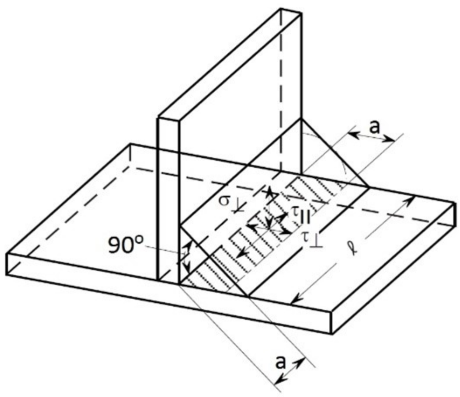


Fig. 19.22 Stresses in a fillet weld

Normal stresses acting in the direction of the weld seam need not be considered.

For calculation purposes the weld seam area is a · ℓ

Due to equilibrium condition the following applies to the flank area vertical to the shaded weld seam area

$$\tau_\perp = \sigma_\perp \qquad [\text{N/mm}^2]$$

The equivalent stress is to be calculated by the following formula:

$$\sigma_v = \sqrt{\sigma_\perp^2 + \sigma_\perp^2 + \tau_{||}^2} \qquad [\text{N/mm}^2]$$

1.2 Definitions

a	=	throat thickness [mm]
ℓ	=	length of fillet weld [mm]
P	=	single force [N]
M	=	bending moment at the position considered [Nm]
Q	=	shear force at the point considered [N]
S	=	first moment of the cross-sectional area of the flange connected by the weld to the web in relationship to the neutral beam axis [cm^3]
I	=	moment of inertia of the girder section [cm^4]
W	=	section modulus of the connected section [cm^3]

2. Determination of stresses

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 calculated as follows:

$$\sigma = \tau = \frac{P}{\sum a \cdot \ell} \quad [N/mm^2]$$

Joint as shown in Fig. 19.23:

— Shear stresses in frontal fillet welds as shown in Fig. 19.23, defined as:

$$\tau_{\perp} = \frac{P_1}{2 \cdot a(\ell_1 + \ell_2)} \quad [N/mm^2]$$

$$\tau_{||} = \frac{P_2}{2 \cdot a(\ell_1 + \ell_2)} \pm \frac{P_2 \cdot e}{2 \cdot a \cdot F_t} \quad [N/mm^2]$$

F_t = area, defined as:

$$= (\ell_1 + a)(\ell_2 + a) \quad [mm^2]$$

— Shear stresses in flank fillet welds as shown in Fig. 19.23, defined as :

$$\tau_{\perp} = \frac{P_2}{2 \cdot a(\ell_1 + \ell_2)} \quad [N/mm^2]$$

$$\tau_{||} = \frac{P_1}{2 \cdot a(\ell_1 + \ell_2)} \pm \frac{P_2 \cdot e}{2 \cdot a \cdot F_t} \quad [N/mm^2]$$

ℓ_1, ℓ_2 = length as defined in Fig. 19.23 [mm]

e = distances as defined in Fig. 19.23 and Fig. 19.24 [mm]

— Equivalent stress for frontal and flank fillet welds:

$$\sigma_v = \sqrt{\tau_{\perp}^2 + \tau_{||}^2} \quad [N/mm^2]$$

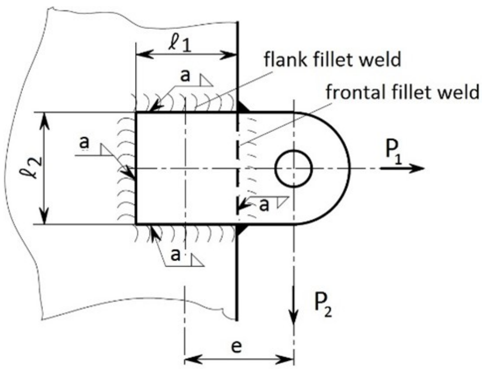


Fig. 19.23 Weld joint of an overlapped lifting eye

— Shear stresses [N/mm²] in joint as shown in Fig. 19.24, defined as:

$$\tau_{\perp} = \frac{P_2}{2 \cdot \ell \cdot a} + \frac{3 \cdot P_1 \cdot e}{\ell^2 \cdot a} \quad [N/mm^2]$$

$$\tau_{||} = \frac{P_1}{2 \cdot \ell \cdot a} \quad [N/mm^2]$$

— Equivalent stress :

$$\sigma_v = \sqrt{\tau_{\perp}^2 + \tau_{||}^2} \quad [N/mm^2]$$

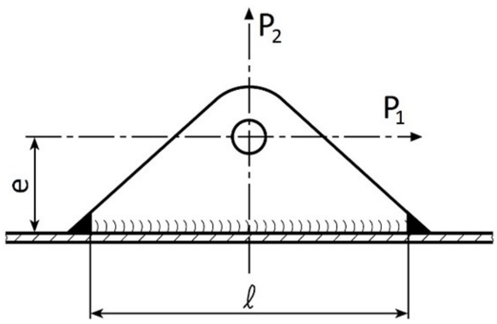


Fig. 19.24 Weld joint of a vertically mounted lifting eye

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):

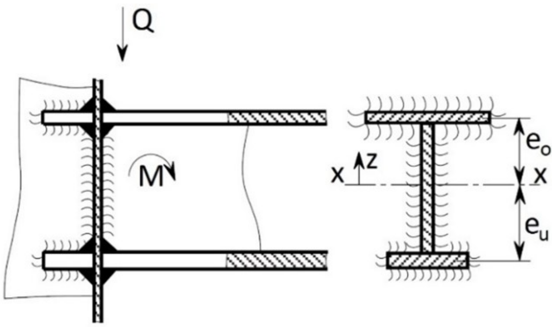


Fig. 19.25 Fixing point of cantilever beam

1) Normal stress due to bending moment:

$$\sigma_{\perp(z)} = \frac{M}{I_s} \cdot z \quad [N/mm^2]$$

$$\sigma_{\perp,max} = \frac{M}{I_s} \cdot e_u \quad [N/mm^2], \quad \text{if} \quad e_u > e_0$$

$$= \frac{M}{I_s} \cdot e_0 \quad [N/mm^2], \quad \text{if} \quad e_u < e_0$$

2) Shear stress due to shear force:

$$\tau_{||(z)} = \frac{Q \cdot S_S(Z)}{10 \cdot I_s \cdot \sum a} \quad [N/mm^2]$$

$$\tau_{||,max} = \frac{Q \cdot S_{Smax}}{20 \cdot I_s \cdot a} \quad [N/mm^2]$$

I_S = moment of inertia of the welded joint related to the x-axis [cm^4]

$S_{S(z)}$ = the first moment of the connected weld section at the point under consideration[cm^3]

z = distance from the neutral axis [cm].

3) Equivalent stress :

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 $\sigma_V = \sqrt{\sigma_\perp^2 + \tau_{||}^2}$ exceed the permitted limits given in 2.8 at any given point. The equivalent stress σ_V should always be calculated at the web-flange connection.

2.3 Fillet welded joints stressed by bending and torsional moments and shear forces

Regarding the normal and shear stresses resulting from bending, see 2.2. Torsional stresses τ_T resulting from the torsional moment MT are to be calculated:

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

M_T = torsional moment [Nm]

A_m = sectional area [mm^2] enclosed by the weld seam

The equivalent stress composed of all three components (bending, shear and torsion) is calculated by means of the following formulae:

$$\sigma_V = \sqrt{\sigma_\perp^2 + \tau_{||}^2 + \tau_T^2} \quad [N/mm^2]$$ where $\tau_{||}$ and τ_T have not the same direction

$$\sigma_V = \sqrt{\sigma_\perp^2 + (\tau_{||} + \tau_T)^2} \quad [N/mm^2]$$ where $\tau_{||}$ and τ_T have the same direction

2.4 Continuous fillet welded 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 to be considered. In the case of continuous double fillet weld connections the shear stress $\tau_{||}$ is to be calculated as follows:

$$\tau_{||} = \frac{Q \cdot S}{20 \cdot I \cdot a} \quad [N/mm^2]$$

The fillet weld thickness required a_{req} is:

$$a_{req} = \frac{Q \cdot S}{20 \cdot I \cdot \tau_{perm}} \quad [mm]$$

2.5 Intermittent fillet weld joints between web and flange of bending girders

In the case of intermittent fillet weld joints the shear stress $\tau_{||}$ and the required fillet weld thickness a_{req} are to be determined by the following formulae:

$$\tau_{||} = \frac{Q \cdot S \cdot \alpha}{10 \cdot I \cdot a} \left[\frac{b}{\ell}\right] \quad [N/mm^2]$$

$$a_{req} = \frac{Q \cdot S \cdot 1,1}{20 \cdot I \cdot \tau_{perm}} \cdot \left[\frac{b}{\ell}\right] \quad [mm]$$

b = pitch of intermittent fillets welds [mm]

α = 1,1 stress concentration factor which takes into account increases in shear stress at the ends of the fillet weld seam "ℓ".

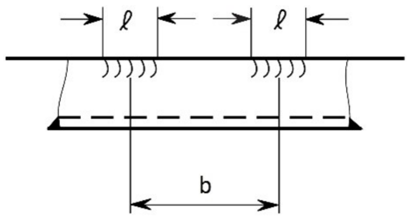


Fig. 19.26 Intermittent fillet weld joint

2.6 Fillet weld connections on overlapped profile joints

2.6.1 Profiles joined by means of two flank fillet welds connections on overlapped profile joints the shear stresses $\tau_{||}$ and $\tau_{\perp}$ are to be determined by the following formulae (see Fig. 19.27):

$$\tau_{\perp} = \frac{Q}{2 \cdot a \cdot d} \quad [N/mm^2]$$

$$\tau_{||} = \frac{M \cdot 10^3}{2 \cdot a \cdot c \cdot d} \quad [N/mm^2]$$

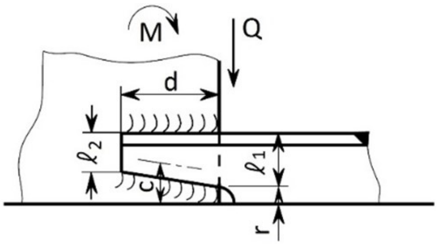


Fig. 19.27 Profile joined by means of two flank fillet joints

The equivalent stress is :

$$\sigma_v = \sqrt{\tau_{\perp}^2 + \tau_{||}^2} \quad [N/mm^2]$$

c, d, ℓ_1, ℓ_2, r [mm] see Fig. 19.27

$$c = r + \frac{3 \cdot \ell_1 - \ell_2}{4} \quad [mm]$$

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 :

$$a_{req} = \frac{W.10^3}{1,5 \cdot c \cdot d} \quad [mm]$$

2.6.2 Profiles joined by means of two flank and two frontal fillet welds (all round welding as shown in Fig. 19.28), the shear stress $\tau_{||}$ and $\tau_{\perp}$ are to be determined by the following formulae:

$$\tau_{\perp} = \frac{Q}{a \cdot (2 \cdot d + \ell_1 + \ell_2)} \quad [N/mm^2]$$

$$\tau_{||} = \frac{M.10^3}{a \cdot c(2 \cdot d + \ell_1 + \ell_2)} \quad [N/mm^2]$$

The equivalent stress is :

$$\sigma_v = \sqrt{\tau_{\perp}^2 + \tau_{||}^2} \quad [N/mm^2]$$

The required fillet weld thickness a_{req} is :

$$a_{req} = \frac{W \cdot 10^3}{1,5 \cdot c \cdot d \left[1 + \frac{\ell_1 + \ell_2}{2.d}\right]} \text{ [mm]}$$

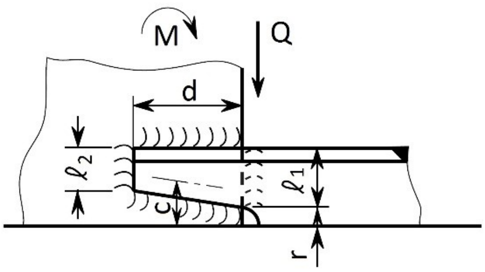


Fig. 19.28 - Profile joined by means of two flank and two frontal fillet welds (all round welding)

2.7 Bracket joints

Where profiles are joined to brackets as shown in Fig. 19.29, the average shear stress is :

$$\tau = \frac{3 \cdot M \cdot 10^3}{4 \cdot a \cdot d^2} + \frac{Q}{2 \cdot a \cdot d} \quad [N/mm^2]$$

d = length of overlap [mm]

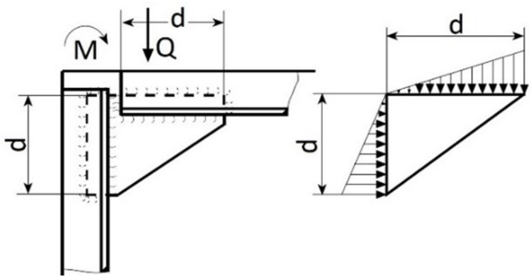


Fig. 19.29 Bracket joint with idealized stress distribution resulting from moment M and shear force Q

The required fillet weld thickness is to be calculated from the section modulus of the profile as follows:

$$a_{req} = \frac{1000 \cdot W}{d^2} \quad [mm]$$

(The shear force Q has been neglected.)

2.8 Permissible stresses

The permissible stresses for various materials under mainly static loading conditions are given in Table 19.3. 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 shall be increased accordingly (see also B.3.3.2).

Table 19.3 Permissible stresses in fillet weld seams

Material		R_{eH} or $Rp_{0,2}$ [N/mm^2]	Permissible stresses for: equivalent stress (σ_v), shear stress(τ_{perm}) [N/mm^2]
normal strength hull structural steel	Kl - A/B/D/E	235	115
higher strength hull structural steel	Kl - A/D/E/F 32	315	145
	Kl - A/D/E/F 36	355	160
	Kl - 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	
	1.4429/316 LN	295	130
	1.4439/317 LN	285	
	1.4462/318 LN	480	205
aluminium alloys	Al Mg 3/5754	80[1]	35
	Al Mg 4,5 Mn 0,7/5083	125[1]	56
	Al Mg Si/6060	65[2]	30
	Al Mg Si Mn/6082	110[2]	45

1) Plates, soft condition

2) Sections, cold hardened

Table 19.4 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	0,30	
plating in way of bottom strengthening forward 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	
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 sheerstrakes (see also Section 7, A.2)	0,50	
Frames, stiffeners, beams etc.		
General	0,15	x
in peak tanks	0,30	x
bilge keel to shell	0,15	
Transverse, 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.1.7)	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.

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Section 20 Fatigue Strength

Preamble

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

1. Definitions

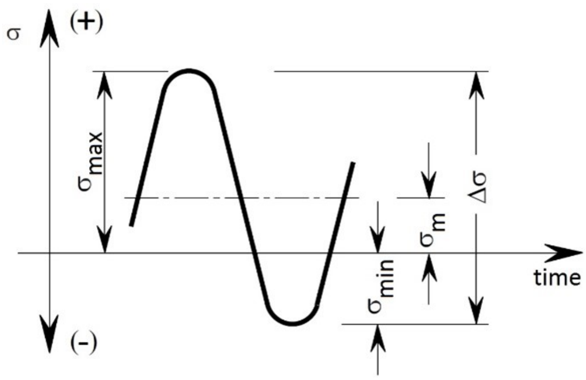


Fig. 20.1 Dynamic Load cycle

$\Delta\sigma$ = applied stress range [N/mm^2], see also Fig. 20.1, defined as:

= $\sigma_{max} - \sigma_{min}$

σ_{max} = maximum upper stress of a stress cycle [N/mm^2]

σ_{min} = maximum lower stress of a stress cycle [N/mm^2]

σ_m = mean stress [N/mm^2], define as:

= $(\sigma_{max} + \sigma_{min})/2$

$\Delta\sigma_{max}$ = applied peak stress range within a stress range spectrum [N/mm^2]

$\Delta\sigma_p$ = permissible stress range [N/mm^2]

$\Delta\tau$ = corresponding range for shear stress [N/mm^2]

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 number 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.

2. Scope

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).

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 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:

$$\Delta\sigma_{max} \le 2{,}5 \cdot \Delta\sigma_R \quad [\text{N/mm}^2]$$

— sum of the peak stress ranges due to seaway-induced dynamic loads and due to changes of draught or loading condition, respectively:

$$\Delta\sigma_{max} \le 4{,}0 \cdot \Delta\sigma_R \quad [\text{N/mm}^2]$$

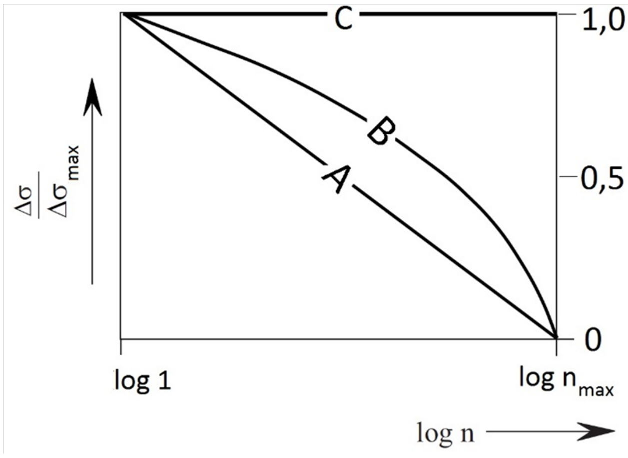
Note

For welded structures of FAT class 80 or higher a fatigue strength analysis is required only in case of extraordinary high dynamic stresses.

2.3 The rules are applicable to constructions made of normal and higher-strength hull structural steels according to Section 2, B, 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 minimum nominal upper yield point. In special cases the fatigue strength analysis may be performed by considering the local elasto-plastic stresses.

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 $\Delta\sigma$ according to 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 $n_{max} = 5 \cdot 10^7$. 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, B and 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 9, B.3.5), in longitudinal and transverse structures due to torsional deformations (see for this also Section 5, F.1.1) as well as additional stresses due to the application of non-symmetrical sections, have to be considered, see Section 3, L.

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 superpositioning of the largest stress ranges (e.g. in accordance with the "rainflow counting method"). If nothing else is specified, 10^3 load cycles have to be assumed for changes in loading condition or draught.

Table 20.1 Maximum and minimum value for seaway-induced cyclic loads

Load		Maximum load	Minimum load
Vertical longitudinal bending moments (Section 5, B) [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, B)		$M_{SW} + M_{ST} + f_Q \cdot (0{,}6 \cdot M_{WVhog} + M_{WH})$	$M_{SW} + M_{ST} + f_Q \cdot (0{,}6 \cdot M_{WVhog} - M_{WH})$
Vertical longitudinal bending moments, horizontal wave bending moments and torsional moments [1] (Section 5, B)		$f_F \cdot [M_{SW} + M_{ST} + f_Q \cdot [(0{,}43 + C) \cdot M_{WVhog} + M_{WH} + M_{WT}]]$	$f_F \cdot [M_{SW} + M_{ST} + f_Q \cdot [(0{,}43 + C \cdot (0{,}5 - C)) \cdot M_{WVhog} + C \cdot (0{,}43 + C) \cdot M_{WVsag} - M_{WH} - M_{WT}]]$
		$C = \left(\frac{x}{L} - 0{,}5\right)^2$	
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**		$10\,(\mathbf{T} - z) + p_0 \cdot c_F \left[1 + \frac{z}{\mathbf{T}}\right]$	$10(\mathbf{T} - z) - p_0 \cdot c_F \left[1 + \frac{z}{\mathbf{T}}\right]$ but ≥ 0
above **T**		$p_0 \cdot c_F \frac{20}{10 + z - \mathbf{T}}$	0
Loads on ship's bottom [2], [4] (Section 4, B.3)		$10 \cdot \mathbf{T} + p_0 \cdot c_F$	$10 \cdot \mathbf{T} - p_0 \cdot c_F$
Liquid pressure in completely filled tanks (Section 4, D.1)	upright [4]	$9{,}81 \cdot h_1 \cdot \rho(1 + a_v) + 100 \cdot p_v$	$9{,}81 \cdot h_1 \cdot \rho(1 - a_v) + 100 \cdot p_v$
	heeled	$9{,}81 \cdot \rho[h_1 \cdot \cos\varphi + (0{,}3 \cdot b + y) \sin\varphi] + 100 \cdot p_v$	$9{,}81 \cdot \rho[h_1 \cdot \cos\varphi + (0{,}3 \cdot b - y) \sin\varphi] + 100 \cdot p_v$; but $\geq 100 \cdot p_v$
Loads due to cargo [5] (Section 4, C.1 and E.1)		$p\,(1 + a_v)$ $p \cdot a_x \cdot 0{,}7$ $p \cdot a_y \cdot 0{,}7$	$p\,(1 - a_v)$ $- p \cdot a_x \cdot 0{,}7$ $- p \cdot a_y \cdot 0{,}7$
Loads due to friction forces [3] (Section 17, B.5.5.5)		P_H	$- P_H$
Loads due to rudder forces [3] (Section 14, B)		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.1.

[2] With probability factor f for calculation 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 friction 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 super positioning of sea and tank pressures within $0{,}2 < x/\mathbf{L} \leq 0{,}7$: Where appropriate, proof is to be furnished for $\mathbf{T}_{min}$.

[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.

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 Fig. 3.32 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.

3. Quality requirements (fabrication tolerances)

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 Rules for Welding (Pt.1, Vol.VI) Annex 6.

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 3.1 may be required, e.g. stricter tolerances or improved weld shapes, see also B.3.2.4.

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)
	=	1,30	butt welds (corresponding type A3–A10)
	=	1,45	cruciform joints (corresponding type D1–D5)
	=	1,25	T-joints (corresponding type D1 – D3)
	=	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

1. Definition of nominal stress and detail Classification for welded joints

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.

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 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 BKI case by case.

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 the neighbourhood of the detail, have also to be incorporated into the nominal stress.

1.4 In the case of combined normal and shear stress the relevant stress range may be taken as the range of the principal stress at the potential crack location which act approximately perpendicular (within ± 45°) to the crack front as shown in Table 20.3 as long as it is larger than the individual stress components.

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.

2. Permissible stress range for standard stress range spectra or calculation of the cumulative damage ratio

2.1 For standard stress range spectra according to Fig. 20.2, the permissible peak stress range can be calculated as follows:

$$\Delta\sigma_R = f_n \cdot \Delta\sigma_{Rc}$$

$\Delta\sigma_{Rc}$ = FAT class or fatigue strength reference value, respectively, corrected according to 3.2

f_n = factor as given in Table 20.2.

The peak stress range of the spectrum shall not exceed the permissible value, i.e.

$$\Delta\sigma_{max} \le \Delta\sigma_p$$

Table 20.2 Factor f_n for the determination of the permissible range for standard stress range spectra

stress range spectrum	Welded Joints					Plates Edges														
	(m_0 = 3)					type E1 (m_0 = 5)					type E2, E2a (m_0 = 4)					type E3 (m_0 = 3,5)				
	n_{max} =					n_{max} =					n_{max} =					n_{max} =				
	10^3	10^5	5×10^7	10^8	3×10^8	10^3	10^5	5×10^7	10^8	3×10^8	10^3	10^5	5×10^7	10^8	3×10^8	10^3	10^5	5×10^7	10^8	3×10^8
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	(10,3) (11,2)[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_o see 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:

$$\text{Log } f_n = \log f_{n1} + \log(n_{max}/n_{max1}) \cdot \frac{\log(f_{n2}/f_{n1})}{\log(n_{max2}/n_{max1})}$$

For the stress spectrum C intermediate values may be calculated according to 3.1.2 by taking N = n_{max} and $f_n = \frac{\Delta\sigma}{\Delta\sigma_R}$

1) f_n for non-corrosive environment, see also 3.1.4.

2) for $\Delta\sigma_R$ = 100 [N/mm^2]

3) for $\Delta\sigma_R$ = 140 [N/mm^2]

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:

$$D = \sum_{i=1}^{I} \left(\frac{N_1}{N_i}\right)$$

I = total number of blocks of the stress range spectrum for summation (normally I ≥ 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 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 sum 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.

3. Design S-N Curves

3.1 Description of the design S-N curves

3.1.1 The design S-N curves for the calculation of the cumulative damage ratio according to 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 curve (FAT classess) 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 3.2.

3.1.2 The S-N curves represent section wise linear relationships between log ($\Delta\sigma$) and log (N):

log (N) = 7,0 + m · Q

Q = $\log(\Delta\sigma_R/\Delta\sigma) - 0{,}69897/m_0$

m = slope exponent of S-N curve, see 3.1.3 and 3.1.4

m_0 = inverse slope in the range N ≤ 1 · 10^7

= 3 for welded joints

= 3,5 $\sim$ 5 for free plate edges (see Fig. 20.4)

The S-N curve for FAT class 160 forms the upper limit also 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.

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 ≤ 10^7 (Q ≤ 0)

= 2 · m_0 - 1 for N > 10^7 (Q > 0)

3.1.4 For stress ranges of constant magnitude (stress range spectrum C) in non-corrosive environment from N = 1 · 10^7 the S-N curves of type "O" in Fig. 20.3 and 20.4 can be used, thus:

m = m_0 for N ≤ 10^7 (Q ≤ 0)

= 22 for N > 10^7 (Q > 0)

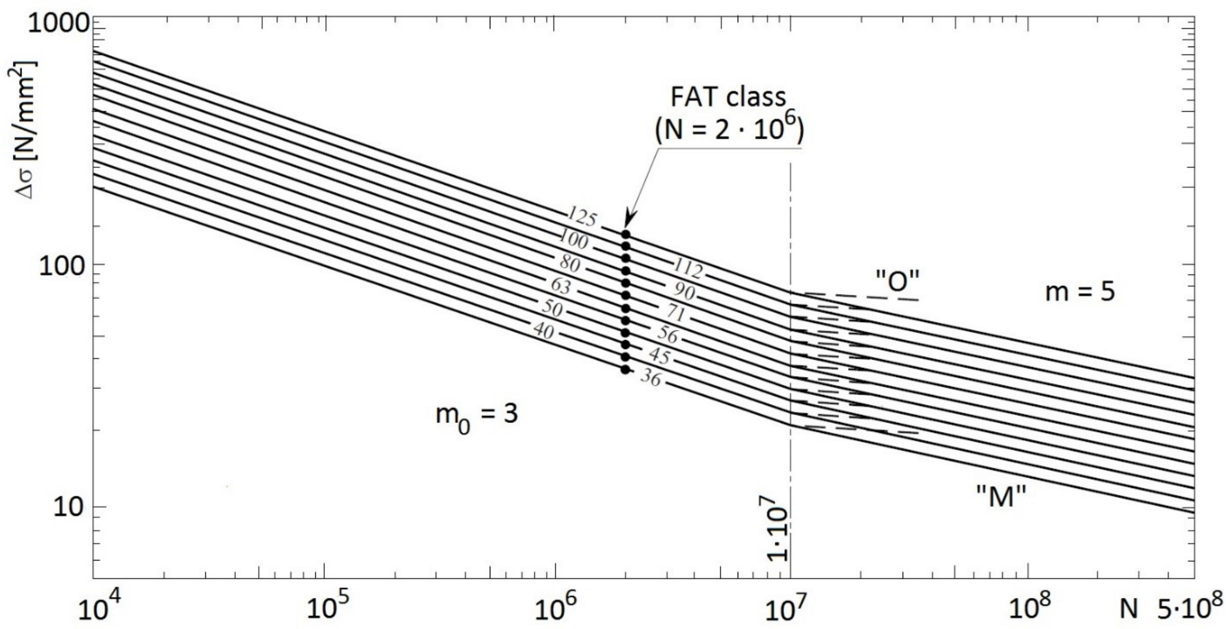


Fig. 20.3 S-N Curves for welded joint steel

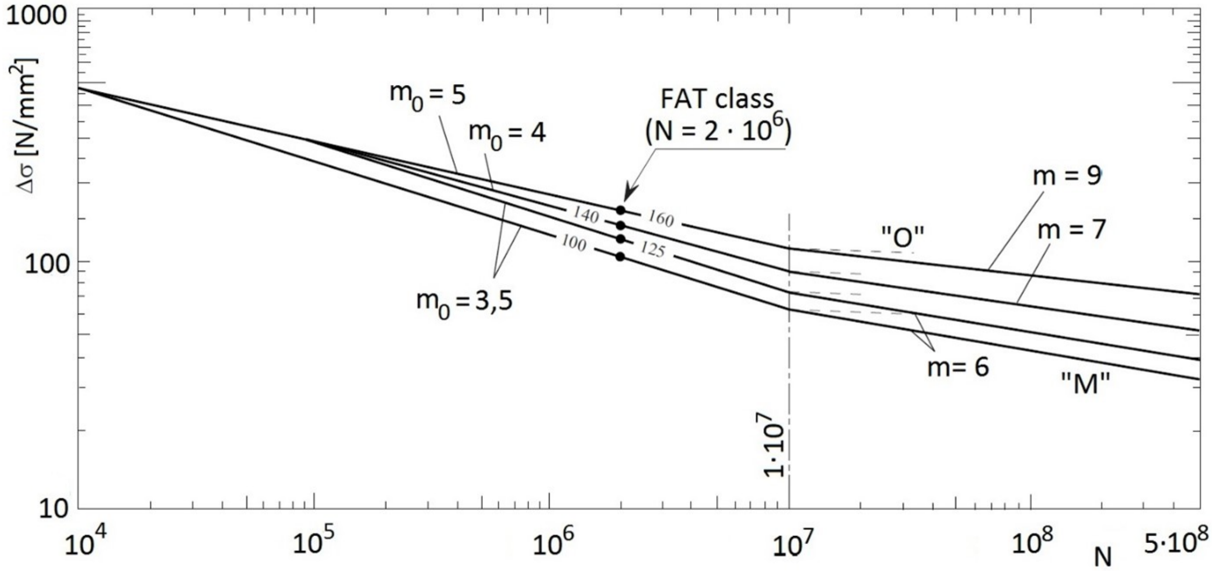


Fig. 20.4 S-N Curves for notch at plate edge steel plate

3.2 Correction of the reference value of the design S-N curve

3.2.1 A correction of the reference value of the S-N curve (or 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 = factor according to 3.2.2 - 3.2.6

For the description of the corrected design S-N curve, the formulae given in 3.1.2 may be used by replacing $\Delta\sigma_R$ by $\Delta\sigma_{Rc}$.

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 point is accounted for as follows:

$$f_m = 1 + \frac{R_{eH} - 235}{1200}$$

For aluminium alloys, f_m = 1,0 generally applies.

3.2.3 Effect of mean stress (f_R)

The correction factor f_R is to be determined by the following formulae:

— in the range of tensile pulsating stresses, i.e.

$$f_R = 1{,}0 \qquad \text{for} \qquad \sigma_m \geq \frac{\Delta\sigma_{max}}{2}$$

— in the range or alternating stresses, i.e.

$$f_R = 1 + c\left[1 - \frac{2.\sigma_m}{\Delta\sigma_{max}}\right] \qquad \text{for} \qquad -\frac{\Delta\sigma_{max}}{2} \leq \sigma_m \leq \frac{\Delta\sigma_{max}}{2}$$

— in the range of compressive pulsating stresses, i.e.

$$f_R = 1 + 2 \cdot c \qquad \text{for} \qquad \sigma_m \leq -\frac{\Delta\sigma_{max}}{2}$$

c	=	0	for welded joints subjected to constant stress cycles (stress range spectrum C)
	=	0,15	welded joints subjected to variable stress cycles (corresponding to stress range spectrum A or B)
	=	0,3	for unwelded base material

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 shall 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:

- disk grinder $f_w = 1{,}15$
- burr grinder $f_w = 1{,}30$

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.

3.2.5 Influence of importance of structural element (fi)

In general the following applies:

$$f_i = 1{,}0$$

For secondary structural elements failure of which may cause failure of larger structural areas, the correction factor f_i is to be taken as:

$$f_i = 0{,}9$$

For notches at plate edges in general the following correction factor is to be taken which takes into account the radius of rounding:

$$f_i = 0{,}9 + 5/r \leq 1{,}0$$

r	=	notch radius [mm]; for elliptical roundings the mean value of the two main half axes may be taken.

3.2.6 Plate thickness effect (ft)

In order to account for the plate thickness effect, application of the reduction factor f_t is required by BKI for butt welds oriented transversely to the direction of applied stress for plate thicknesses t > 25 mm.

$$f_t = \left(\frac{25}{t}\right)^{n-k} \leq 1{,}0$$

n = exponent for additional notch effect at weld toe, defined as:
= 0,20 as welded
= 0,10 toe-ground

k = exponent for misalignment (see A.3.3), defined as:
= 0,10 for butt welds with k_m = 1,30
= 0,05 for butt welds with k_m = 1,15

k_m = factor according to A.3.3

For all other weld connections consideration of the thickness effect may be required subject to agreement with BKI.

C. Fatigue Strength Analysis for Welded Joints Based on Local Stresses

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.

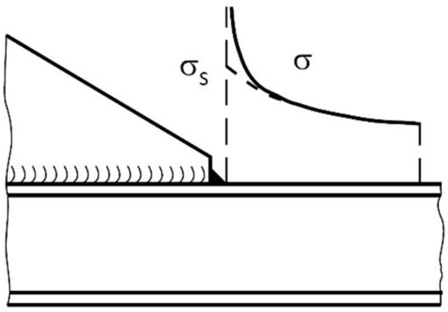


Fig. 20.5 Structural stress

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 × 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.

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 type A1 - A6 and 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. types 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.

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:

$$f_s = \frac{1}{k'_m - \frac{\Delta\sigma_{s,b}}{\Delta\sigma_{s,max}}(k'_m - 1)}$$

$\Delta\sigma_{s,max}$ = 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 – 0,05

k_m = stress increase factor due to misalignment under axial loading, at least km according A.3.3

The permissible stress range or cumulative damage ratio, respectively, has to be determined according to B.2.

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 throat 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

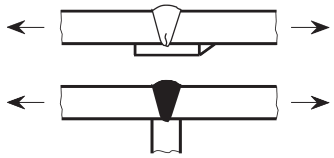
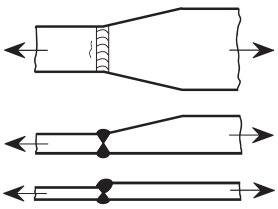
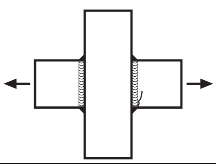
A. Butt welds, transverse loaded				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
A1		Transverse butt weld ground flush to plate, 100% NDT (Non Destructive Testing)	11	45
A2		Transverse butt weld made in the shop in the flat position, max. weld reinforcement 1 mm + 0,1 x weld width, smooth transitions, NDT	90	36
A3		Transverse butt welds 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 Butt weld, welded on ceramic backing, root crack	71 80	25 28
A5		Transverse butt welds between plates of different widths or thickness, NDT as for joint type No. 2, slope 1 : 5 as for joint type No. 2, slope 1 : 3 as for joint type No. 2, slope 1 : 2 as for joint type No.3, slope 1 : 5 as for joint type No.3, slope 1 : 3 as for joint type No.3, slope 1 : 2 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.	 90 80 71 80 71 63	 32 28 25 25 22 20
A6		Transverse butt welds welded from one side without backing bar, full penetration root: – controlled by NDT – not controlled NDT For tubular profiles $\Delta\sigma_R$ may be lifted to the next higher detail category Laser (t ≤ 8,0 mm) and laser hybrid (t ≤ 12 mm) butt welds	71 36 80	28 12 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	12
A8		Full penetration butt weld at crossing flanges Welded from both sides.	50	18

Table 20.3 Catalogue of Details *(continued)*

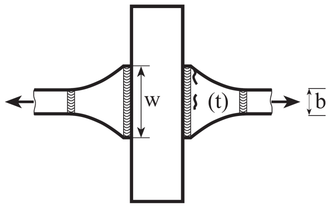
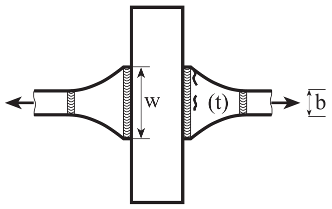
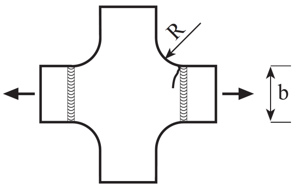
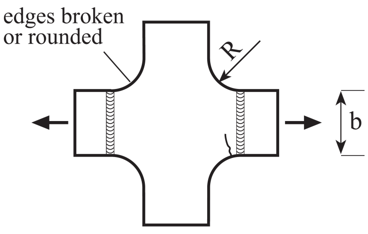
A. Butt welds, transverse loaded				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
A9		Full penetration butt weld at crossing flanges Welded from both sides, Cutting edges in the quality 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 $\leq$ 1,0 mm + 0,1 $\times$ 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

Table 20.3 Catalogue of Details *(continued)*

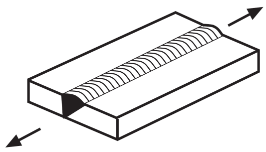
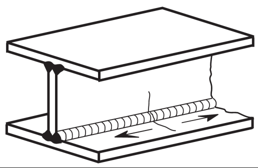
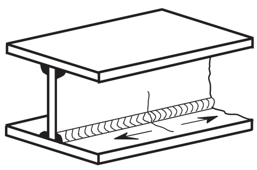
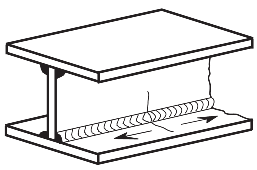
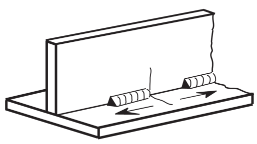
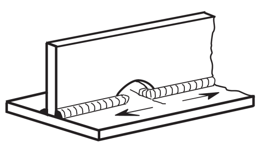
B. Longitudinal load-carrying weld				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
B1		Longitudinal butt welds both sides ground flush parallel to load direction without start/stop positions, NDT with start/stop positions	125 125 90	50 50 36
B2		Continuous automatic longitudinal fully penetrated K-butt weld 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 fillet at weld ends) If cut outs 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 is recommended.*	71 63	28 25

Table 20.3 Catalogue of Details *(continued)*

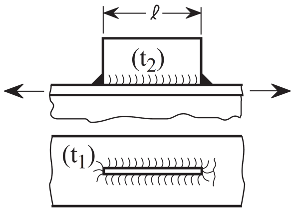
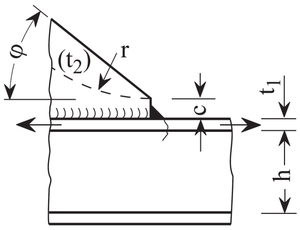
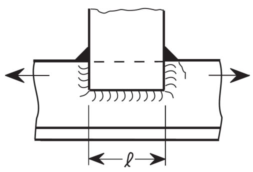
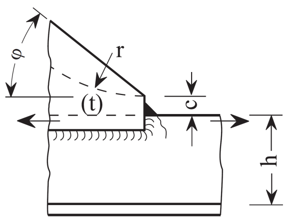
C. Non-load-carrying attachments				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
C1		Longitudinal gusset welded on beam flange, bulb or plate : $\ell \le 50$ mm 50 mm < $\ell \le 150$ mm 150 mm < $\ell \le 300$ mm ℓ > 300 mm For $t_2 \le 0{,}5\ t_1$, $\Delta\sigma_R$ may be increased by one category, 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 category.	 80 71 63 56	 28 25 20 18
C2		Gusset with smooth transition (sniped end or radius) welded on beam flange, bulb or plate; $c \le 2\ t_2$, max 25 mm $r \ge 0{,}5 \times h$ $r < 0{,}5 \times h$ or $j \le 20°$ $\varphi > 20°$ see joint type C1 For $t_2 \le 0{,}5\ t_1$, $\Delta\sigma_R$ may be increased by one category; not valid for bulb profiles. When welding close to edges of plates or profiles (distance less than 10 mm), $\Delta\sigma_R$ is to be decreased by one category.	 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 ℓ > 150 mm, $\Delta\sigma_R$ has to be decreased by one category, while for $\ell \ge 50$ mm, $\Delta\sigma_R$ may be increased by one category. If the component is subjected to bending, $\Delta\sigma_R$ has to be reduced by one category.	 56 56 50	 20 20 18
C4		Fillet welded lap joint with smooth transition (sniped end with $j \le 20°$ or radius) welded to longitudinally stressed component. – flat bar – to bulb section – to angle section $c \le 2 \cdot t$, max. 25 mm	 56 56 50	 20 20 18

Table 20.3 Catalogue of Details *(continued)*

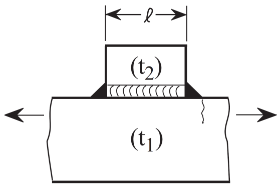
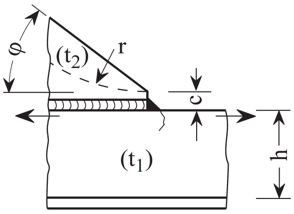
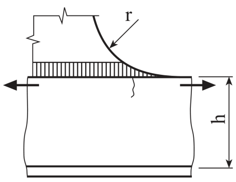
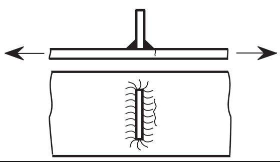
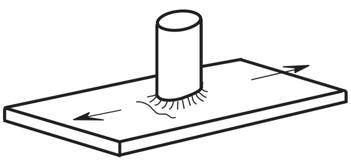
C. Non-load-carrying attachments				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
C5		Longitudinal flat side gusset welded on plate or beam flange edge $\ell \le 50$ mm 50 mm < $\ell \le 150$ mm 150 mm < $\ell \le 300$ mm $\ell > 300$ mm For $t_2 \le 0{,}7\ t_1$, $\Delta\sigma_R$ may be increased by one category, 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 category.	 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 ≤ 2 t_2, max. 25 mm r ≥ 0,5 × h r < 0,5 × h or j ≤ 20° φ > 20° see joint type C5 For $t_2 \le 0{,}7\ t_1$, $\Delta\sigma_R$ may be increased by one category.	 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 ≥ 150 mm 1/6 < r/h < 1/3 r/h < 1/6 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.	 90 71 50	 36 28 22
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

Table 20.3 Catalogue of Details *(continued)*

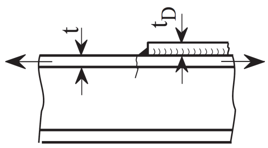
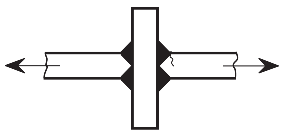
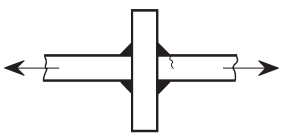
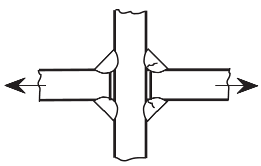
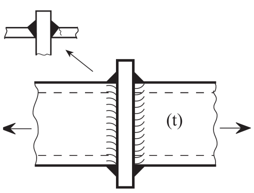
C. Non-load-carrying attachments				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
C9		End of long doubling plate on beam, welded ends (based on stress range in flange at weld toe) $t_D \le 0{,}8 \cdot t$ $0{,}8 \cdot t < t_D \le 1{,}5 \cdot t$ $t_D > 1{,}5 \cdot t$ The following features increase $\Delta\sigma_R$ by one category accordingly: - reinforced ends according to Fig. 19.4 - weld toe angle ≤ 30° - length of doubling ≤ 300 mm For length of doubling ≤ 150 mm, $\Delta\sigma_R$ may be increased by two categories.	56 50 45	20 18 16
D. Cruciform joints and T-joints				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
D1		Cruciform or tee-joint K-butt welds with full penetration or with defined incomplete root penetration according to Fig. 19.4. cruciform joint tee-joint	71 80	25 28
D2		Cruciform or tee-joint with transverse fillet weld, toe failure (root failure particularly for throat thickness a < 0,7 · t , see joint type D3) cruciform joint tee-joint	63 71	22 25
D3		Welded metal in transverse load-carrying fillet weld at cruciform or tee - joint, root failure (based on stress range in weld throat). See also joint type No. D2 a ≥ 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 ≤ 8,0 mm, $\Delta\sigma_R$ has to be decreased by one category.	56 50	20 18

Table 20.3 Catalogue of Details *(continued)*

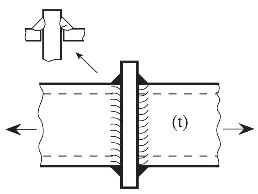
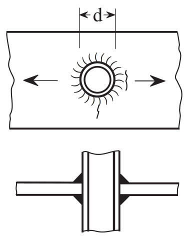
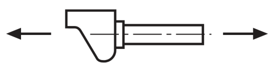
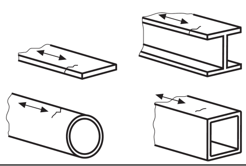
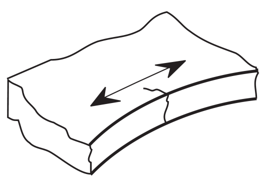
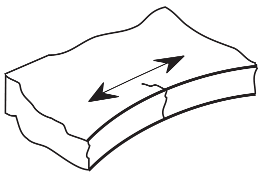
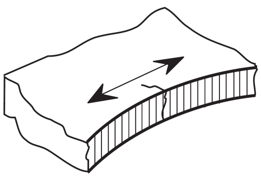
D. Cruciform joints and T-joints				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
D5		Fillet weld at the connection between a hollow section (e.g. pillar) and a plate, for tubular section for rectangular hollow section The stress is to be related to the weld sectional area. For t ≤ 8,0 mm, $\Delta\sigma_R$ has to be decreased by one category.	45 40	16 14
D6		Continuous butt or fillet weld connecting a pipe penetrating through a plate d ≤ 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
E. Unwelded base material				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
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)	-

Table 20.3 Catalogue of Details *(continued)*

E. Unwelded base material				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
E2		Plate edge sheared or machined cut by any thermal process with surface free of cracks and notches, corners broken or rounded. Stress increase due to geometry of cut-outs to be considered[1)].	140 (m_0 = 5)	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 cutouts to be considered.	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:

$$\Delta\sigma_{max} = K_t \cdot \Delta\sigma_N$$

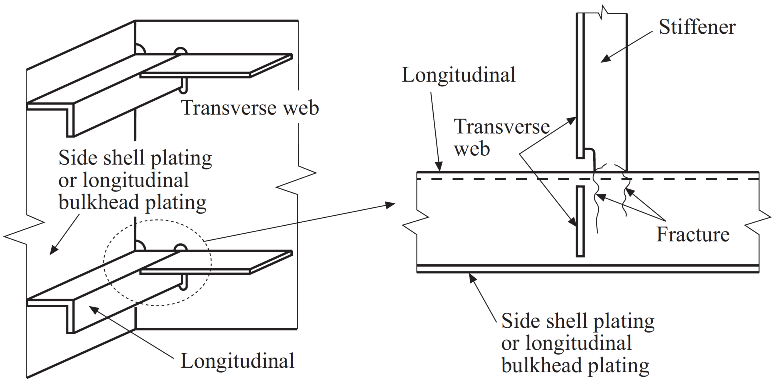
K_t = Notch factor according to Section 3, J

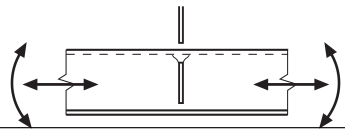
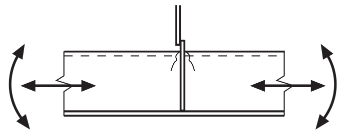
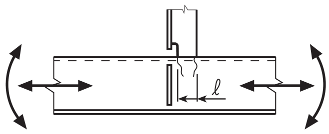
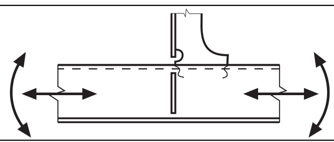
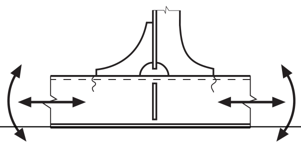
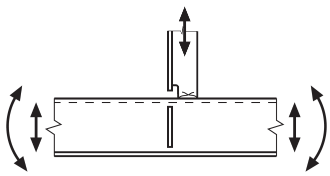
$\Delta\sigma_N$ = Nominal stress range related to net section

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 Location being at risk for cracks	**Description of joint**	**FAT class $\Delta\sigma_R$ steel**			
	Non-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) For predominant longitudinal load only.	71	71	71	71
 2	With heel stiffener Direct ℓ ≤ 150 connection ℓ > 150 Overlapping ℓ ≤ 150 connection ℓ > 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 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 category, when longitudinal loads only

Table 20.5 Examples of details

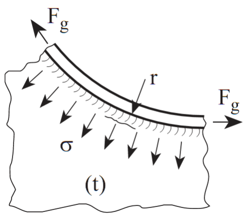
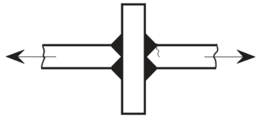
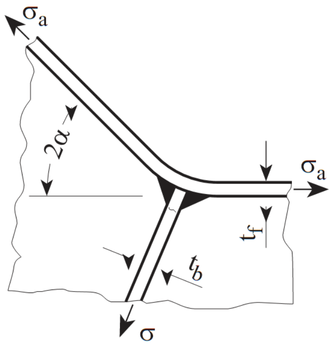
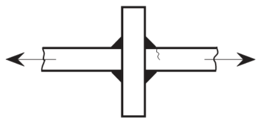
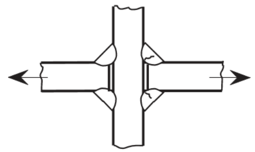
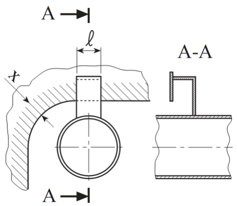
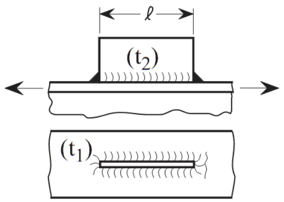
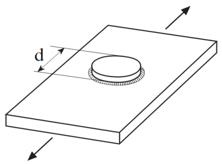
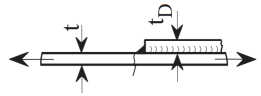
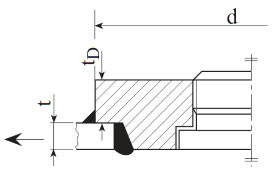
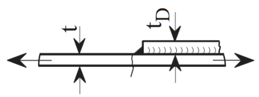
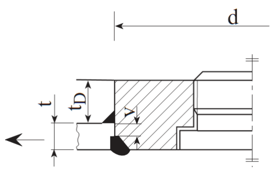
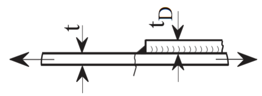
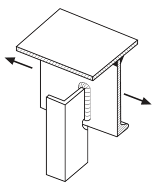
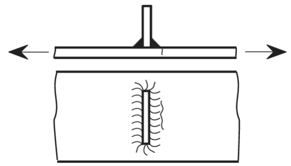
Structure or equipment detail	Description of structure or equipment detail	Type No.	Join configuration showing mode of fatigue cracking and stress σ considered	Description of joint	FAT class $\Delta\sigma_R$ steel
	Unstiffened flange to web joint, to be assessed according to type D1, D2 or D3, depending 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 principal 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 Fig. 19.4. 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 $\sigma = \sigma_a \frac{t_f}{t_b} 2\sin\alpha$	D2		Cruciform or tee-joint with transverse fillet weld, toe failure (root failure particularly 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 weld 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		ℓ ≤ 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] x 100 mm ≤ r ≤ 400 mm In case of an elliptical rounding the mean value of both semiaxes to be applied	71

Table 20.5 Examples of details *(continued)*

Structure or equipment detail	Description of structure or equipment detail	Type No.	Join 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		$t_D \le 0{,}8t$ $0{,}8t < t_D \le 1{,}5t$ $t_D > 1{,}5t$	71 63 56
	Drain plud with full penetration d ≤ 150 mm Assesment corresponding to doubling plate	C9		$t_D \le 0{,}8t$ $0{,}8t < t_D \le 1{,}5t$ $t_D > 1{,}5t$ for d > 150 mm $\Delta\sigma_R$ has to be decreased by one class	71 63 56
	Drain plug with partial penetration butt weld abnd a defined gap d ≤ 150 mm For v < 0,4t or v < 0,4t_D	C9		$0{,}2t < t_D \le 0{,}8t$ $0{,}8t < t_D \le 1{,}5t$ $1{,}5t < t_D < 2{,}0t$ for d > 150 mm $\Delta\sigma_R$ has to be decreased by one class	50 45 40
	For v ≥ 0,4t or v ≥ 0,4t_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 circumferental welded holders For stiffener 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

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Section 21 Hull Outfit

A. General

1. References

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.6

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

1. General

Spaces, which are to be accessible for the service of the ship, hold spaces and accommodation spaces are to be gastight against each other.

2. Partition bulkheads between engine and boiler rooms

2.1 General

2.1.1 Boiler rooms generally are to be separated from adjacent engine rooms by bulkheads. Unless these bulkheads are watertight or tank bulkheads according to Section 11 or 12, the scantlings according to 2.2 are sufficient.

2.1.2 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.

2.1.3 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 Rules for Machinery Installations (Pt.1, Vol.III) are complied with.

2.2 Scantlings

2.2.1 The thickness of watertight parts of the partition bulkheads is not to be less than 6,0 mm. The thickness or the remaining parts may be 5,0 mm.

2.2.2 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.

2.2.3 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 of stiffener [m].

Where the stiffener spacing deviates from 900 mm, the section modulus is to be corrected in direct proportion.

3. Moveable grain bulkheads

3.1 General

Movable grain bulkheads may consist of moveable ‘tween deck covers or just by moveable bulkheads.

3.2 Sealing system

3.2.1 A detailed drawing of the sealing system is to be submitted for approval.

3.2.2 Sufficient tightness regarding grain leakage is to be ensured.

3.2.3 A BKI type approval of a moveable bulkhead sealing system is acceptable in lieu of ship specific examination.

C. Ceiling

1. Bottom ceiling

1.1 Where in the holds of general cargo ships a tight bottom ceiling is to be fitted from board to board, the thickness of a wooden ceiling shall not be less than 60 mm.

1.2 On single bottoms ceilings are to be removable for inspection of bottom plating at any time.

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.

1.4 It is recommended to fit double ceilings under the hatchways.

1.5 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.

2. Side ceiling, ceiling at tank bulkheads

2.1 In cargo holds of ordinary dry cargo ships, side ceiling is to be fitted in general. The side ceiling may be omitted if agreed by the Owner. The side ceilings shall extend from the upper turn of bilge or from tweendeck up to the lower edge of deck beam brackets. The clear distance between adjacent wooden battens shall not exceed 250 – 300 mm. The thickness shall, in general, not to be less than 50 mm.

2.2 Where tanks are intended to carry liquids at temperatures exceeding 40°C, their boundaries facing the cargo hold shall be fitted with a ceiling. At vertical walls, sparred ceilings are sufficient except in holds intended to carry grain. The ceiling may be dispensed with only with Owners' consent.

D. Side Scuttles, Windows and Skylights

1. General

1.1 Side scuttles and windows, together with their glasses, deadlights and storm covers, if fitted, shall 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, Ch. II, Reg. 23(1))

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 shall be treated as windows.

(ICLL Annex I, Ch. II, Reg. 23(2))

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, Ch. II, Reg. 23(3))

1.4 Side scuttles to the following spaces shall 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 shall be capable of being closed and secured watertight if fitted below the freeboard deck and weathertight if fitted above.

(ICLL Annex I, Ch. II, Reg. 23(4))

1.5 Side scuttles shall not 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, whichever is the greatest distance, above the Summer Load Line (or Timber Summer Load Line if assigned), see Fig. 21.1.

(ICLL Annex I, Ch. II, Reg. 23(5))

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 shall be of the non-opening type.

(ICLL Annex I, Ch. II, Reg. 23(6))

1.7 Windows shall not 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, Ch. II, Reg. 23(7))

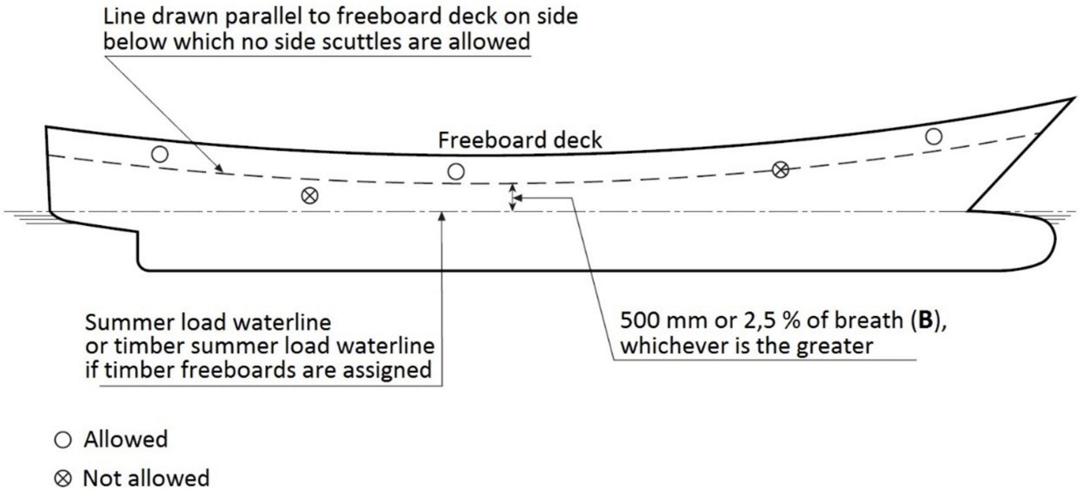


Fig. 21.1 Arrangement of side scuttles

1.8 Side scuttles and windows at the side shell in the second tier shall 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, Ch. II, Reg. 23(8))

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 1.4 shall 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, Ch. II, Reg. 23(9))

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, Ch. II, Reg. 23(10))

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, Ch. II, Reg. 23(11))

1.12 Fixed or opening skylights shall have a glass thickness appropriate to their size and position as required for side scuttles and windows. Skylight glasses in any position shall be protected from mechanical damage and, where fitted in position 1 or 2, shall be provided with permanently attached deadlights or storm covers.

(ICLL Annex I, Ch. II, Reg. 23(12))

Note:

The interpretation of the requirements of the International Convention on Load Lines, 1966, Annex I, Chapter II, Regulation 23, as stated in paragraphs 1.1 and 1.12, should comply with Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.7.LL62

1.13 Additional requirements for passenger vessels given in Section 29 have to be observed.

1.14 Additional requirements for oil tankers given in Section 24 have to be observed.

2. Design Load

2.1 The design load shall be in accordance with Section 4 and Section 16.

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.

2.3 Deviations and special cases are subject to separate approval.

3. Frames

3.1 The design has to be in accordance with ISO Standard 1751, and 3903 or any other recognised, equivalent National or International standard.

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.

4. Glass panes

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.

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 2. For sizes deviating from the standards, the formulas given in ISO 21005 may be used.

4.3 Heated glass panes have to be in accordance with ISO 3434.

4.4 An equivalent thickness (ts) of laminated toughened safety glass is to be determined from the following formula:

$$t_s = \sqrt{t_1^2 + t_2^2 + ... + t_n^2}$$

$t_1, t_2, ... t_n$: thicknesses of laminate layers

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 29, K.

E. Side Shell Fittings, Scuppers and Freeing Ports

1. Side Shell Fittings and Scuppers

1.1 General

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, Ch. II, Reg. 22(2))

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, Ch. II, Reg. 22(3))

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 water line are to be provided with a non-return valve at the shell. This valve, unless required by 1.2.1, may be omitted if the piping is of substantial thickness (see 1.3 below)

(ICLL Annex I, Ch. II, Reg. 22(4))

1.1.4 Scuppers leading from superstructures or deckhouses not fitted with doors complying with the requirements of S. shall be led overboard.

(ICLL Annex I, Ch. II, Reg. 22(5))

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, Ch. II, Reg. 22(6))

1.1.6 Requirements for seawater valves related to operating the power plant shall be observed see Rules for Machinery Installations (Pt.1, Vol.III) Sec.11.

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 life boats 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.

1.2 Valves

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 S. shall, except as provided in 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**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**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, Ch. II, Reg. 22(1a))

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, Ch. II, Reg. 22(1b))

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, Ch. II, Reg. 22(1c))

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, Ch. II, Reg. 22(1d))

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, Ch. II, Reg. 22(1e))

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, Ch. II, Reg. 22(1f))

1.2.7 Table 21.1 provides the acceptable arrangements of scuppers, inlets and discharges.

(ICLL Annex I, Ch. II, Reg. 22(1g))

1.3 Scuppers and discharge pipes

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 6,0 mm.

Intermediate sizes shall be determined by linear interpolation.

(ICLL Annex I, Ch. II, Reg. 22(7a))

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 7,0 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.

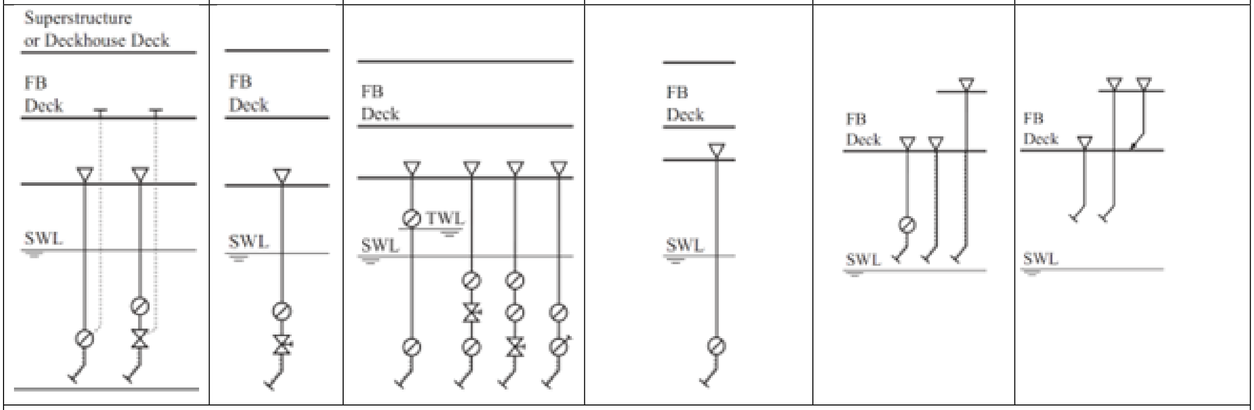
(ICLL Annex I, Ch. II, Reg. 22(7b))

2. Freeing ports

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, Ch. II, Reg. 24(1a))

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 E.1.2.1 where inboard end ≤ 0,01L above SWL	Discharges through machinery space	Alternatives (see E.1.2.1) where inboard end		outboard end > 450 mm below FB deck or ≤ 60 mm above SWL see H.1	otherwise see E.1.2.1
		> 0,01L above SWL	> 0,02L above SWL		
					

symbol

inboard end of pipes	non return valve without positive means of closing	remote controll
outboard end of pipes	Non return valve with positive means of closing controlled locally	normal thickness
Pipes terminating on the open deck	valve controlled locally	substantial thickness

2.2 Except as provided in 2.3 to 2.8 the minimum freeing port area A [mm^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 shall be one half of the area obtained by the formulae.

$$A = 0,7 + 0,035 \cdot \ell \quad [m^2] \quad \text{for } \ell \leq 20 \text{ m}$$

$$= 0,07 \cdot \ell \quad [m^2] \quad \text{for } \ell > 20 \text{ m}$$

ℓ = length of bulwark [m]

ℓ_{max} = 0,7**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, Ch. II, Reg. 24(1b))

2.3 In ships with no sheer the area calculated according to 2.2 is to be increased by 50%. Where the sheer is less than the standard the percentage shall be obtained by linear interpolation.

(ICLL Annex I, Ch. II, Reg. 24(1c))

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, Ch. II, Reg. 24(1d))

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, Ch. II, Reg. 24(1e))

2.6 Wells on raised quarterdecks are to be treated as being on freeboard decks.

(ICLL Annex I, Ch. II, Reg. 24(1f))

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, Ch. II, Reg. 24(1g))

2.8 Where a ship is fitted with a trunk on the freeboard deck, which will not be take 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, Ch. II, Reg. 24(2))

Table 21.2 Minimum area of freeing ports

Breadth 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 breadth is to be obtained by linear interpolation	

2.9 The effectiveness of the freeing area in bulwarks required by 2.1 – 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:

- If the free flow area is not less than the freeing area calculated from 2.8 as if the hatchway coamings were continuous, then the minimum freeing port area calculated from 2.1 –2.7 is to be deemed sufficient.

— If the free flow area is equal to, or less than the area calculated from 2.1 – 2.7, the minimum freeing area in the bulwarks is to be determined from 2.8.

— If the free flow area is smaller than calculated from 2.8, but greater than calculated from 2.1 – 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 2.1 – 2.7

F_2 = minimum freeing area calculated from 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, Ch. II, Reg.24(3))

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 As:

   a) calculate the freeing port area (A) required for an open well of length ℓ_t in accordance with 2.2 with standard height bulwark assumed;

   b) multiply by a factor of 1,5 to correct for the absence of sheer, if applicable, in accordance with 2.3;

   c) 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;

   d) 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:

$$1 - \left(\frac{\ell_w}{\ell_t}\right)^2$$

   e) 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:

$$0.5 \cdot \left(\frac{h_s}{w_t}\right)$$

   h_w = distance of the well deck above the freeboard deck

   h_s = one standard superstructure height

3) To determine A_w:

   a) the freeing port area for the open well (A_w) is to be calculated in accordance with 2.10.2).a, 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:

$A_c = 0,004 \cdot l_w \cdot ((h_b) - 0,9/0,1)$	$[m^2]$	for bulwarks with $h_b < 0{,}9$ m
$A_c = 0$		for bulwarks with $0{,}9 \le h_b \le 1{,}2$ m
$A_c = 0,004 \cdot l_w \cdot ((h_b) - 1,2/0,1)$	$[m^2]$	for bulwarks with $h_b > 1{,}2$ m

b) 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 2.10.).a and 2.10.2).e, 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:

$$A_W = (0,07 \cdot \ell_W + A_c) \cdot (\text{sheer correction}) \cdot 0,5 \cdot \left(\frac{h_s}{h_W}\right) \qquad [m^2]$$

freeing port area As for the open superstructure:

$$A_W = 0,07 \cdot \ell_t \cdot (\text{sheercorrection}) \cdot 0,5 \cdot \left(\frac{b_o}{\ell_t} \cdot \left(1 - 2\frac{\ell_W}{\ell_t}\right)\right) \cdot \left(0,5 \cdot \frac{h_s}{h_W}\right) \qquad [m^2]$$

Where ℓ_t is 20 m or less, the basic freeing port area is A = 0,7 + 0,035 · ℓ_t in accordance with 2.2.

(ICLL Annex I, Ch. II, Reg.24(4))

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 shall 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, Ch. II, Reg. 24(5))

2.12 All such openings in the bulwarks shall be protected by rails or bars spaced approximately 230 mm apart. If shutters are fitted to freeing ports, ample clearance shall be provided to prevent jamming. Hinges shall have pins or bearings of non-corrodible material.

(ICLL Annex I, Ch. II, Reg. 24(6))

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 sectional area A_q of :

$$A_q = 0,07 \cdot b_o \qquad [m^2]$$

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

1. Each tank is to be fitted with air pipes, overflow pipes and sounding pipes. The air pipes are in general to be led to above the exposed deck. For the arrangement and scantlings of pipes see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.11.R. The height from the deck of the point where the water may have access is to be at least 760 mm on the freeboard deck and 450 mm on a superstructure deck.

2. Suitable closing appliances are to be provided for air pipes, overflow pipes and sounding pipes, see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.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.

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.

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.

5. Special strength requirements for fore deck fittings

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)

5.2 Application

5.2.1 For ships that are contracted for construction on or after 1^{st} January 2004 on the exposed deck over the forward 0,25**L**, applicable to:

- all ship types of seagoing service of length 80 m or more, where the height of the exposed deck in way of the item is less than 0,1**L** or 22 m above the summer load waterline, whichever is the lesser

(IACS UR S27.2.1)

5.2.2 For ships that are contracted for construction prior to 1 January 2004 only for air pipes, ventilator pipes and their closing devices on the exposed deck serving spaces forward of the collision bulkhead, and to spaces which extend over this line aft-wards, applicable to:

- Bulk carriers, ore carriers, and combination carriers (as defined in Rules for Classification and Surveys (Pt.1, Vol.I) Annex A.7) and general dry cargo ships (excluding container vessels, vehicle carriers, Ro-Ro ships and woodchip carriers), of length 100 m or more.

(IACS UR S27.2.2)

5.3 Applied loading for air pipes, ventilator pipes and their closing devices

5.3.1 The pressures p acting on air pipes, ventilator pipes and their closing devices may be calculated from:

$$p = 0,5 \cdot \rho \cdot V^2 \cdot C_D \cdot C_s \cdot C_p \qquad [kN/m^2]$$

ρ = density of sea water (1,025 t/m^3)

V = velocity of water over the fore deck, defines as:

$= 13,5$ m/sec for $d \le 0,5 \cdot d_1$

$= 13,5\sqrt{2\left(1 - \frac{d}{d_1}\right)}$ m/sec for $0,5 \cdot d_1 \le d \le d_1$

d = distance from summer load waterline to exposed deck

d_1 = distance [m], defined as:

= min [0,1 · **L** ; 22]

C_d = shape coefficient

= 0,5 for pipes

= 0,8 for an air pipe or ventilator head of cylindrical form with its axis in the vertical direction

= 1,3 for air pipes or ventilator heads

C_s = slamming coefficient

= 3,2

C_p = protection coefficient

= 0,7 for pipes and ventilator heads located immediately behind a breakwater or forecastle

= 1,0 elsewhere and immediately behind a bulwark

(IACS UR S27.4.1.1)

5.3.2 Forces acting in the horizontal direction on the pipe and its closing device may be calculated from 5.3.1 using the largest projected area of each component.

(IACS UR S27.4.1.2)

5.4 Strength requirements for air pipes, ventilator pipes and their closing devices

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)

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)

5.4.3 For other configurations, loads, according to 5.3 are to be applied, and means of support determined in order to comply with the requirements of 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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.11, Table 11.20a.

(IACS UR S27.5.1.4)

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 5.4.2.

(IACS UR S27.5.1.5)

Table 21.3 760 mm air pipe thickness and bracket 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)]

1) See IACS Unified Interpretation LL 36.c
2) Brackets see 5.4.3 need not extend over the joint flange for the head.
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.

Note:
For other ventilator heights, the relevant requirements of 5.4 are to be applied.

(IACS UR S27 Table 1)

Table 21.4 900 mm air pipe thickness and bracket standards

Nominal pipe diameter [mm]	Minimum fitted 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 5.4 are to be applied.

(IACS UR S27 Table 2)

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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.11, Table 11.20a.

(IACS UR S27.5.1.6)

5.4.6 All component part and connections of the air pipe or ventilator are to be capable of withstanding the loads defined in 5.3.

(IACS UR S27.5.1.7)

5.4.7 Rotating type mushroom ventilator heads are unsuitable for application in the areas defined in 5.2.

(IACS UR S27.5.1.8)

G. Ventilators

1. General

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, Ch. II, Reg. 19(1))

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, Ch. II, Reg. 19(2))

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, Ch. II, Reg. 19(3))

1.4 Except as provided in 1.3, 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, Ch. II, Reg. 19(4))

1.5 In exposed locations, the height of coamings may be increased to the satisfaction of the administration.

(ICLL Annex I, Ch. II, Reg. 19(5))

1.6 Ventilators of cargo holds are not to have any connection with other spaces.

1.7 The thickness of the coaming plates is to be 7,5 mm where the clear opening sectional area of the ventilator coamings 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 6,0 mm will generally be sufficient within not permanently closed superstructures.

1.8 The thickness of ventilator posts should be at least equal to the thickness of coaming as per 1.7.

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.

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.

1.11 Coamings and posts particularly exposed to wash of sea are to be efficiently connected with the ship's structure.

1.12 Coamings of a height exceeding 900 mm are to be specially strengthened.

1.13 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.

1.14 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.

2. Weathertight Closing appliances

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 not more 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 openings to which they belong.

2.2 For ventilator posts which exceed 4,5 m in height above the freeboard deck or raised quarterdeck and above exposed superstructure decks forward of 0,25**L** from **FP** and for ventilator posts exceeding 2,3 m in height above exposed superstructure decks abaft 0,25**L** from **FP** closing appliances are required in special cases only.

2.3 For the case of fire draught-tight fire dampers are to be fitted.

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.

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).

2.6 For Special strength requirements for fore deck fittings, see F.5.

H. Stowage of Containers

1. General

1.1 All parts for container stowing and lashing equipment are to comply with the Rules for Stowage and Lashing of Containers (Pt.4, Vol.I). 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 for Materials (Pt.1, Vol.V).

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.

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 2 and 3).

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 rounding in the hatchway corners.

1.5 Where inner bottom, decks, or hatchcovers 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.

2. Load assumptions

2.1 The scantlings of the local ship structures and of the container substructures are to be determined on the basis of the Containers Stowage and Lashing Plans.

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:

$0{,}5 \cdot g \cdot G$ [kN] for ship's transverse (y-) direction:

$(1+a_v) \cdot g \cdot G$ [kN] for ship's transverse (z-) direction:

g = gravitational acceleration [m/s^2], defined as:

= 9,81

G = stack mass [t]

a_v = see Section 4, C.1.1

3. Permissible stresses

3.1 For hatchway covers in pos. 1 and 2 loaded with containers, the permissible stresses according to Section 17, B.3.1 are to be observed.

3.2 The stresses in local ship structures and in substructure 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:

$$\sigma_b = \frac{R_{eH}}{1,5} \quad [N/mm^2]$$

$$\tau = \frac{R_{eH}}{2,3} \quad [N/mm^2]$$

$$\sigma_v = \sqrt{\sigma_a^2 + 3 \cdot \tau^2} \leq \frac{R_{eH}}{1,3} \quad [N/mm^2]$$

R_{eH} = minimum nominal upper yield point of the material.

3.3 For dimensioning the double bottom in case of single point loads due to 20'- or 40'-containers, see Section 8, B.2.

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.

J. 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.

K. Car Decks

1. General

1.1 These Rules apply to movable as well as to removable car decks not forming part of the ship's structure.

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.

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

2. Design loads

2.1 For determining the scantlings of remaining component parts of the decks, the following loads are to be used:

— 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 [kN/m^2].

— 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

= 0,3 x axle load for 4 wheels per axle

= 0,2 x axle load for 6 wheels per axle.

Where no data is available, P is to be taken as 25 [kN].

2.2 For determining the scantlings of the suspensions, the increased wheel load in case of four and six wheels per axle as per 2.1 need not be considered.

3. Plating

3.1 The thickness of the plating is to be determined according to the formulae as per Section 7, B.2. Where aluminium alloy is used, the thickness is to be determined as per Section 2, D.1.

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.

4. Permissible stresses

4.1 In steel stiffeners and girders as well as in the steel structural elements of the suspensions, subjected to loads as per 2. including the acceleration factor a_v according to Section 4, C.1.1 the following permissible stresses are to be observed:

Normal and bending stresses (tension and compression):

$$\sigma = \frac{140}{k} \qquad [\text{N/mm}^2]$$

Sheer stresses:

$$\tau = \frac{90}{k} \qquad [\text{N/mm}^2]$$

Equivalent stresses:

$$\sigma_v = \sqrt{\sigma^2 + 3 \cdot \tau^2} \leq \frac{180}{k} \qquad [\text{N/mm}^2]$$

k = material factor according to Section 2, B

= 0,72 for Fe 510 D1 (St 52-3)

= 1,0 for Fe 360 B (R St 37-2)

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 $1/k_A$.

$k_{A\ell}$ = material factor for aluminium according to Section 2, D.1

5. Permissible deflection

5.1 The deflection of girders subjected to loads stipulated under 2. is not to exceed:

$$f = \frac{\ell}{200}$$

ℓ = unsupported span of girder

5.2 An adequate safety distance should be maintained between the girders of a loaded deck and the top of car stowed on the deck below.

6. Buckling

The buckling strength of girders is to be proved according to Section 3, F, if required.

L. Life Saving Appliances

1. It is assumed that for the arrangement and operation of life boats and other life saving appliances the regulations of SOLAS 74 or those of the competent Authority are complied with.

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.

M. Signal and Radar Masts

1. General

1.1 Drawings of masts, mast substructures and hull connections are to be submitted for approval.

1.2 Loose component parts are to comply with the Guidelines for Loading Gear on Seagoing Ships and Offshore Installations (Pt.4, Vol. 3) . They are to be tested by BKI.

1.3 Other masts than covered by 2. and 3. as well as special designs, shall as regards dimensions and construction in each case be individually agreed with BKI.

2. Single tubular masts

The following requirements apply to tubular or equivalent rectangular sections made of steel with an ultimate tensile strength of 400 N/mm^2, which are designed to carry only signals (navigation lanterns, flag and day signals).

2.1 Stayed masts

2.1.1 Stayed masts may be constructed as simply supported masts (rocker masts) or may be supported by one or more decks (constrainedt masts).

2.1.2 The diameter of stayed steel masts in the uppermost housing is to be at least 20 mm for each 1,0 m length of hounding.

The length of the mast top above the hounds is not to exceed $1/3 \cdot \ell_W$ (ℓ_W denotes the hounding [m]).

2.1.3 Mast according to 2.1.2 may be gradually tapered towards the hounds 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 4 mm, see 4.1.

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 x 7 with a tensile breaking strength of 1570 N/mm^2.

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 1570 N/mm^2 according to Table 21.5.

Table 21.5 Rope and sackles of stayed steel masts

height of hound over the hauling of the shrouds	[m]	6	8	10	12	14	16
Rope diameter	[mm]	14	16	18	20	22	24
Nominal size of shackle, rigging screw, rope socket		2,5	3	4	5	6	8

2.1.6 Where steel wire ropes according to Table 21.5 are used, the following conditions apply:

$$b \geq 0{,}3\ h$$

$$0{,}15\ h \leq a \leq b$$

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 staying are to be of equivalent stiffness

2.2 Unstayed masts

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).

2.2.2 The scantlings for unstayed steel masts are given in the Table 21.6

Table 21.6 Dimensions of unstayed steel masts

ℓ_m	[m]	6	8	10	12	14
D x t	[mm]	160 x 4	220 x 4	290 x 4,5	360 x 5,5	430 x 6,5
ℓ_m = length of mast from uppermost support to the top D = diameter of mast at uppermost support t = plate thickness of mast						

2.2.3 The diameter of masts may be gradually tapered to D/2 at the height of $0{,}75 \cdot \ell_m$.

3. Box girder and frame work masts

3.1 For dimensioning the dead loads, acceleration forces and wind loads are to be considered.

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.

3.3 Single tubular masts mounted on the top may be dimensioned according to 2.

3.4 In case of thin walled box girder masts stiffeners and additional buckling stiffeners may be necessary.

4. Structural details

4.1 Steel masts closed all-round are to have a wall thickness of at least 4,0 mm. For masts not closed all-round the minimum wall thickness is 6,0 mm. For masts used as funnels a corrosion addition of at least 1,0 mm is required.

4.2 The ship's side foundations are to be dimensioned in accordance with the acting forces.

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.

4.4 In case of tubular constructions all welded fastenings and connections shall be of full penetration weld type.

4.5 If necessary, slim tubes are to be additionally supported in order to avoid vibrations.

4.6 The dimensioning normally does not require a calculation of vibrations. However, in case of undue vibrations accuring during the ship's trial a respective calculation will be required.

4.7 For determining scantlings of masts made from aluminium or austenitic steel, the requirements given in Section 2, D and E apply.

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 neccessary.

4.9 If possible from the construction point of view, ladders should be at least 0,30 m wide.

The distance between the rungs shall be 0,30 m. The horizontal distance of the rung centre from fixed parts shall not be less than 0,15 m. The rungs shall be aligned and be made of square steel bars 20/20 edge up.

4.10 Platforms on masts which have to be used for operational reasons, shall 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.

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.

N. Loading and Lifting Gear

1. The design appraisal and testing of loading and lifting gear on ships are not part of Classification.

2. 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:

Where BKI is entrusted with the judgement of loading and lifting gears, Guidelines for Loading Gear on Seagoing Ships and Offshore Installations (Pt.4, Vol. 3) are to be applied.

O. Access to Cargo Area of Oil Tankers and Bulk Carriers

1. Application

1.1 Ships with the class notation **OIL TANKER** of less than 500 gross tonnage are to comply with the requirements of 2, 4, 5 to 11. Ships with the class notation **OIL TANKER** of 500 gross tonnage and over are to comply with the requirements of SOLAS, 1974 as amended, Ch. II-1, Reg. 3-6 for detail and arrangements of opening and attachments to the hull structure.

1.2 Ships with the class notation **BULK CARRIER** of less than 20000 gross tonnage are to comply with the requirements of 3, 4, and 11. Ships with the class notation **BULK CARRIER** of 20000 gross tonnage and over are to comply with the requirements of SOLAS, 1974 as amended, Ch. II-1, Reg. 3-6.

2. Safe access [1] 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 or to forward ballast tanks 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.

[1] Refer to the Recommendations for entering enclosed spaces aboard ships, adopted by the Organization by resolution A.1050(27) or Rules for Classification and Surveys (Pt.1, Vol.I) Annex A.1.

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.

Ladders are to be so designed and arranged that the risk of damage from the cargo handling gear is minimised.

Vertical ladders may be permitted provided they are arranged above each other in line with other ladders to which they form access and resting positions are provided at not more than 9,0 m apart.

Tunnel passing through cargo holds are to be equipped with ladders or steps at each end of the hold so that personnel may get across such tunnels.

Where it may be necessary for work to be carried out within a cargo hold preparatory to loading, consideration is to be given to suitable arrangements for the safe handling of portable staging or movable platform

4. For access through horizontal openings, hatches or manholes, the dimensions is to be sufficient to allow a person wearing a self-contained air-breathing 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 to be not 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.

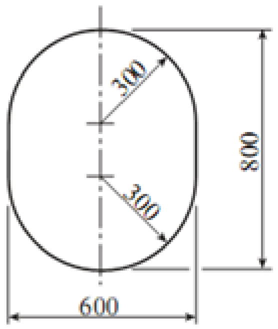
Access hatch coamings having a height greater than 900 mm shall also have steps on the outside in conjunction with the ladder.

5. 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 to be not 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.

Note:

For the purpose of 4 and 5 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:*



6. For oil tankers of less than 5000 tonnes deadweight, the Administration may approve, in special circumstances, smaller dimensions for the openings referred to in para 4 and 5, if the ability to transverse such openings or to remove an injured person can be proved to the satisfaction of the Administration.

7. Access ladder of cargo tanks are to be fitted with hand-rails and to be securely attached to the tanks structure. They are not to be fitted vertically, unless justified by the size of tanks. Rest platforms are to be provided at suitable intervals of not more than 10 m.

8. Any tank openings, e.g. tank cleaning openings, ullage plugs and sighting ports are not to be arranged in enclosed spaces.

9. Ullage plugs and sighting ports are to be fitted as high as possible, for instance in the hatch-way 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, Section 24, E is to be observed.

10. 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.

11. With regard to accessibility for survey purposes of cargo and ballast tanks see also the Rules for Classification and Surveys (Pt.1, Vol.I) Sec.3.A.5.2 and Sec.4.I.A.5.

P. Access to Ships

The design appraisal and testing of accesses to ships (accomodation ladders, gangways) are not part of Classification. However, approval of substructures in way of accomodation ladders and gangways is part of Classification.

Q. Protection of the Crew

1. The deckhouses used for accommodation of the crew are to be constructed to an acceptable level of strength.

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 1,0 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.

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.

4. Satisfactory means of safe passage required by R. (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.

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.

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.

7. Guard rail stanchions are not to be welded to the shell plating.

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).

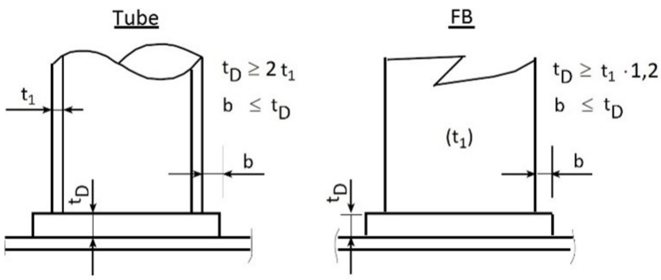


Fig. 21.2 Plates below guard-rail stanchions

9. In the case of ships with rounded gunwales the guard-rail supports are to be placed on the flat part of the deck.

R. Means for Safe Passage of Crew

1. The safe passage of crew is to be provided by at least one of the means mentioned below:

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.

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 1,0 m high with three courses and constructed as required in Q.8. A foot-stop is to be provided.

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 Q.3. 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.

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.

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 1,0 m high with courses as required by Q.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.

2. Permitted transverse locations for arrangements in 1.3 and 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.

3. General provisions

3.1 Where wire ropes are fitted, turnbuckles are to be provided to ensure their tautness.

3.2 Where necessary for the normal operation of the ship, steel wire ropes may be accepted in lieu of guard rails.

3.3 Where necessary for the normal operation of the ship, chains fitted between two fixed stanchions are acceptable in lieu of guard rails.

3.4 Where stanchions are fitted, every third stanchion is to be supported by a bracket or stay.

3.5 Removable or hinged stanchions are to be capable of being locked in upright position.

3.6 A means of passage over obstructions such as pipes or other fittings of a permanent nature is to be provided.

3.7 Generally, the width of the gangway or deck-level walkway should not exceed 1,5 m.

S. Doors

1. All access openings in end bulkheads of closed superstructures are to be fitted with weathertight 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.

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.

3. Unless otherwise permitted by the Administration, doors are to open outwards to provide additional security against the impact of the sea.

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.

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.

T. Machinery Space Openings

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 Section 17, E 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, Ch. II, Reg.17(1))

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 S.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 S.1, without having to fit weathertight closing appliances.

(ICLL Annex I, Ch. II, Reg.17(3))

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.1.4, 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, Ch. II, Reg.17(4))

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, Ch. II, Reg.17(5))

Section 22 Structural Fire Protection

A. General

1. Application, Submission of Plans

1.1 The requirements of this Section apply to passenger ships and cargo ships (including tankers) of 500 gross tonnage and upwards, engaged in international voyages. Ships other than those specified above may diverge from the requirements provided that an adequate level of safety is ensured [1)].

1.2 As a minimum this Section incorporates the structural fire protection requirements of Chapter II-2 of SOLAS 74 as amended, including any relevant IMO guidelines and interpretations.

The terms used in this Section is same with the definitions as per Chapter II-2, Regulation 3 of SOLAS 74.

1.3 The term "Approved" relates to a material or construction, for which BKI 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.

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..

1.5 Documents to be Submitted

The following drawings and documents are to be submitted in the form of soft copy (electronic) for approval. BKI reserves its right to ask for supplementary copies, if deemed necessary.

- Escape way plan
- Fire division plan
- Insulation plan
- Joiner plan
- Ventilation and Air condition scheme
- Deck covering plan
- Door plan

[1)] Reference is made to the "No. 99 Recommendation for the Safety of Cargo Vessels of less than Convention Size (Guidance for Marine Industry (Pt.1, Vol.AC) Section 5, R-99)" or equivalent

[2)] Reference is made to the "Guidelines on Alternative Design and Arrangements for Fire Safety" adopted by IMO by MSC/Circ.1002

- 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)

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

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.

1.7 For regulations on fire alarm systems and on fire extinguishing arrangements, see Rules for Machinery Installations (Pt.1, Vol.III) Sec.12.

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 Passenger

1. Materials

1.1 The hull, decks, structural bulkheads, superstructures and deckhouses are to be of steel or other equivalent materials (Aluminium alloy suitably insulated).

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:

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.

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 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 1.2.1 shall apply at the end of half an hour.

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.

Note:

The interpretation of the Crowns of Machinery Spaces of Category A, as stated in paragraph 1.2.3, should comply with Guidance for Code and Convention Interpretation (Pt.1, Vol.Y), Sec.11, SC.302

2. Main Vertical Zones and Horizontal Zones

2.1 The hull, superstructures 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 1600 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.

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.

3. Bulkheads within Main Vertical Zones

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.

3.2 All bulkheads required to be "B" class divisions 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.

4. Fire Integrity of Bulkheads and Decks

4.1 In addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned else wherein this Section, the minimum fire integrity of all bulkheads and decks shall be as prescribed in Tables 22.1 to 22.2.

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.

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 Table 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 Tables 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 bulkheads 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 below \ Spaces above		[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, work-shops, 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 deck house sides situated below and adjacent to the liferaft's 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 4,0 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 4,0 m^2 or less). Specie rooms, operating rooms, electrical distribution boards (see 4.3.2 and 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 4,0 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 4,0 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).

4.3.1 In respect of category [5] spaces BKI 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 Tables 22.1 and 22.2 necessitate enclosure of spaces which in the opinion of BKI need not be enclosed.

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.

4.3.3 If distribution boards are located in an identifiable space having a deck area of less than 4,0 m^2, this space shall be categorized in [7].

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.

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.

4.6 Protection of atriums

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.

4.6.2 Decks separating spaces within atriums shall have a fire rating determined in accordance with Table 22.2, as applicable.

5. Protection of Stairways and Lifts in Accomodation and Service Spaces

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:

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.

5.1.2 Stairways fitted within a closed public space need not be enclosed.

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 public spaces, corridors, public toilets, special category spaces, other escape stairways required by 12.3.3 and external areas are permitted to have direct access to these stairway enclosures.

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.

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.

6. Openings in “A” Class Divisions

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 6.7.

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.

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 BKI 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 mm. A non-combustible sill shall be installed under the door such that floor coverings do not extend beneath the closed door.

6.4 Watertight doors need not be insulated.

6.5 It shall be possible for each door to be opened and closed from each side of the bulkhead by one person only.

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:

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.

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.

[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.

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.

6.6.4 Hold-back hooks not subject to central control station release are prohibited.

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 Rules for Electrical Installations (Pt.1, Vol.IV) Sec.9).

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.

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.

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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.14).

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.

6.6.10 Remote-released sliding or power-operated doors shall be equipped with an alarm that sounds for at least 5,0 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.

6.6.11 A door designed to re-open upon contacting an object in its path shall re-open not more than 1,0 m from the point of contact.

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.

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 6.6.3 and 6.6.10.

6.6.14 The components of the local control system shall be accessible for maintenance and adjusting.

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:

.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;

.2 The power supply for all other doors not subject to fire shall not be impaired; and

.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.

6.7 The requirements for "A" class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and side scuttles, provided that there is no requirement for such boundaries to have "A" class integrity in 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.

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.

7. Openings in "B" Class Divisions

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.

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 BKI. 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.

7.3 Cabin doors in "B" class divisions shall be of a self-closing type. Hold-backs are not permitted.

7.4 The requirements for "B" class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and side scuttles. Similarly, the requirements for "B" class integrity shall not apply to exterior doors in superstructures and deckhouses.

8. Windows and Side Scuttles

8.1 All windows and side scuttles in bulkheads within accommodation and service spaces and control stations other than those to which the provisions of 6.6 and of 7.4 apply, shall be so constructed as to preserve the integrity requirements of the type of bulkheads in which they are fitted.

8.2 Notwithstanding the requirements of the Tables 22.1 to 22.2 all windows and side scuttles 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.

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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.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.

9. Ventilation Systems

9.1 In general, the ventilation fans shall be so disposed that the ducts reaching the various spaces remain within the main vertical zone.

9.2 A duct, irrespective of its cross-section, serving more than one ’tween-deck accommodation space, service space or control station, shall be fitted, near the penetration of each deck of such spaces, with an automatic smoke damper that shall also be capable of being closed manually from the protected deck above the damper. Where a fan serves more than one ’tween-deck space through separate ducts within a main vertical zone, each dedicated to a single ’tween-deck space, each duct shall be provided with a manually operated smoke damper fitted close to the fan.

9.3 Vertical ducts shall, if necessary, be insulated as required by Tables 22.1 to 22.2. Ducts shall be insulated as required for decks between the space they serve and the space being considered, as applicable.

9.4 The main inlets and outlets of ventilation systems shall be capable of being closed from outside the spaces being ventilated. The means of closing shall be easily accessible as well as prominently and permanently marked and shall indicate the operating position of the closing device.

9.5 Ventilation ducts shall be constructed of the following materials:

9.5.1 Ventilation ducts, including single and double wall ducts, shall be of steel or equivalent material except flexible bellows of short length not exceeding 600 mm used for connecting fans to the ducting in air-conditioning rooms. Unless expressly provided otherwise in paragraph 9.5.2, any other material used in the construction of ducts, including insulation, shall also be non-combustible.

9.5.2 Combustible gaskets in flanged ventilation duct connections are not permitted within 600 mm of openings in ”A” or ”B” class divisions and in ducts required to be of ”A” class construction.

9.5.3 Where ventilation ducts penetrate ”A” or ”B” Class divisions due regard shall be given to ensuring the fire integrity of the division.

9.5.4 However, short ducts, not generally exceeding 2,0 m in length and with a free cross-sectional area* not exceeding 0,02 m^2, need not be of steel or equivalent material, subject to the following conditions:

.1 The ducts shall be made of non-combustible material, which may be faced internally and externally with membranes having low flame-spread characteristics and, in each case, a calorific value [4)] not exceeding 45 MJ / m^2 of their surface area for the thickness used;

.2 The duct is used only at the end of the ventilation device; and

.3 The ducts are not situated less than 600 mm, measured along the duct, from an opening in an ”A” or ”B” class division, including continuous ”B” class ceiling.

Note:

** The term free cross-sectional area means, even in the case of a pre-insulated duct, the area calculated on the basis of the inner dimensions of the duct itself and not the insulation.*

Paragraphs 9.5.1 and 9.5.4 are to be interpreted in accordance with Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11.SC264

9.6 Stairway enclosures shall be served by an independent ventilation fan and duct system (exhaust and supply) which shall not serve any other spaces in the ventilation systems

9.7 All power ventilation, except machinery and cargo spaces ventilation and any alternative system which may be required under 9.10, 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.

9.8 Where a thin plated duct with a free cross-sectional area equal to or less than 0,02 m^2 passes through ”A” class division, the opening shall be lined with a steel sheet sleeve having a thickness of at least 3,0 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 penetrated.

[4)] Refer to the recommendations published by the International Organization for Standardization, in particular publication ISO 1716 : 2002, Reaction to the fire tests for building products – Determination of the heat of combustion.

9.8.1 Where ventilation ducts with a free cross-sectional area exceeding 0,02 m^2, but not more than 0,075 m^2, pass through "A" class divisions, the openings shall be lined with steel sheet sleeves. The ducts and sleeves shall have a thickness of at least 3,0 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 division through which the duct passes. The interpretation of this paragraph refers to Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11.SC300.

9.8.2 Automatic fire dampers shall be fitted in all ducts with a free cross-sectional area exceeding 0,075 m^2 that pass through "A" class divisions. Each damper shall be fitted close to the division penetrated and the duct between the damper and the division penetrated shall be constructed of steel in accordance with paragraphs 9.12.1. The fire damper shall operate automatically, but shall also be capable of being closed manually from both sides of the division. The damper shall be fitted with a visible indicator which shows the operating position of the damper. 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 penetrate. A duct of cross-sectional area exceeding 0,075 m^2 shall not be divided into smaller ducts at the penetration of an "A" class division and then recombined into the original duct once through the division to avoid installing the damper required by this provision.

9.8.3 All fire dampers shall be capable of manual operation. The dampers shall have a direct mechanical means of release or, alternatively, be closed by electrical, hydraulic, or pneumatic operation. All dampers shall be manually operable from both sides of the division. Automatic fire dampers, including those capable of remote operation, shall have a failsafe mechanism that will close the damper in a fire even upon loss of electrical power or hydraulic or pneumatic pressure loss. Remotely operated fire dampers shall be capable of being reopened manually at the damper.

9.8.4 The following arrangement shall be tested in accordance with the Fire Test Procedures Code[3].

.1 Fire dampers, including their relevant means of operation, however, the testing is not required for dampers located at the lower end of the duct in exhaust ducts for galley ranges, which must be of steel and capable of stopping the draught in the duct; and

.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.

9.9 Exhaust ducts from galley ranges shall be constructed in accordance with paragraphs 9.12.2 and insulated to "A-60" class standard throughout accommodation spaces, service spaces, or control stations they pass through. They shall also be fitted with:

9.9.1 A grease trap readily removable for cleaning unless an alternative approved grease removal system is fitted;

9.9.2 A fire damper located in the lower end of the duct at the junction between the duct and the galley range hood which is automatically and remotely operated and, in addition, a remotely operated fire damper located in the upper end of the duct close to the outlet of the duct;

9.9.3 A fixed means for extinguishing a fire within the duct (see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.12);

9.9.4 Remote control arrangements for shutting off the exhaust fans and supply fans, for operating the fire dampers mentioned in 9.9.2 and for operating the fire-extinguishing system, which shall be placed in a position outside the galley close to the entrance to the galley. Where a multi branch system is installed, a remote means located with the above controls shall be provided to close all branches exhausting through the same main duct before an extinguishing medium is released into the system; and

9.9.5 Suitably located hatches for inspection and cleaning, Including one provided close to the exhaust fan and one fitted in the lower end where grease accumulates.

9.9.6 Exhaust ducts from ranges for cooking equipment installed on open decks shall conform to paragraph 9.9 to 9.9.5, as applicable, when passing through accommodation spaces or spaces containing combustible materials.

Note:

With respect to the application of paragraphs 9.9, to determine fire insulation for trunks and ducts passing through enclosed spaces, the term 'pass through' pertains to the part of the trunk/duct contiguous to the enclosed space. The interpretations provided in Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11.SC301 should be observed.

9.10 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 there in 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.

9.11 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.

9.12 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 9.12.1 or 9.12.2.

9.12.1 Constructed of steel having a thickness of at least 3,0 mm and 5,0 mm for ducts with a free cross-sectional area of less than 0,075 m^2, at least 4,0 mm for ducts with a free cross-sectional area of between 0,075 $m^2$and 0,45 m^2, and at least 5,0 mm for ducts with a free cross-sectional area of over 0,45 m^2;

suitably supported and stiffened;

fitted with automatic fire dampers close to the boundaries penetrated; and

insulated to "A-60" class standard from the boundaries of the spaces they serve to a point at least 5,0 m beyond each fire damper; or

9.12.2 Constructed of steel in accordance with paragraphs 9.12.1; and

insulated to "A-60" class standard within the machinery space, galley, vehicle space, ro-ro cargo space or special category space;

For the purposes of paragraphs 9.12.1 and 12.2, ducts shall be insulated over their entire cross sectional external surface. Ducts that are outside but adjacent to the specified space, and share one or more surfaces with it, shall be considered to pass through the specified space, and shall be insulated over the surface they share with the space for a distance of 450 mm past the duct.

9.12.3 Except that penetrations of main zone divisions shall also comply with the requirements of 9.14.

9.13 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 9.13.1 or 9.13.2.

9.13.1 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 9.12.1; or

9.13.2 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 9.12.2;

9.13.3 Except that penetrations of main zone division shall also comply with the requirements in 9.15.

9.14 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.

The interpretation in the Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11.SC300 should also be observed.

9.15 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 constructed of steel in accordance with paragraphs 9.12.1 and insulated to to at least the same fire integrity as the division penetrated. The damper shall be fitted on at least one side of the division with a visible indicator showing the operating position of the damper.

9.16 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.

9.17 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.

9.18 Ventilation ducts shall be provided with hatches for inspection and cleaning. The hatches shall be located near the fire damper.

9.19 Ventilation openings or air balance ducts between two enclosed spaces shall not be provided except as permitted by paragraphs 7.2.

9.20 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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.12).

9.21 Exhaust ducts from laundries and drying rooms of category (13) spaces as defined in paragraph 4.3 shall be fitted with:

9.21.1 Filters readily removable for cleaning purposes;

9.21.2 A fire damper located in the lower end of the duct which is automatically and remotely operated;

9.21.3 Remote-control arrangements for shutting off the exhaust fans and supply fans from within the space and for operating the fire damper mentioned in 9.21.2; and

9.21.4 Suitably located hatches for inspection and cleaning.

9.22 Ventilation rooms serving machinery spaces of category A containing internal combustion Machinery.

9.22.1 Where a ventilation room serves only such an adjacent machinery space and there is no fire division between the ventilation room and the machinery space, the means for closing the ventilation duct or ducts serving the machinery space shall be located outside of the ventilation room and machinery space.

9.22.2 Where a ventilation room serves such a machinery space as well as other spaces and is separated from the machinery space by a "A-0" class division, including penetrations, the means for closing the ventilation duct or ducts for the machinery space can be located in the ventilation room.

10. Restriction of Combustible Materials

10.1 Except in cargo spaces, mail rooms, baggage rooms, saunas[5)] or refrigerated compartments of service spaces, all linings, grounds, draught stops, ceilings and insulations 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.

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.

10.3 The following surfaces shall have low flame spread characteristics[4]:

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;

10.3.2 Concealed or inaccessible spaces in accommodation, service spaces and control stations.

10.3.3 Exposed surfaces of cabin balconies, except for natural hard wood decking systems.

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.

10.5 Combustible materials used on surfaces and linings covered by the requirements of 10.3 shall have a calorific value[6)] not exceeding 45 MJ/m^2 of the area for the thickness used. This does not apply to surfaces of furniture fixed to liningscor bulkheads as well as to traditional wooden benches and wooden linings on bulkheads and ceilings in saunas.

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.

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

10.7.1 Case furniture shall be constructed entirely of approved non-combustible materials, except that a combustible veneer not exceeding 2,0 mm may be used on the working surface;

10.7.2 Free-standing furniture shall be constructed with frames of non-combustible materials;

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 kg/m^2 [7)] ;

[5)] Insulation materials used in saunas shall be of non-combustible material.

[6)] 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.

[7)] 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.

10.7.4 Up holstered furniture shall have qualities of resistance to the ignition and propagation of flame [8)] and

10.7.5 Bedding components shall have qualities of resistance to the ignition and propagation of flame[9)].

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 [10)].

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 [11)].

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.

11. Details of Construction

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.

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.

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.

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 a gas fire extinguishing system, are to be equipped with self-closing doors.

11.5 Construction and arrangement of saunas

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].

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.

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.

11.5.4 The traditional wooden benches are permitted to be used in the sauna.

[8)] 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.

[9)] 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.

[10)] 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.

[11)] 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.

11.5.5 The sauna door shall open outwards by pushing.

11.5.6 Electrically heated ovens shall be provided with a timer.

12. Means of Escape

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.

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, and
- 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.

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:

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.

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.

12.3.3 At least one of the means of escape required by paragraphs 12.3.1 and 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 Rules for Electrical Installations (Pt.1, Vol.IV) Sec.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:

.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 1800 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[12)] .

.2 All stairways sized for more than 90 persons shall be aligned fore and aft.

.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.

.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°.

[12)] 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.

.5 Landings at each deck level shall be not less than 2,0 m^2 in area and shall increase by 1,0 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.

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.

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 athwart ship 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.

12.3.6 In addition to the emergency lighting (see also Rules for Electrical Installations (Pt.1, Vol.IV) Sec.3 and 10), The means of escape including stairways and exits, shall be marked by lighting or photo luminescent 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 photo luminescent material or marked by lighting. Such lighting or photo luminescent equipment shall be of an approved type [13].

.1 In lieu of the escape route lighting system required by paragraph 12.3.6, alternative evacuation guidance systems may be accepted if they are of approved type (see also the BKI Rules for Electrical Installations (Pt.1, Vol.IV) Sec.14)[13) .

12.3.7 The requirement of 12.3.6 shall also apply to the crew accommodation areas.

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 12.3.3.

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.

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 12.3.1, .2 and .3.

12.6 Two means of escape shall be provided from each machinery space. In particular, the following provisions shall be complied with:

12.6.1 Where the space is below the bulkhead deck the two means of escape shall consist of either:

.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 × 800 mm, and shall have emergency lighting provisions, or

[13)] 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).

.2 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.

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.

12.6.3 A ship of a gross tonnage less than 1000 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 1000 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.

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.

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.

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.

Note:

The interpretation regarding requirements of means escape from machinery spaces on passenger ships in paragraph 12.6.1, 12.6.2 and 12.6.6 should be complied with Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11.SC276

12.6.7 On ships constructed on or after 1 January 2016, two means of escape shall be provided from the main workshop within a machinery space. At least one of these escape routes shall provide a continuous fire shelter to a safe position outside the machinery space.

12.6.8 On ships constructed on or after 1 January 2016, all inclined ladders/stairways fitted to comply with paragraph 12.6.1 with open treads in machinery spaces being part of or providing access to escape routes but not located within a protected enclosure shall be made of steel. Such ladders/stairways shall be fitted with steel shields attached to their undersides, such as to provide escaping personnel protection against heat and flame from beneath.

12.7 Additional requirements for ro-ro passenger ships

12.7.1 Handrails or other handholds shall be provided in all corridors along the entire escape route, so that a firm hand hold 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 m in width and transverse corridors more than 1,0 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 750N/m applied in the direction of the centre of the corridor or space, and a distributed vertical load of 750 N/m applied in the downward direction. The two loads need not be applied simultaneously.

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.

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.

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.

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.

12.7.6 Cabin and state room doors shall not require keys to unlock them from inside the room. Neither shall there beany doors along any designed escape route which require keys to unlock them when moving in the direction of escape.

12.7.7 The lowest 0,5 m of bulkheads and other partitions forming vertical divisions along escape routes shall be able to sustain a load of 750 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.

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.

12.7.9 External routes shall be provided from open decks, referred to in paragraph 12.7.8, to the survival craft embarkation stations.

12.7.10 Escape routes are to be evaluated by an evacuation analysis early in the design process[14)]. 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 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.

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.

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.

13. Fixed Fire Detection and Fire Alarm Systems and Automatic Sprinkler, Fire Detection and Fire Alarm Systems.

13.1 Any ship shall be equipped with:

13.1.1 An automatic sprinkler, fire detection and fire alarm system in all service spaces, control stations and accommodation spaces, including corridors and stairways (see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.12); and

13.1.2 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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.12).

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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.12).

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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.12), when furniture and furnishings on such balconies are not complying with 10.7.

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.

[14)] Reference is made to the Interim Guidelines for evacuation analyses for new and existing passenger ships adopted by IMO by MSC/Circ. 1238.

14. Protection of Vehicle, Special Category and Ro-Ro Spaces

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.

14.1.1 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.

14.2 Fixed Fire-Extinguishing system

14.2.1 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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.12).

14.2.2 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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.12).

14.3 Ventilation system

There shall be provided an effective power ventilation system for the 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 9.12.1 and 9.12.2.

Permanent openings in the side plating, the ends or deck head 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 space.

14.4 Fire detection

There shall be provided a fixed fire detection and fire alarm system of an approved type (see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.12).

A sample extraction smoke detection system of an approved type (see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.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.

15. Special Arrangements in Machinery Spaces of Category A

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.

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.

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.

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.

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.

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.

15.7 The floor plating of normal passageways shall be made of steel.

16. Special Requirements for Ships Carrying Dangerous Goods

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.

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 3,0 m horizontally away from such bulkheads. Other boundaries between such spaces shall be insulated to ”A-60” standard.

16.3 Miscellaneous items

The kind and extent of the fire extinguishing equipment are defined in the Rules for Machinery Installations (Pt.1,Vol.III) Sec.12.

Electrical apparatus and cablings are to meet the requirements of the Rules for Electrical Installations (Pt.1,Vol.IV) Sec.16.

17. Safety Centre on Passenger Ships

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.

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.

17.3 Layout and ergonomic design

The layout and ergonomic design of the safety centre shall take into account the IMO guidelines[15)] (communication and control and monitoring of safety systems see also the Rules for Electrical Installations (Pt.1, Vol.IV) Sec.14.

C. Passenger Ships carrying not more than 36 Passengers

1. Materials

1.1 The hull, decks, structural bulkheads, superstructures and deckhouses are to be of steel or other equivalent materials (aluminium alloy suitably insulated).

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:

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.

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 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 1.2.1 shall apply at the end of half an hour.

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 there in, if any, shall be suitably arranged and protected to prevent the spread of fire.

> ***Note:***
>
> *The interpretation of the Crowns of Machinery Spaces of Category A, as stated in paragraph 1.2.3, should comply with Guidance for Code and Convention Interpretation (Pt.1, Vol.Y), Sec.11, SC.302*

2. Main Vertical Zones and Horizontal Zones

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.

[15)] Refer to guidelines according to MSC.1/Circ. 1368

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 1600 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.

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.

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.

3. Bulkheads within Main Vertical Zone

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.

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.

3.3 All bulkheads required to be "B" class division, except corridor bulkheads prescribed in 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.

4. Fire Integrity of Bulkheads and Decks

4.1 In addition to complying with the specific provisions for fire integrity of bulkheads and deck mentioned else where in this Section, the minimum fire integrity of all bulkheads and decks shall be as prescribed in Tables 22.3 to 22.4.

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.

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 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 22.3 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 decks 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-30[8]
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	A-30[8]
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-30[8]

Notes to be applied to Tables 22.3 and 22.4, as appropriate

1 For clarification as to which applies see 3 and 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 2.1 "B-0" and "C", where appearing in Tables 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.

8 Ships constructed before 1 July 2014 shall comply, as a minimum, with the previous requirements applicable at the time the ship was contracted between builder and buyer (yard and owner).

For the application of 2.1, a 7, where appearing in Tables 22.4 except for categories 8 and 10, shall be read as "A-0".

Table 22.4 Fire integrity of decks separating adjacent spaces

Spaces above / Spaces 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-60[8]
Corridors	[2]	A-0	7	7	A-0	7	A-60	A-0	A-0	A-0	7	A-30[8]
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-30[8]
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-30[8]	A-30[8] A-0[4]	A-30[8]	A-0	A-60[8]	A-0	A-0	A-30	A-0	A-30[8]
See note under Table 22.3												

[1] Control stations

Spaces containing emergency sources of power and lighting. Wheelhouse and chart-room. 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 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 machinery spaces) and enclosures there to.

In this connection, a stairways 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 4,0 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

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 4,0 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 superstructures and deckhouses).

[11] Special category spaces and ro-ro cargo spaces

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.

4.5 See B.4.5.

4.6 Protection of atriums

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.

4.6.2 Decks separating spaces within atriums shall have a fire rating determined in accordance with Table 22.4, as applicable.

5. Protection of stairways and lifts in accommodation and service spaces.

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:

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.

5.1.2 Stairways fitted within a closed public space need not be enclosed.

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 public spaces, corridors, public toilets, special category spaces, other escape stairways required by 12.3.3 and external areas are permitted to have direct access to these stairway enclosures. 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.

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.

6. Openings in "A" class divisions

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 6.7.

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.

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 BKI 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 mm. A non-combustible sill shall be installed under the door such that floor coverings do not extend beneath the closed door.

6.4 Watertight doors need not be insulated.

6.5 It shall be possible for each door to be opened and closed from each side of the bulkhead by one person only.

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:

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.

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.

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.

6.6.4 Hold-back hooks not subject to central control station release are prohibited.

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 Rules for Electrical Installations (Pt.1, Vol.IV) Sec.9)

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.

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.

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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.14).

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.

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.

6.6.11 A door designed to re-open upon contacting an object in its path shall re-open not more than 1,0 m from the point of contact.

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.

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 6.6.3 and 6.6.10.

6.6.14 The components of the local control system shall be accessible for maintenance and adjusting.

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:

.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;

.2 the power supply for all other doors not subject to fire shall not be impaired; and

.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.

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.

6.8 The requirements for "A" class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and side scuttles, provided that there is no requirement for such boundaries to have "A" class integrity in 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.

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.

7. Openings in "B" class divisions

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, arrangement shall be made to ensure that the fire resistance is not impaired. See also B.7.1.

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 divisions3 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 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 BKI.

7.3 Cabin doors in "B" class division shall be of a self closing type. Hold-backs are not permitted.

7.4 The requirements for "B" class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and side scuttles. Similarly, the requirements for "B" class integrity shall not apply to exterior doors in superstructures and deckhouses.

7.5 Where an automatic sprinkler system is fitted:

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

7.5.2 Openings in corridor bulkheads of "B" class materials shall be protected in accordance with the provisions of 3.2.

8. Windows and side scuttles

8.1 All windows and side scuttles in bulkheads within accommodation and service spaces and control stations other than those to which the provisions of 6.8 and 7.4 apply, shall be so constructed as to preserve the integrity requirements of the type of bulkheads in which they are fitted.

8.2 Notwithstanding the requirements of the Table 22.3 and 22.4, all windows and side scuttles 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.

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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.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.

9. Ventilation systems

9.1 Ventilation ducts including single and double wall ducts, shall be of steel or equivalent material except flexible bellows of short length not exceeding 600 mm used for connecting fans to the ducting in air-conditioning rooms. Unless expressly provided otherwise in paragraph 9.8, any other material used in the construction of ducts, including insulation, shall also be non-combustible.

However, short ducts, not generally exceeding 2,0 m in length and with a free cross-sectional area* not exceeding 0,02 m^2, need not be of steel or equivalent material, subject to the following conditions :

9.1.1 The ducts shall be made of non-combustible material, which may be faced internally and externally with membranes having low flame-spread characteristics and, in each case, a calorific value[4)] not exceeding 45 MJ/m^2 of their surface area for the thickness used;

9.1.2 The ducts only be used at the end of the ventilation device; and

9.1.3 The ducts 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.

Note:

** The term free cross-sectional area means, even in the case of a pre-insulated duct, the area calculated on the basis of the inner dimensions of the duct itself and not the insulation.*

Paragraph 9.1 is to be interpreted in accordance with Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11.SC264

9.2 Where a thin plated duct with a free cross-sectional area equal to or less than 0,02 m^2 passes through "A" class divisions, the opening shall be lined with a steel sheet sleeve having a thickness of at least 3,0 mm and a length of at least 200 mm, divided preferably into 100 mm on each side of a bulkhead or, in the case of a deck, wholly laid on the lower side of the decks penetrated.

9.3 Where ventilation ducts with a free cross-sectional area exceeding 0,02 m^2 but not more than 0,075 m^2 pass through "A" class divisions, the opening shall be lined with a steel sheet sleeve. The ducts and sleeves shall have a thickness of at least 3,0 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 division through which the duct passes. The interpretation of this paragraph refers to Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11.SC300.

9.4 Automatic fire dampers shall be fitted in all ducts with a free cross-sectional area exceeding 0,075 m^2 that pass through "A" class divisions. Each damper shall be fitted close to the division penetrated and the duct between the damper and the division penetrated shall be constructed of steel in accordance with paragraphs B.15.1. The fire damper shall operate automatically, but shall also be capable of being closed manually from both sides of the division. The damper shall be fitted with a visible indicator which shows the operating position of the damper. 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 penetrate. A duct of cross-sectional area exceeding 0,075 m^2 shall not be divided into smaller ducts at the penetration of an "A" class division and then recombined into the original duct once through the division to avoid installing the damper required by this provision.

9.5 All fire dampers shall be capable of manual operation. The dampers shall have a direct mechanical means of release or, alternatively, be closed by electrical, hydraulic, or pneumatic operation. All dampers shall be manually operable from both sides of the division. Automatic fire dampers, including those capable of remote operation, shall have a failsafe mechanism that will close the damper in a fire even upon loss of electrical power or hydraulic or pneumatic pressure loss. Remotely operated fire dampers shall be capable of being reopened manually at the damper.

9.5.1 The following arrangement shall be tested in accordance with the Fire Test Procedures Code[3]:

.1 Fire dampers, including their relevant means of operation, however, the testing is not required for dampers located at the lower end of the duct in exhaust ducts for galley ranges, which must be of steel and capable of stopping the draught in the duct; and

.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.

9.6 Fire dampers shall be easily accessible. Where they are placed behind ceilings or linings, these ceilings or linings shall be provided with an inspection hatch on which the identification number of the fire damper is marked. The fire damper identification number shall also be marked on any remote controls provided.

9.7 The main inlets and outlets of ventilation systems shall be capable of being closed from outside the spaces being ventilated. The means of closing shall be easily accessible as well as prominently and permanently marked and shall indicate the operating position of the closing device.

9.8 Combustible gaskets in flanged ventilation duct connections are not permitted within 600 mm of openings in "A" or "B" class divisions and in ducts required to be of "A" class construction.

9.9 Ventilation ducts shall be provided with hatches for inspection and cleaning. The hatches shall be located near the fire dampers.

9.10 Ventilation openings or air balance ducts between two enclosed spaces shall not be provided except as permitted by paragraphs 7.2.

9.11 Where passing through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges shall be constructed in accordance with paragraphs 9.15. Each exhaust duct shall be fitted with:

9.11.1 A grease trap readily removable for cleaning;

9.11.2 an automatically and remotely operated fire damper located in the lower end of the duct at the junction between the duct and the galley range hood and, in addition, a remotely operated fire damper in the upper end of the duct close to the outlet of the duct;

9.11.3 Arrangements, operable from within the galley, for shutting off the exhaust fan and supply fans; and;

9.11.4 Fixed means for extinguishing a fire within the duct (see Rules for Machinery Installations (Pt.1, Vol.III) Sec.12).

9.12 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.

9.13 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.

However, the galley ventilation systems on cargo ships of less than 4000 gross tonnage and in passenger ships carrying not more than 36 passengers need not be completely separated from other ventilation systems, but may be served by separate ducts from a ventilation unit serving other spaces. In such a case, an automatic fire damper shall be fitted in the galley ventilation duct near the ventilation unit.

9.14 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 9.14.1 or 9.14.2:

9.14.1 Constructed of steel having a thickness of at least 3,0 mm for ducts with a free cross-sectional area of less than 0,075 m^2, at least 4,0 mm for ducts with a free cross-sectional area of between 0,075 m^2 and 0,45 m^2, and at least 5,0 mm for ducts with a free cross-sectional area of over 0,45 m^2. ;

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 5,0 m beyond each fire damper; or

9.14.2 Constructed of steel suitable supported and stiffened in accordance with 9.14.1 and insulated to "A-60" class standard within the machinery space, galley, vehicle space, ro-ro cargo space or special category space;

For the purposes of paragraphs 9.14.1 and 14.2, ducts shall be insulated over their entire cross sectional external surface. Ducts that are outside but adjacent to the specified space, and share one or more surfaces with it, shall be considered to pass through the specified space, and shall be insulated over the surface they share with the space for a distance of 450 mm past the duct.

Note:

With respect to the application of paragraphs 9.13, 9.14, 9.15 and 9.18, to determine fire insulation for trunks and ducts passing through enclosed spaces, the term 'pass through' pertains to the part of the trunk/duct contiguous to the enclosed space. The interpretations provided in Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11.SC301 should be observed.

9.15 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 9.15.1 or 9.15.2:

9.15.1 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 9.14.1; or

9.15.2 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 9.14.2.

9.15.3 except that penetrations of main zone division shall also comply with the requirements of 9.19.

9.16 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.

The interpretation in the Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11.SC300 should also be observed.

9.17 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.

9.18 Where it is necessary that a ventilation duct passes through a main vertical zone division, an automatic 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 control location shall be readily accessible and be clearly and prominently marked. The duct between the division and the damper shall be of constructed of steel in accordance with the requirements of 9.15.1 and insulated to at least the same fire integrity as the division penetrated. The damper shall be fitted on at least one side of the division with a visible indicator showing the operating position of the damper.

9.19 Ventilation rooms serving machinery spaces of category A containing internal combustion machinery

9.19.1 Where a ventilation room serves only such an adjacent machinery space and there is no fire division between the ventilation room and the machinery space, the means for closing the ventilation duct or ducts serving the machinery space shall be located outside of the ventilation room and machinery space.

9.19.2 Where a ventilation room serves such a machinery space as well as other spaces and is separated from the machinery space by a "A-0" class division, including penetrations, the means for closing the ventilation duct or ducts for the machinery space can be located in the ventilation room.

10. Restriction of Combustible Materials

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 insulations 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.

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

10.3 The following surfaces shall have low flame spread characteristics[4]:

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;

10.3.2 Concealed or inaccessible spaces in accommodation, service spaces and control stations.

10.3.3 Exposed surfaces of cabin balconies, except for natural hard wood decking systems.

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 sauna. 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.

10.5 Combustible materials used on surfaces and linings covered by the requirements of 10.3 shall have a calorific value[16)] 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.

10.6 Furniture in stairway enclosures shall be limit 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. Locker 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.

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).

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].

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].

10.10 Waste receptacles (see B.10.10).

11. Details of construction

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.

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.

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.

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 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.

[16)] The gross calorific value measured in accordance with ISO Standard 1716 - "Building Materials - Determination of Calorific Potential", should be quoted.

11.5 Construction and arrangement of saunas. See B.11.5.

12. Means of escape

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.

12.2 Doors in escape routes shall, in general, open in-way of the direction of escape, except that

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

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.

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:

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.

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.

12.3.3 At least one of the means of escape required by paragraphs 12.3.1 and 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 Rules for Electrical Installations (Pt.1, Vol.IV) Sec.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 Table 22.3 and 22.4. The widths, number and continuity of escapes shall be as follows:

.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 1800 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].

.2 All stairways sized for more than 90 persons shall be aligned fore and aft.

.3 Doorways and corridors and intermediate landings included in means of escape shall be sized in the same manner as stairways.

.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°.

.5 Landings at each deck level shall be not less than 2,0 m^2 in area and shall increase by 1,0 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.

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.

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 athwart ship 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.

12.3.6 In addition to the emergency lighting (see also Rules for Electrical Installations (Pt.1, Vol.IV) Sec.3 and 11) the means of escape including stairways and exits, shall be marked by lighting or photo luminescent 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 photo luminescent material or marked by lighting. Such lighting or photo luminescent equipment shall be of an approved type[13].

In lieu of the escape route lighting system required in above paragraph, alternative evacuation guidance systems may be accepted if they are of approved type (see also Rules for Electrical Installation (Pt.1, Vol.IV) Sec.14.

12.3.7 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 12.3.3.

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.

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 12.3.1, .2 and .3.

12.6 Two means of escape shall be provided from each machinery space. In particular, the following provisions shall be complied with:

12.6.1 Where the space is below the bulkhead deck the two means of escape shall consist of either:

.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 life boat 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 Table 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 mm × 800 mm, and shall have emergency lighting provisions.

.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.

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.

12.6.3 A ship of a gross tonnage less than 1000 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 1000 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.

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.

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.

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.

12.6.7 On ships constructed on or after 1 January 2016, two means of escape shall be provided from the a workshop within a machinery space. At least one of these escape routes shall provide a continuous fire helper to a safe position outside the machinery space.

12.6.8 On ships constructed on or after 1 January 2016, all inclined ladders/stairways fitted to comply with paragraph 12.6.1 with open treads in machinery spaces being part of or providing access to escape routes but not located within a protected enclosure shall be made of steel. Such ladders/stairways shall be fitted with steel shields attached to their under sides, such as to provide escaping personnel protection against heat and flame from beneath.

12.7 Additional requirements for ro-ro passenger ships

See B.12.7.

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:

13.1 a fixed fire detection and fire alarm system (see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.12); or

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.

13.3 Cabin balconies (see B.13.3).

14. Protection of vehicle, special category and ro-ro spaces

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.

14.2 Structural protection

The boundary bulkheads and decks of special category spaces shall be insulated as required for category [11] spaces in Table 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.

14.3 Fixed fire-extinguishing system

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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.12).

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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.12).

14.4 Ventilation system

There shall be provided an effective power ventilation system for the 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 9.11.

Permanent openings in the side plating, the ends or deck head 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.

14.5 Fire detection

There shall be provided a fixed fire detection and fire alarm system of an approved type (see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.12).

A sample extraction smoke detection system of an approved type (see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.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.

15. Special Arrangements in Machinery Spaces of Category A

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.

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.

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.

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.

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.

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.

15.7 The floor plating of normal passageways shall be made of steel.

16. Special Requirements for Ships Carrying Dangerous Goods

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.

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 3,0 m horizontally away from such bulkheads. Other boundaries between such spaces shall be insulated to ”A-60” standard.

16.3 Miscellaneous items

The kind and extent of the fire extinguishing equipment are defined in Rules for Machinery Installations (Pt.1, Vol.III) Sec.12.

Electrical apparatus and cablings are to meet the requirements of Rules for Electrical Installations (Pt.1, Vol.IV) Sec.14.

17. Safety Centre on Passenger Ships

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.

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.

17.3 Layout and ergonomic design

The layout and ergonomic design of the safety centre shall take into account the IMO guidelines16 (communication and control and monitoring of safety systems see also the BKI Rules for Electrical Installations (Pt.1, Vol.IV) Sec.14.

D. Passenger Ships with 3 or more Main Vertical Zones or with a Load Line Length of 120 m and over

1. The requirements of this Sub-section are additional to those of B or C.

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. (Reference is made to the "Interim Explanatory Notes for the Assessment of Passenger Ship Systems' Capabilities after a Fire or Flooding casualty" adopted by IMO MSC.1/Circ. 1369 as amended by IMO MSC.1/Circ 1437.)

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

1. Materials

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.

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:

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 anytime during the applicable fire exposure to the standard fire test.

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 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 1.2.1 shall apply at the end of half an hour.

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.

Note:

The interpretation of the Crowns of Machinery Spaces of Category A, as stated in paragraph 1.2.3, should comply with Guidance for Code and Convention Interpretation (Pt.1, Vol.Y), Sec.11, SC.302

2. Accommodation and Service Spaces

2.1 One of the following methods of protection shall be adopted in accommodation and service areas:

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 10.1; or

2.1.2 Method IIC

The fitting of an automatic sprinkler, fire detection and fire alarm system, as required by 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

2.1.3 Method IIIC

The fitting of a fixed fire detection and fire alarm system, as required by 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.

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.

3. Bulkheads within the accommodation and service spaces

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 ceiling or linings are fitted on both sides of the bulkhead in which case the bulkhead may terminate at the continuous ceiling or lining.

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.

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.

3.3.1 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 area of any accommodation space or space 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.

4. Fire Integrity of Bulkheads and Decks

4.1 In addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned else wherein this Section, the minimum fire integrity of bulkheads and decks shall be as prescribed in Tables 22.5 and 22.6.

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 3,0 m horizontally away from such bulkheads. Other boundaries between such spaces shall be insulated to ”A-60” standard.

4.3 Continuous ”B” class ceiling 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.

4.4 External boundaries which are required in 1.1 to be of steel or other equivalent material may be pierced for the fitting of windows and side scuttles provided that there is no requirement for such boundaries to have "A" class integrity else wherein 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.

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.

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 decks 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-03	A-60	A-0	A-0	A-0	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 and vehicle spaces	[11]											A-30[11]

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 3 and 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 is 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 3,0 m horizontally from such bulkhead.

7 For cargo spaces in which dangerous goods are intended to be carried 4.2 applies.

8 deleted

9 Fire insulation need not be fitted if the machinery spaces 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.

11 Ships constructed before 1 July 2014 shall comply, as a minimum, with the previous requirements applicable at the time the ship was contracted between builder and buyer (yard and owner).

Table 22.6 Fire integrity of decks separating adjacent spaces

Spaces Above / Spaces 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
Accommodation 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	-	A-0[11]
Ro-ro and vehicle spaces	[11]	A-60	A-30	A-30	A-30	A-0	A-60	A-0	A-0	A-30	A-0[11]	A-30[11]
See notes under Table 22.5												

[1] Control stations

Spaces containing emergency sources of power and lighting. Wheelhouse and chart-room. 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 provision for the storage of flammable liquids and having areas less than 4,0 m^2 and drying rooms and laundries.

[6] Machinery spaces of category A

Spaces and trunks to such spaces which contain:

internal combustible machinery used for main propulsion; or

internal combustible 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 4,0 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

5. Protection of Stairways and Lift Trunks in Accommodation Spaces, Service Spaces and Control Stations

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.

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 5.1 to ”B-0”.

5.3 All stairways shall be of steel frame construction or of other equivalent material.

6. Openings in Fire Resisting Divisions

6.1 Where ”A” or ”B” class division 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.

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 .[17)]

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 doorframes in ”A” class divisions shall be constructed of steel. Doors in ”B” class divisions shall be non-combustible. 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.

[17)] 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.

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.

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.

6.6 Watertight doors need not be insulated.

7. Ventilation systems

7.1 Ventilation ducts shall be of non-combustible material. Short ducts, however, not generally exceeding 2,0 m in length and with a cross-sectional area* not exceeding 0,02 m^2 need not be non-combustible, subject to the following conditions:

7.1.1 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[4)] not exceeding 45 MJ / m^2 of their surface area for the thickness used;

7.1.2 they may only be used at the end of the ventilation device;

7.1.3 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.

Note:

** The term free cross-sectional area means, even in the case of a pre-insulated duct, the area calculated on the basis of the inner dimensions of the duct itself and not the insulation.*

Paragraph 7.1 is to be interpreted in accordance with Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11.SC264

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 3,0 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:

7.2.1 The sleeves shall have a thickness of at least 3,0 mm and a length 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.

7.2.2 Ducts with a free cross-sectional area exceeding 0,075 m^2 shall be fitted with the fire dampers in addition to the requirements of 7.2.1. The fire dampers 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.

7.2.3 The following arrangement shall be of an approved type[3].

.1 fire dampers, including relevant means of operation

.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.

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.

7.4 Where they pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges shall be constructed in accordance with paragraphs 7.7. Each exhaust duct shall be fitted with:

7.4.1 a grease trap readily removable for cleaning;

7.4.2 an automatically and remotely operated fire damper located in the lower end of the duct at the junction between the duct and the galley range hood and, in addition, a remotely operated fire damper in the upper end of the duct close to the outlet of the duct;

7.4.3 arrangements, operable from within the galley, for shutting off the exhaust fan and supply fans; and

7.4.4 fixed means for extinguishing a fire within the duct (see Rules for Machinery Installations (Pt.1, Vol.III) Sec.12).

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 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.

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 4000 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.

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:

7.7.1 constructed of steel having a thickness of at least 3,0 mm and 5,0 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 5,0 m beyond each fire damper; or

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.

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:

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

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.

Note:

With respect to the application of paragraphs 7.6, 7.7 and 7.8, to determine fire insulation for trunks and ducts passing through enclosed spaces, the term 'pass through' pertains to the part of the trunk/duct contiguous to the enclosed space. The interpretations provided in Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11.SC301 should be observed.

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.

The interpretation in the Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11.SC300 should also be observed.

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.

8. Restricted use of Combustible Materials

8.1 All exposed surfaces in corridors and stairway enclosures and surfaces including grounds in concealed or in accessible 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[4] .

8.2 Paints, varnishes and other finished used on exposed interior surfaces shall not offer an undue fire hazard and shall not be capable of producing excessive quantities of smoke[11] .

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[12] .

8.4 Waste receptacles (see B.10.10)

9. Details of Construction

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.

9.2 Method 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.

9.3 Methods IC, IIC and IIIC

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 shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame-spread characteristics.

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[18)] not exceeding 45 MJ/m^2 of the area for the thickness used.

9.3.3 The total volume of combustible facings, moulding, 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 mm veneer on the combined area of the walls and ceilings.

9.3.4 Air spaces enclosed behind ceilings, panellings, or linings, shall be divided by close fitting draught stops spaced not more than 14 m apart. In the vertical direction, such air spaces, including those behind linings of stairways, trunks, etc., shall be closed at each deck.

10. Fixed fire detection and fire alarm systems, automatic sprinkler, fire detection and fire alarm systems

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.

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.

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.

11. Means of Escape

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.

11.2 Doors in escape routes shall, in general, open in-way of the direction of escape, except that

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

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.

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:

[18)] 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.

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.

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 stairway.

11.3.3 Above the lowest open deck the means of escape shall be stairways or doors to an open deck or a combination there of.

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 1800 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[13] .

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.

11.6 No dead-end corridors having a length of more than 7,0 m shall be accepted. A dead-end corridor is a corridor or part of a corridor from which there is only one escape route.

11.7 If a radio telegraph 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.

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.

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:

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 × 800 mm, and shall have emergency lighting provisions; or

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.

11.9.3 For a ship of a gross tonnage less than 1000, 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.

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.

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 5,0 m or less.

> ***Note:***
>
> *The interpretation of the requirements for means of escape from machinery spaces on cargo ships, as stated in paragraphs 11.9 and 11.10, should comply with Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Sec.11.SC277*

Furthermore, the interpretation of the means of escape requirements for the steering gear space, as stipulated in paragraphs 11.9.4 and 11.10, shall be conducted in accordance with Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Sec.11.SC269

11.11 On ships constructed on or after 1 January 2016, all inclined ladders/stairways fitted to comply with paragraph 11.9 with open treads in machinery spaces being part of or providing access to escape routes but not located within a protected enclosure shall be made of steel. Such ladders/stairways shall be fitted with steel shields attached to their undersides, such as to provide escaping personnel protection against heat and flame from beneath.

11.12 On ships constructed on or after 1 January 2016, two means of escape shall be provided from the machinery control room located within a machinery space of category "A". At least one of these escape routes shall provide a continuous fire shelter to a safe position outside the machinery space.

11.13 On ships constructed on or after 1 January 2016, two means of escape shall be provided from the main workshop within a machinery space of category "A". At least one of these escape routes shall provide a continuous fire shelter to a safe position outside the machinery space.

12. Miscellaneous Items

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.

12.2 Construction and arrangement of saunas, see B.11.5.

13. Protection of Cargo Spaces

13.1 Fire-extinguishing arrangements in cargo spaces

Fire-extinguishing arrangements according to Rules for Machinery Installations (Pt.1, Vol.III) Sec.12 are to be provided for cargo spaces.

14. Protection of Vehicle and Ro-ro Spaces

14.1 Fire detection

There shall be provided a fixed fire detection and fire alarm system of an approved type (see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.12).

A sample extraction smoke detection system of an approved type (see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.12) may be accepted as equivalent, except for open ro-ro and vehicle spaces.

14.2 Fire-extinguishing arrangements

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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.12).

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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.12).

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.

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 duct, including dampers, shall be made of steel.

Permanent openings in the side plating, the ends or deck head 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.

15. Special requirements for ships carrying dangerous goods

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.

> ***Note:***
>
> *In addition to these requirements, the applicable provisions of the IMSBC Code must be complied with. The interpretation regarding cargo space ventilation, as outlined in Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11.SC89 should also be observed.*

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 3,0 m horizontally away from such bulkheads. Other boundaries between such spaces shall be insulated to ”A-60” standard.

15.3 Separation of spaces

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 requirements of 14.

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.

15.4 Miscellaneous items

The kind and extent of the fire extinguishing equipment are to meet the requirements of Rules for Machinery Installations (Pt.1, Vol.III) Sec.12.

Electrical apparatus and cablings are to meet the requirements of Rules for Electrical Installations (Pt.1, Vol.IV) Sec.16.

F. Oil Tankers of 500 GT and over

(These requirements are additional to those of E. except as provided otherwise in 3 and 4.)

1. Application

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.

1.2 Where liquid cargoes other than those referred to in 1.1 or liquefied gases which introduce additional fire hazard are intended to be carried the requirements of Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX) and the requirements of Rules for Ships Carrying Dangerous Chemicals in Bulk (Pt.1, Vol.X) are to be taken into account.

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.

1.4 Chemical tankers and gas carriers shall comply with the requirements of this Section, unless other and additional safety precautions according the requirements of Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX) and the requirements of Rules for Ships Carrying Dangerous Chemicals in Bulk (Pt.1, Vol.X) apply.

2. Construction

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 3,0 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.

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 ships but not less than 3,0 m from the end of the superstructure or deckhouse facing the cargo area. This distance, however, need not exceed 5,0 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.

2.3 Windows and side scuttles facing the cargo area and on the sides of the superstructures and deck-houses within the limits specified in 2.2 shall be of the fixed (non-opening) type[3].

Such windows and side scuttles, 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 2.1.

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.

2.5 Furthermore the requirements of Section 24, Paragraph A.4 are to be observed.

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.

4. Fire Integrity of Bulkheads and Decks

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.

4.2 The following requirements shall govern application of the Tables:

Tables 22.7 and 22.8 shall apply respectively to the bulkhead and deck separating adjacent spaces.

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 Decks not forming steps in main vertical zones nor bounding zones

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-01	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 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-02	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 bulkheads separating adjacent spaces

Spaces Below / Spaces Above		[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 spaces (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 4,0 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 4,0 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 super structures and deckhouses).

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.

4.5 External boundaries which are required in E.3.1 to be of steel or other equivalent material may be pierced for the fitting of windows and side scuttles provided that there is not requirement for such boundaries to have "A" class integrity else where 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.

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 gas tightness of the bulkhead or deck is maintained.

4.7 Construction and arrangement of saunas.

See B.11.5.

G. Helicopter Decks

1. Helicopter decks shall be of a steel or steel equivalent fire-resistant construction. If the space below the helicopter deck forms the deck head 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:

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.

1.2 If the platform is located above the ship's deckhouse or similar structure, the following conditions shall be satisfied:

1.2.1 the deckhouse top and bulkheads under the platform shall have no openings;

1.2.2 all windows under the platform shall be provided with steel shutters;

1.2.3 the required fire-fighting equipment shall be in accordance with the requirements of Rules for Machinery Installations (Pt.1, Vol.III) Sec.12.

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.

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.

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Section 23 Bulk Carriers, Ore Carriers and Ships with Strengthenings for Bulk Cargo and Heavy Cargo

A. Strengthenings for Bulk Cargo and Heavy Cargo

1. General

1.1 For ships, occasionally or regularly carrying heavy cargo, such as iron, ore, phosphate etc., and not intended to get the notation "**BULK CARRIER**" (see B.) or "**ORE CARRIER**" (see C.) affixed to their character of classification Strengthenings according to the following regulations are recommended.

1.2 Ships complying with these requirements will get the following notation affixed to their character of classification "**STRENGTHENED FOR HEAVY CARGO**".

1.3 It is recommended to provide adequate strengthening or protection of structural elements within the working range of grabs.

In addition, these ships have to fulfil IMO Resolution MSC. 277(85) as defined in the Rules for Classification and Surveys (Pt.1, Vol.I) Sec.2.

The stability requirements of Section 36 apply and in addition for ships engaged in the carriage of grain in bulk the Grain Code apply.

1.4 References

1.4.1 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 S1A Rev.6

IACS UR S12 Rev.5

IACS UR S17 Rev.10

IACS UR S18 Rev.10

IACS UR S19 Rev.5

IACS UR S20 Rev.6

IACS UR S22 Rev.3

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.

2. Double Bottom

2.1 Where longitudinal framing is adopted for the double bottom, the spacing of plate floors should, in general, not 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, B.

For the longitudinal girder system, see Section 8, B.7.5.

2.2 Where transverse framing is adopted for the double bottom, plate floors according to Section 8, B.6 are to be fitted at every frame in way of the cargo holds.

2.3 For strengthening of inner bottom, deep tank tops etc. in way of grabs, see B.4.3.

2.4 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. Bulk Carriers

1. General

1.1 Definitions

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 1000 mm apart. The distance between the watertight boundaries is to be measured perpendicular to the side shell.

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 1000 mm or above apart. The distance between the watertight boundaries is to be measured perpendicular to the side shell.

For accessibility see Section 1, D.1.

1.2 The requirements of Section 1 to 22 and stability requirements of Section 36 apply to bulk carriers unless otherwise mentioned in A.1.1 is also to be observed.

1.3 For hull structural design of bulk carriers with **L** ≥ 90 m and being self-propelled ship with unrestricted navigation, contracted for construction on or after 1 July 2015 [1)] and in accordance with the definition in 1.4, the Rules for Bulk Carriers and Oil Tankers (Pt. 1, Vol. XVII) are applicable.

In addition to **BULK CARRIER** these ships will be assigned the Notation **CSR**.

[1)] Refer to IMO Resolution MSC.290(87) (adopted on 21 May 2010), Adoption Of Amendments To The International Convention For The Safety Of Life At Sea, 1974, As Amended. Regulation 3-10 shall apply to oil tankers of 150 m in length and above and to bulk carriers of 150 m in length and above, constructed with single deck, top-side tanks and hopper side tanks in cargo spaces, excluding ore carriers and combination carriers:

- for which the building contract is placed on or after 1 July 2016;
- in the absence of a building contract, the keels of which are laid or which are at a similar stage of construction on or after 1 July 2017; or
- the delivery of which is on or after 1 July 2020.

1.4 Bulk carrier according to the Rules for Bulk Carriers and Oil Tankers (Pt. 1, Vol. XVII) means a ship which is constructed generally with single deck, double bottom, top-side tanks and hopper side tanks in cargo spaces, with single or double side skin construction in cargo length area and is intended primarily to carry dry cargo in bulk. Typical midship sections are given in Fig. 23.14.

1.5 For bulk carriers carrying also oil in bulk also Section 24, G applies.

1.6 Where reduced freeboards according to ICLL shall be assigned, the respective requirements of the ICLL are to be observed.

1.7 The scantlings of the bottom construction are to be determined on the basis of direct calculations according to Section 8, B.8.

1.8 For corrosion protection for cargo hold spaces see Section 38, G.

1.9 For dewatering requirements of forward spaces of bulk carrier, see Rules for Machinery Installations (Pt.1, Vol.III) Sec.11.N.

1.10 For water ingress detection system of bulk carrier, see Rules for Electrical Installations (Pt.1, Vol.IV) Sec.18.

2. Longitudinal strength

2.1 General

The longitudinal strength of the ship is to comply with the requirements of Section 5 irrespective of the ship's length.

For alternate loading conditions Section 8, B.8.2.2 is to be observed.

2.2 Flooding

2.2.1 In addition to the loading conditions defined in Section 5, A.4 for all bulk carriers of 150 m in length and above, intending to carry solid bulk cargoes having a density of 1,0 t/m^3 or above, and with,

- single side skin construction, or
- double side skin construction in which any part of longitudinal bulkhead is located within **B**/5 or 11,5 m, whichever is less, inboard from the ship's side at right angle to the centreline at the assigned summer load line

The hull girder strength checked according to Section 5, C is to be adequate for the flooded conditions defined in 2.2.3, 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 in port" as well as "ballast water exchange" need not be considered.

(IACS UR S17.1)

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 with a permeability of zero.

(IACS UR S17.3)

2.2.3 Flooding conditions

.1 Floodable hold

Each cargo hold is to be considered individually flooded up to the equilibrium waterline. This requirement is to be applied to self-unloading bulk carriers (SUBC) where the unloading system maintains the watertightness during seagoing operations. In SUBCs with unloading systems that do not maintain watertightness, the longitudinal strength in the flooded conditions are to be considered using the extent to which the flooding may occur.

(IACS UR S17.2.1)

.2 Load

The still water loads in flooded conditions are to be calculated for the above cargo and ballast loading conditions.

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, B.3.1 and Section 5, B.3.2.

(IACS UR S17.2.2)

2.2.4 Stress assessment

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

$$\sigma_{fld} = \frac{M_{swf} + 0,8 \cdot M_{WV}}{W_z} \cdot 10^3$$

where:

M_{SWf} = still water bending moment in the flooded conditions [kNm]

M_{WV} = wave bending moment as given in Section 5, B.3.1 [kNm]

W_Z = section modulus for the corresponding location in the hull girder [cm^3]

The shear strength of the side shell and the inner hull (longitudinal bulkhead) if any, at any location of the ship, is to be checked according to the requirements specified in Section 5, D.3 in which Q_{SW} and Q_{WV} are to be replaced respectively by Q_{SWf} and Q_{WVf}, where:

Q_{SWf} = still water shear force in the flooded conditions [kN]

Q_{WVf} = 0,8 · Q_{WV}

Q_{WV} = wave shear force as given in Section 5, B.3.2 [kN]

(IACS UR S17.4)

2.2.5 Strength criteria

The damaged structure is assumed to remain fully effective in resisting the applied loading.

Permissible stress and axial stress buckling strength are to be in accordance with Section 5.

(IACS UR S17.5)

3. Definitions

k = material factor according to Section 2, B.

t_K = corrosion addition according to Section 3, K.

p_{bc} = bulk cargo pressure as defined in Section 4, C.1.4.

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.

$\overline{GM}$ = metacentric height [m], defines as:

= $0{,}24 \cdot \mathbf{B}$ [m]

z = centre of gravity of the steel coil loading [m], defined as:

= $h_{DB} + (1 + 0{,}866 \cdot (n_1 - 1)) \cdot d_c / 2$ [m]

a_v = acceleration addition according to Section 4, C.1.

B_H = breadth [m] of cargo hold

c_d = coefficient for the distance of steel coils in ship's longitudinal direction, defined as:

= $\min\left(0,2\,;\,\frac{0,3}{\ell_c}\right)$

d_c = diameter [m] of steel coils

g = gravitational acceleration [m/s^2], defined as:

= 9,81 [m/s^2]

h_{DB} = height [m] of double bottom

l_c = length [m] of steel coils

L = corresponds to the length of the ship as **L**, but not to be taken greater than 200 m

p_L = bulk cargo pressure according to Section 4, C.1.4.

p_i = load on inner bottom according to Section 4, C.1.2.

W = mass [kg] of one steel coil

φ = design roll angle [°], defined as:

= 30 [°]

μ = coefficient of friction, defined as:

= 0,3 in general

ρ = sea water density [t/m^3], defined as:

= 1,025 [t/m^3]

$\sigma_{L,i}$ = maximum design hull girder bending stress in the inner bottom according to Section 5, D.

$\sigma_{L,l}$ = maximum design hull girder bending stress in the longitudinal bulkhead according to Section 5, D.

σ_{perm} = permissible design stress [N/mm^2], as defined:

= $\left(0,8 + \frac{\mathbf{L}}{450}\right) \cdot \frac{230}{k}$ for **L** < 90 m

= $\frac{230}{k}$ for **L** ≥ 90 m

τ_L = maximum design shear stress due to longitudinal hull girder bending according to Section 5, D.

4. Scantlings of bottom structure

4.1 General

The scantlings of double bottom structures in way of the cargo holds are to be determined by means of direct calculations according to Section 8, B.8.

For ships according to 2.2.1 and D. has to be observed in addition.

Note:

Upon request, BKI will carry out calculations for the bottom structure.

4.2 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 E.4.1.1.

4.3 Inner bottom and tank side slopes

4.3.1 The thickness of the inner bottom plating is to be determined according to Section 8, B.4.

When determining the load on inner bottom p_i, a cargo density of not less than 1,0 t/m^3 is to be used.

For determining scantlings of tank side slopes the load pi is not to be taken less than the load which results from an angle of heel of 20°.

4.3.2 Where the plating has been designed according to the following formula, in connection with 9. The Notation “**G**” may be entered into the Certificate behind the Character of Classification:

$$t_G = (0,1 \cdot \mathbf{L} + 5) \cdot \sqrt{k} \qquad [\text{mm}]$$

The thickness, however, need not exceed 30 mm.

Note:

The stressing of the inner bottom plating depends mainly on the use of grabs, therefore, damage of plating cannot be excluded, even in case of compliance with the above recommendation.

4.3.3 Sufficient continuity of strength is to be provided for between the structure of the bottom wing tanks and the adjacent longitudinal structure.

5. Side Structures

5.1 Side longitudinals, longitudinal stiffeners, main frames

The scantlings of side longitudinals are to be determined according to Section 9, B. 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 4.3.1. For the longitudinal stiffeners of the topside tanks within the upper flange Section 9, B.1.3 is to be observed.

(IACS UR S12.4)

5.2 Main frames and end connection

The section modulus of main frames of single side skin bulk carrier is to be increased by at least 20% above the value required by Section 9, A.2.1.1.

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)

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:

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

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 **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:

$$\frac{h_w}{t_w} = 60 \cdot \sqrt{k} \qquad \text{for symmetrically flanged frames}$$

$$\frac{h_w}{t_w} = 50 \cdot \sqrt{k} \qquad \text{for asymmetrically flanged frames}$$

The outstanding flange b_1 is not to exceed 10 times the flange thickness, see Fig. 23.1.

(IACS UR S12.5)

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, A.5.5.

(IACS UR S12.6)

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.

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:

$$t_{w,min} = C \cdot (7,0 + 0,03 \cdot \mathbf{L}) \quad [mm]$$

where **L** need not be taken greater than 200 m.

C = 1,15 for the frame webs in way of the foremost hold

= 1,0 for the frame webs in way of other holds

(IACS UR S12.3)

The thickness of the brackets at the lower frame ends is not to be less than the required web thickness tw 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)

5.3 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 $t_{p,min}$ [mm], given by :

$$t_{p,min} = \sqrt{\mathbf{L}} \quad [mm]$$

(IACS UR S12.8)

5.4 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 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)

6. Topside tanks

6.1 The plate thickness of the topside tanks is to be determined according to Section 12.

6.2 Where the transverse stiffening system is applied for the longitudinal walls of the topside tanks and for the shell plating in way of 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, A.3.

6.3 The buckling strength of top side tank structures is to be examined in accordance with Section 3, F.

6.4 Sufficient continuity of strength is to be provided for between the structure of the topside tanks and the adjacent longitudinal structure.

7. Transverses in the wing tanks

Transverses in the wing tanks are to be determined according to Section 12, B.3 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 4.3.1.

8. Cargo hold bulkheads

The following requirement apply to cargo hold bulkheads on the basis of the loading conditions according to Section 5, A.4.

For vertically corrugated transverse cargo hold bulkheads on ships according to 2.2.1 the requirements of E. apply in addition, where the strength in the hold flooded condition has to be ensured.

8.1 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 pbc according to Section 4, C.1.4 is to be used for the load p.

8.2 The scantlings are not to be less than those required for a watertight bulkhead according to Section 11. The plate thickness is in no case to be taken less than 9,0 mm.

8.3 The scantlings of the cargo hold bulkheads are to be verified by direct calculations. Permissible stresses are given in Section 11, B.5.3.1.

8.4 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 $\approx \dfrac{\mathbf{B}}{22}$

— face plate (thickness) = 1,5 times the thickness of the upper plate strake of the bulkhead.

See also E.4.1.3.

8.5 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**H** where the length of the cargo hold is 20 m. Where the length of the cargo hold is greater/smaller, the width of the strip of plating is to be increased/reduced proportionally.

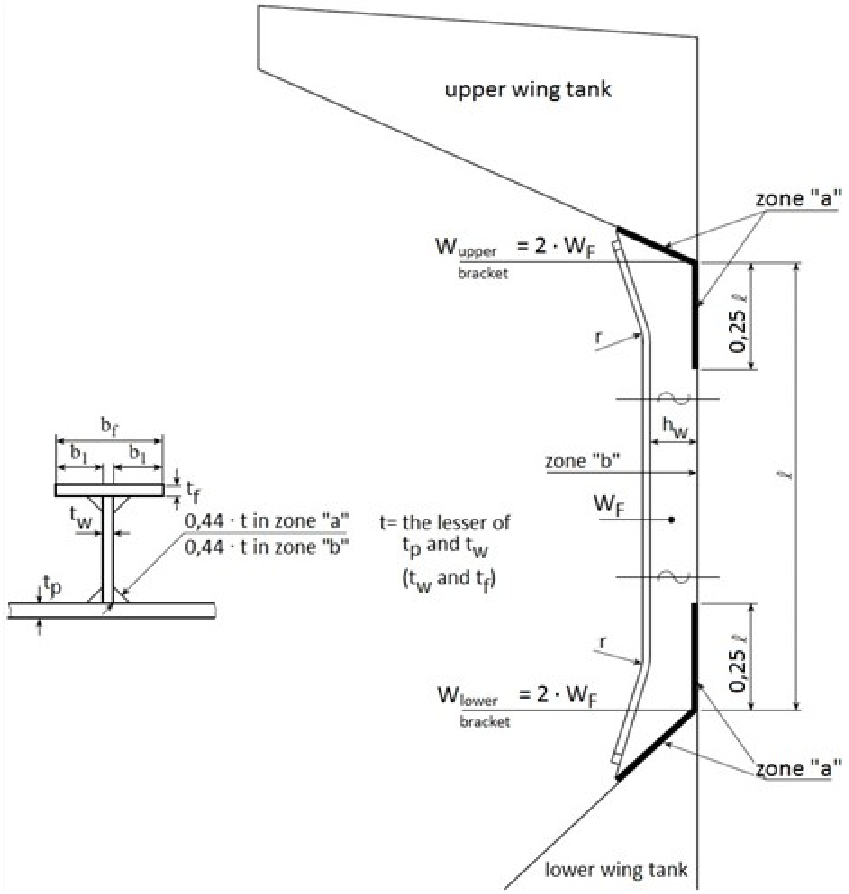


Fig. 23.1 Side frame of single side skin bulk carrier

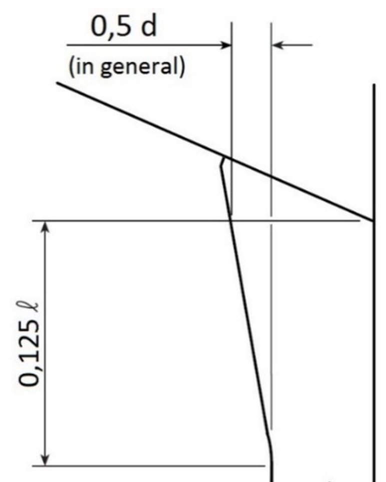


Fig. 23.2 Dimensions of the upper and lower bracket of the side frames

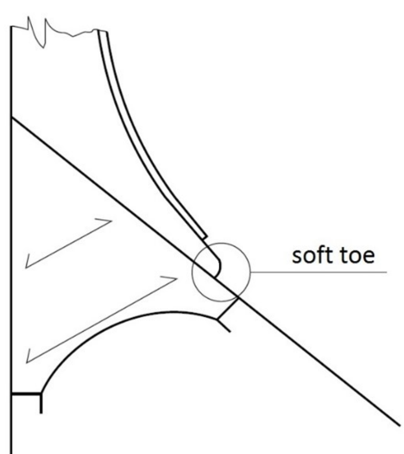


Fig. 23.3 Connecting bracket in the hopper tank

9. Hatchway coamings, longitudinal bulkheads

9.1 Coamings

The scantlings of the hatchway coaming plates are to be determined such as to ensure efficient protection against mechanical damage by grabs.

The coaming plates are to have a minimum thickness of 15 mm. Stays shall be fitted at every alternate frame. The longitudinal hatchway coamings are to be extended in a suitable manner beyond the hatchway corners.

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.

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.

See also Section 17.

9.2 Longitudinal bulkheads

Where longitudinal bulkheads exposed to grabs have got a general corrosion addition according to Section 3, K.2 of t_K = 2,5 mm in connection with 4.3.2 and 9.1 the Notation **G** may be entered into the Certificate behind the Character of Classification.

10. Loading information for Bulk Carriers, Ore Carriers and Combination Carriers

10.1 General, definitions

10.1.1 These requirements are additional to those specified in Section 5, A.4.3 and apply to Bulk Carriers, Ore Carriers and Combination Carriers of 150 m length and above, and are minimum requirements for loading information.

10.1.2 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.

10.1.3 The following definition apply:

Loading manual is a document which in addition to the definition given in Section 5, A.4.1.3 describes:

- envelope results and permissible limits of still water bending moments and shear forces in the hold flooded condition according to 2.2.
- the 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 ship 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, A.4.1.3 shall 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 2.2

are within permissible values.

(IACS UR S1A.2)

10.2 Conditions of approval of loading manuals

In addition to the requirements given in Section 5, A.4.2 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. For ships having ballast holds adjacent to topside wing-, hopper- and double bottom tanks it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty.
- 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, the relevant part load conditions and alternate conditions, where applicable. Typical unloading sequences for these conditions shall also be included. The typical loading/unloading sequences shall also be developed to not exceed applicable strength limitations. The typical loading sequences shall also be developed paying due attention to loading rate and the deballasting capability Fig. 23.4 contains, as guidance only, an example of a loading sequence summary form.
- typical sequences for change of ballast at sea, where applicable.

(IACS UR S1A.3)

10.3 Condition of Approval of the loading instrument

For approval of the loading instrument see Guidelines for Certification of Loading Computer Systems (Pt.4, Vol.1).

10.4 Guidance for loading/unloading sequences[2)]

10.4.1 The typical loading/unloading sequences shall be developed paying due attention to the loading/unloading rate, the ballasting/deballasting capacity and the applicable strength limitations.

10.4.2 The typical loading/unloading sequence is to be prepared and submitted for approval by shipyard:

[2)] In addition, guidance for loading/unloading sequences of existing Bulk Carriers with length of 150 m and above, where one or more cargo holds are bounded by the side shell only, which were contracted for construction before 1st July 1998 refer to Annex 2 of IACS UR S1A.

10.4.3 The typical loading sequences as relevant shall include:

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

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

10.4.5 The sequence shall be built up step by step from commencement of cargo loading to reach full deadweight capacity. Each time the loading equipment changes position to a new hold defines a step. Each step shall be documented and submitted to BKI. In addition to longitudinal strength, the local strength of each hold shall be considered.

10.4.6 For each loading condition, a summary of all steps shall be included. This summary shall highlight the essential information for each step, such as:

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

(IACS UR S1A.Annex 3)

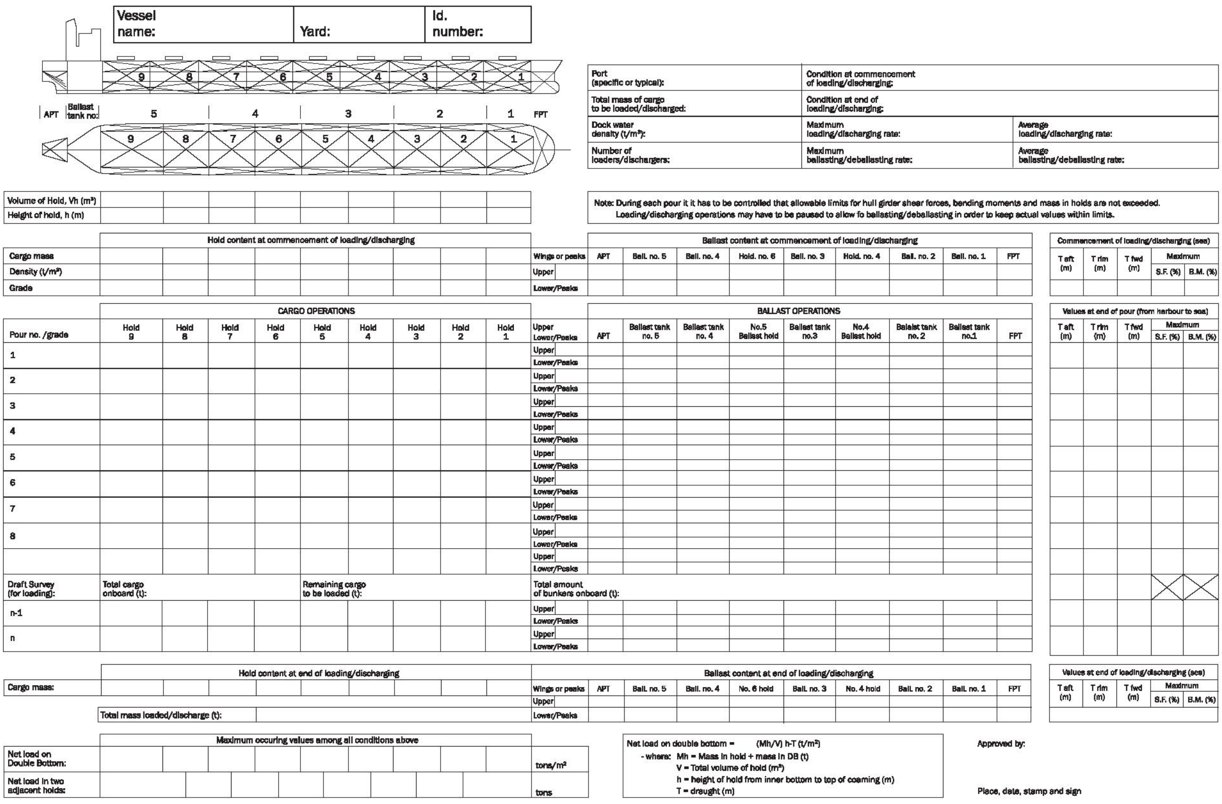

Vessel name:
Yard:
Id. number:
9 8 7 6 5 4 3 2 1
APT Ballast tank no: 5 4 3 2 1 FPT
Port (specific or typical):
Condition at commencement of loading/discharging:
Total mass of cargo to be loaded/discharged:
Condition at end of loading/discharging:
Dock water density (t/m³):
Maximum loading/discharging rate:
Average loading/discharging rate:
Number of loaders/dischargers:
Maximum ballasting/deballasting rate:
Average ballasting/deballasting rate:
Volume of Hold, Vh (m³)
Height of hold, h (m)
Note: During each pour it it has to be controlled that allowable limits for hull girder shear forces, bending moments and mass in holds are not exceeded.
Loading/discharging operations may have to be paused to allow fo ballasting/deballasting in order to keep actual values within limits.
Hold content at commencement of loading/discharging
Cargo mass
Density (t/m³)
Grade
Wings or peaks
Upper
Lower/Peaks
Ballast content at commencement of loading/discharging
APT | Ball. no. 5 | Ball. no. 4 | Hold. no. 6 | Ball. no. 3 | Hold. no. 4 | Ball. no. 2 | Ball. no. 1 | FPT
Commencement of loading/discharging (sea)
T aft (m) | T rim (m) | T fwd (m) | Maximum S.F. (%) | B.M. (%)
CARGO OPERATIONS
Pour no. /grade | Hold 9 | Hold 8 | Hold 7 | Hold 6 | Hold 5 | Hold 4 | Hold 3 | Hold 2 | Hold 1 | Upper Lower/Peaks
1
2
3
4
5
6
7
8
BALLAST OPERATIONS
APT | Ballast tank no. 5 | Ballast tank no. 4 | No.5 Ballast hold | Ballast tank no.3 | No.4 Ballast hold | Balaist tank no. 2 | Ballast tank no.1 | FPT
Values at end of pour (from harbour to sea)
T aft (m) | T rim (m) | T fwd (m) | Maximum S.F. (%) | B.M. (%)
Draft Survey (for loading):
Total cargo onboard (t):
Remaining cargo to be loaded (t):
Total amount of bunkers onboard (t):
n-1
n
Hold content at end of loading/discharging
Cargo mass:
Total mass loaded/discharge (t):
Ballast content at end of loading/discharging
Wings or peaks | APT | Ball. no. 5 | Ball. no. 4 | No. 6 hold | Ball. no. 3 | No. 4 hold | Ball. no. 2 | Ball. no. 1 | FPT
Upper
Lower/Peaks
Values at end of loading/discharging (sea)
T aft (m) | T rim (m) | T fwd (m) | Maximum S.F. (%) | B.M. (%)
Maximum occuring values among all conditions above
Net load on Double Bottom: tons/m²
Net load in two adjacent holds: tons
Net load on double bottom = (Mh/V) h-T (t/m²)
- where: Mh = Mass in hold + mass in DB (t)
V = Total volume of hold (m³)
h = height of hold from inner bottom to top of coaming (m)
T = draught (m)
Approved by:
Place, date, stamp and sign

Fig. 23.4 Loading Sequence Summary Form

(IACS UR S1A.Annex 1)

C. Ore Carriers

1. General

1.1 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 primary to carry ore cargoes in the centre hold only.

1.2 Ships built in accordance with the following requirements will get the Notation "**ORE CARRIER**" affixed to their Character of Classification. Entries will be made into the Certificate as to whether specified cargo holds may be empty in case of alternating loading. Additional indications of the types of cargo for which the ship is strengthened may be entered into the Certificate.

1.3 For ships subject to the provisions of this paragraph the requirements of B. are applicable unless otherwise mentioned in this sub-section.

1.4 For ore carriers carrying also oil in bulk also Section 24, G applies.

1.5 Where reduced freeboards according to ICLL shall be assigned, the respective requirements of the ICLL are to be observed.

2. Double bottom

2.1 For achieving good stability criteria in the loaded condition the double bottom between the longitudinal bulkheads should be as high as possible.

2.2 The strength of the double bottom structure is to comply with the requirements given in B.4.

3. Transverse and longitudinal bulkheads

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.

3.2 The scantlings of cargo hold bulkheads exposed to the load of the ore cargo are to be determined according to B.8. The scantlings of the side longitudinal bulkheads are to be at least equal to those required for tankers.

D. Allowable hold loading, considering flooding

1. General

These requirements apply to all bulk carriers, defined in B.2.2.1.

The loading in each hold is not to exceed the allowable loading according to 4. and shall not exceed the design hold loading in intact condition.

2. Load model

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.

2.2 Inner bottom flooding head

The flooding head h_f (see Fig. 23.5) 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 :

- $1{,}0 \cdot \mathbf{H}$ for the foremost hold
- $0{,}9 \cdot \mathbf{H}$ for the other holds

For ships less than 50000 tdw with Type B freeboard, d_f is:

- $0{,}95 \cdot \mathbf{H}$ for the foremost hold
- $0{,}85 \cdot \mathbf{H}$ for the other holds

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. 23.6
- 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} [mm] is given by:

$$t_{net} = t - 2{,}5 \quad [mm]$$

t = thickness [mm], of floors and girders

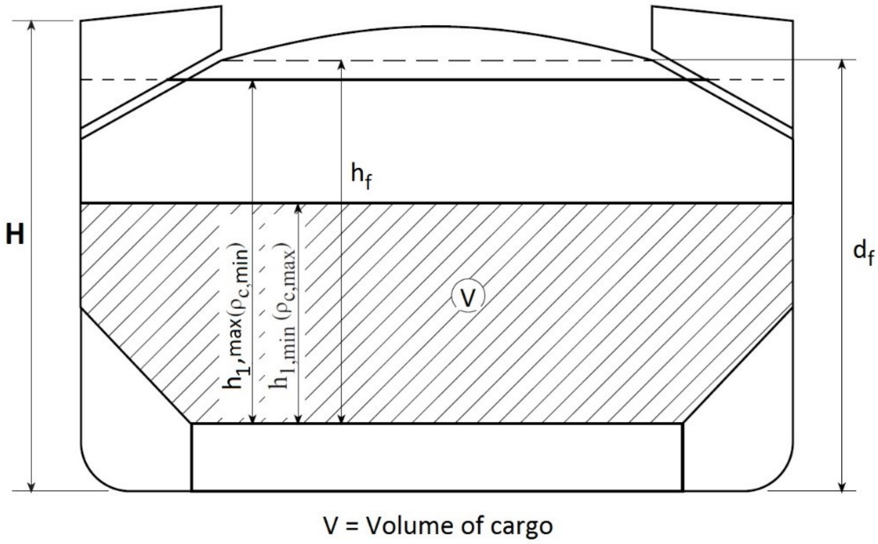


Fig. 23.5 Flooding head h_f of the inner bottom

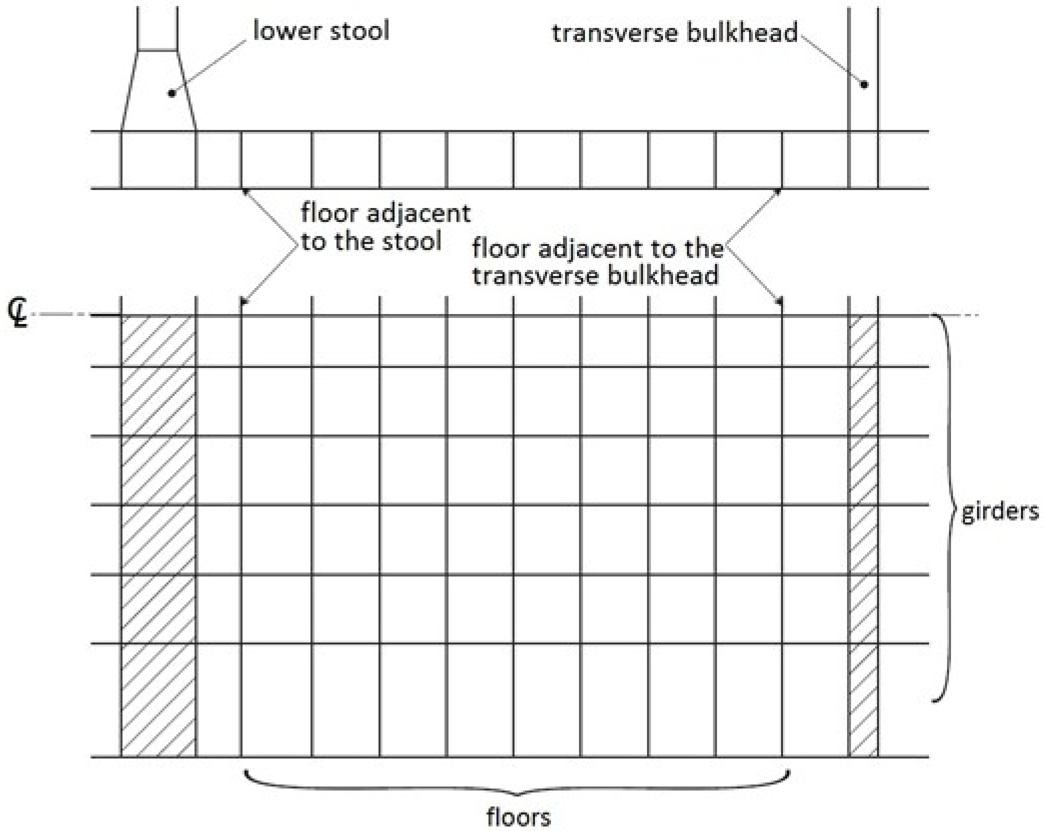


Fig. 23.6 Girders and floors in the double bottom

3.1 Floor shear strength

The floor shear strength in way of the floor panel adjacent to hoppers S_{f1} [kN], 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} [kN], are given by the following expressions:

$$S_{f1} = 10^{-3} \cdot A_r \cdot \frac{\tau_a}{\eta_1}$$

$$S_{f2} = 10^{-3} \cdot A_{f,h} \cdot \frac{\tau_a}{\eta_2}$$

A_f = sectional area [mm^2], of the floor panel adjacent to hoppers

$A_{f,h}$ = net sectional area [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 [N/mm2], to be taken equal to the lesser of

$$= \frac{162 \cdot R_{eH}^{0,6}}{\left(\frac{a}{t_{net}}\right)^{0,8}} \quad \text{and} \quad \frac{R_{eH}}{\sqrt{3}}$$

for floors adjacent to the stools or transverse bulkheads, as identified in 3, τ_a may be taken

as $\frac{R_{eH}}{\sqrt{3}}$

R_{eH} = minimum upper yield stress [N/mm^2], of the hull structural steel

a = spacing of stiffening members [mm], of panel under consideration

η_1 = 1,10

η_2 = 1,20 in general

= 1,10 where appropriate reinforcements are fitted

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} [kN], and the girder shear strength in way of the largest opening in the outmost bay (i.e. that bay which is closer to stool, or transverse bulkhead, if no stool is fitted) S_{g2} [kN], are given by:

$$S_{g1} = 10^{-3} \cdot A_g \cdot \frac{\tau_a}{\eta_1}$$

$$S_{g2} = 10^{-3} \cdot A_{g,h} \cdot \frac{\tau_a}{\eta_2}$$

A_g = minimum sectional area [mm^2], of the girder panel adjacent to stools (or transverse bulkheads, if no stool is fitted)

$A_{g,h}$ = net sectional area [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 [N/mm^2], as given in 3.1

η_1 = 1,10

η_2 = 1,15 in general

= 1,10 where appropriate reinforcements are fitted

4. Allowable hold loading

Calculating the allowable hold loading HL [t], the following condition are to be complied:

HL = the lesser of HL_1 and HL_2

$$HL_1 = \frac{\rho_c \cdot V}{F}$$

HL_2 = HL_{int}

HL_{int} = max. perm. hold loading for intact condition [t]

F = factor, defined as:

= 1,10 in general

= 1,05 for steel mill products

ρ_c = cargo density [t/m^3], for bulk cargoes see 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:

$$= \frac{X}{\rho_c \cdot g}$$

For bulk cargoes, X is the lesser of X_1 and X_2 given by:

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

$$X_2 = Z + \rho \cdot g \cdot (E - h_r \cdot perm)$$

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.

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 BKI.

ρ = 1,025 [t/m^3], sea water density

g = 9,81 [m/s^2], gravitational acceleration

E = (nominal ship) immersion [m] for flooded hold condition

= d_f – 0,1 **H**

Z = the lesser of Z_1 and Z_2:

$$Z_1 = \frac{C_h}{A_{DB,h}} \quad [kN/m^2]$$

$$Z_2 = \frac{C_e}{A_{DB,e}} \quad [kN/m^2]$$

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

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

$A_{DB,h}$ = relative load area [m^2], defined as:

$$= \sum_{i=1}^{i=n} S_i \cdot B_{DB,i} \quad [m^2]$$

$A_{DB,e}$ = relative load area [m^2], defined as:

$$= \sum_{i=1}^{i=n} S_i \cdot (B_{DB,i} \cdot a_\ell) \qquad [m^2]$$

n = number of floors between stools (or transverse bulkheads, if no stool is fitted)

S_i = spacing of ith - floor [m]

$B_{DB,i}$ = breadth [m] of double bottom related to shear strength calculation of floor, defined as:

= $B_{DB} - a_\ell$ for floors whose shear strength is given by S_{f1}, see 3.1

= $B_{DB,h}$ for floors whose shear strength is given by S_{f2}, see 3.1

B_{DB} = breadth of double bottom [m] between hoppers, see Fig. 23.7

$B_{DB,h}$ = distance [m] between the two considered openings, see Fig. 23.7

a_ℓ = spacing [m], of double bottom longitudinals adjacent to hoppers.

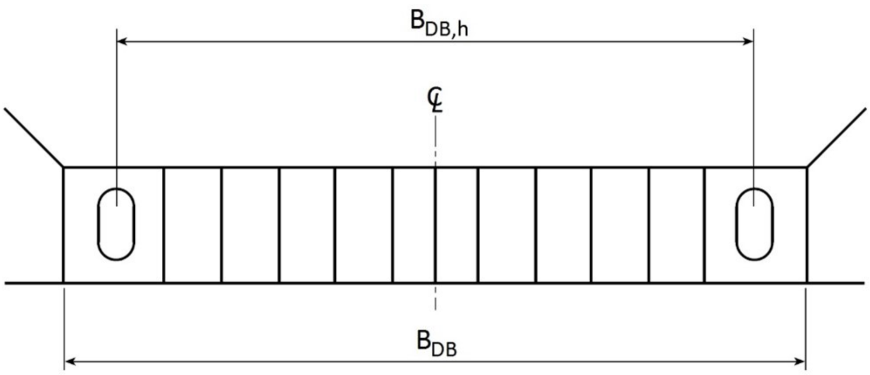


Fig. 23.7 Effective distance B_{DB} and $B_{DB,h}$ for the calculation of shear capacity

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

1. Application and definitions

These requirements apply to all bulk carriers with **L** ≥ 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, and with,

- single side skin construction, or
- double side skin construction in which any part of longitudinal bulkhead is located within **B**/5 or 11,5 m, whichever is less, inboard from the ship's side at right angle to the centreline at the assigned summer load line

The net thickness t_{net} is the thickness obtained by applying the strength criteria given in 4.

The required thickness is obtained by adding the corrosion addition t_K, given in 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

2. Load model

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.

This application is to be applied to self-unloading bulk carriers (SUBC) where the unloading system maintains the watertightness during seagoing operations. In SUBCs with unloading systems that do not maintain watertightness, the combination loads acting on the bulkheads in the flooded conditions are to be considered using the extent to which the flooding may occur.

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 nonhomogeneous 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 shall also be considered to fill that hold up to the upper deck level at centre line.

2.2 Bulkhead corrugation flooding head

The flooding head h_f (see Fig. 23.8) 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.

d_f is in general:

— 1,0 · **H** for the aft transverse corrugated bulkhead of the foremost hold

— 0,9 · **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, the following values can be assumed for d_f :

— 0,95· **H** for the aft transverse corrugated bulkhead of the foremost hold

— 0,85· **H** for the other bulkheads

For ships less than 50000 tdw with Type B freeboard d_f is :

— 0,95 · **H** for the aft transverse corrugated bulkhead of the foremost hold

— 0,85 · **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, the following values can be assumed :

— 0,9· **H** for the aft transverse corrugated bulkhead of the foremost hold

— 0,8· **H** for the other bulkheads.

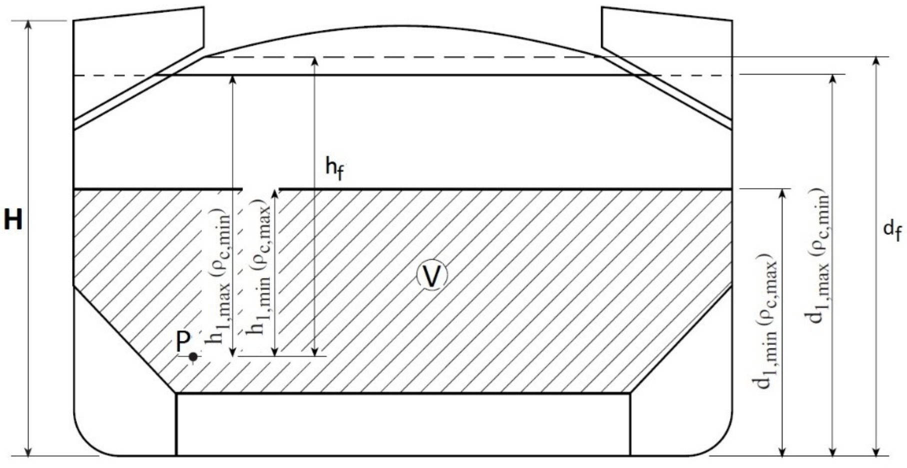


Fig. 23.8 Flooding head h_f of a corrugated bulkhead

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. 23.9 and Fig. 23.10 the pressure p_c [kN/m^2], is given by:

$$p_c = \rho_c \cdot g \cdot h_1 \cdot n$$

ρ_c = bulk cargo density [t/m^3]

g = 9,81 [m/s^2], gravitational acceleration

h_1 = vertical distance [m], from the calculation point to the horizontal plane corresponding to the level height of the cargo (see Fig. 23.8), located at a distance d_1 [m], from the baseline

n = $\tan^2\left(45° - \frac{\gamma}{2}\right)$

γ = angle of repose of the cargo, that may generally be taken as 35° for iron ore and 25° for cement

F_c = force [kN], acting on a corrugation is given by :

$$F_c = \rho_c \cdot g \cdot e_1 \cdot \frac{(d_1 - h_{DB} - h_{L5})^2}{2} \cdot n$$

e_1 = spacing of corrugations [m], see Fig. 23.9

h_{L5} = mean height of t he lower stool [m], from the inner bottom

h_{DB} = height of the double bottom [m]

2.4 Pressure in the flooded holds

2.4.1 Bulk cargo holds

Two cases are to be considered, depending on the values of d_1 and d_f.

a) $d_f \geq d_1$

At each point of the bulkhead located at a distance between d_1 and d_f from the baseline, the pressure $p_{c,f}$ [kN/m^2], is given by :

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

ρ = 1,025 [t/m^3], sea water density

At each point of the bulkhead located at a distance lower than d_1 from the baseline, the pressure $p_{c,f}$ [kN/m^2], is given by:

$$p_{c,f} = \rho \cdot g \cdot h_f + [\rho_c - \rho(1 - \text{perm})]\, g \cdot h_1 \cdot n$$

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 $F_{c,f}$ [kN], acting on a corrugation is given by :

$$F_{c,f} = e_1 \cdot \left[\rho \cdot g \frac{(d_f - d_1)^2}{2} + \frac{\rho \cdot g \cdot (d_f - d_1) + P_{c,f,ie}}{2} \cdot (d_1 - h_{DB} - h_{LS})\right] \quad \text{[kN]}$$

$_{c,f,ie}$ = pressure [kN/m^2], at the lower end of the corrugation

b) $d_f < d_1$

At each point of the bulkhead located at a distance between d_f and d_1 from the baseline, the pressure $p_{c,f}$ [kN/m^2], is given by :

$$p_{c,f} = \rho_c \cdot g \cdot h_1 \cdot n$$

At each point of the bulkhead located at a distance lower than d_f from the baseline, the pressure $p_{c,f}$ [kN/m^2], is given by:

$$p_{c,f} = \rho \cdot g \cdot h_f + [\rho_c \cdot h_1 - \rho(1 - \text{perm}) \cdot h_f]\, g \cdot n$$

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

$$F_{c,f} = e_1 \cdot \left[\rho_c \cdot g \frac{(d_1 - d_f)^2}{2} \cdot n + \frac{\rho_c \cdot g \cdot (d_f - d_1) + P_{c,f,ie}}{2} \cdot (d_f - h_{DB} - h_{LS})\right] \quad \text{[kN]}$$

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 [kN], acting on a corrugation is given by :

$$F_f = e_1 \cdot \rho \cdot g \cdot \frac{(d_f - h_{DB} - h_{LS})^2}{2}$$

2.5 Resultant pressure and force

2.5.1 Homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure p [kN/m^2], to be considered for the scantlings of the bulkhead is given by :

$$p = p_{c,f} - 0{,}8 \cdot p_c$$

The resultant force F [kN], acting on a corrugation is given by :

$$F = F_{c,f} - 0{,}8 \cdot F_c$$

2.5.2 Non homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure p [kN/m^2], to be considered for the scantlings of the bulkhead is given by :

$$p = p_{c,f}$$

The resultant force F [kN], acting on a corrugation is given by :

F = ‘ $F_{c,f}$

3. Bending moment and shear force in the bulkhead corrugations

The bending moment M and the shear force Q in the bulkhead corrugations are obtained using the formulae given in 3.1 and 3.2. The M and Q values are to be used for the checks in 4.2.

3.1 Bending moment

The design bending moment M [kN · m], for the bulkhead corrugations is given by :

$$M = \frac{F \cdot \ell}{8}$$

F = resultant force [kN], as given in 2.5

ℓ = span [m] of the corrugation, to be taken according to Fig. 23.9 and Fig. 23.10

3.2 Shear force

The shear force Q [kN], at the lower end of the bulkhead corrugations is given by:

$$Q = 0{,}8 \cdot F$$

F = resultant force as given in 2.5

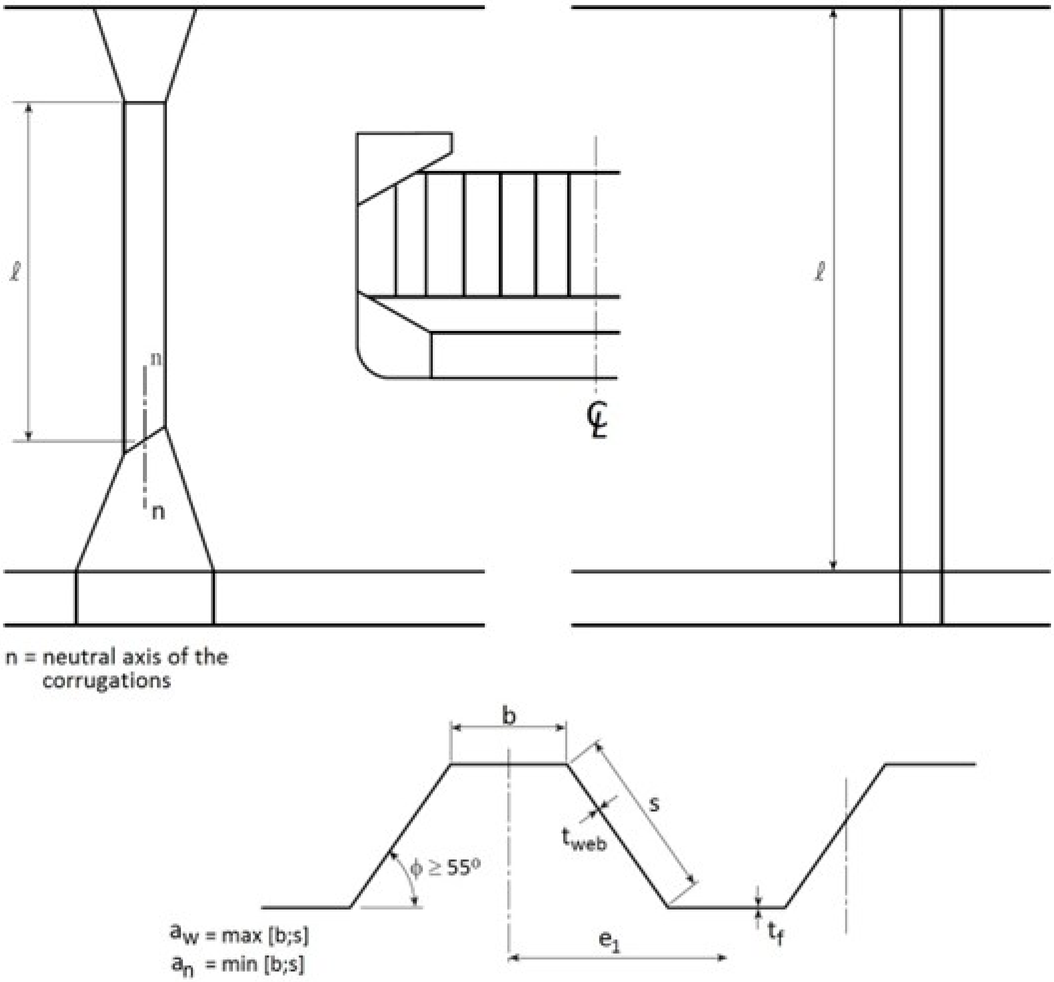
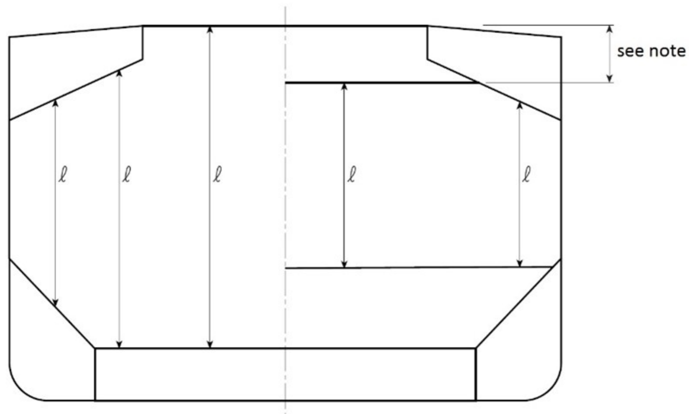


Fig. 23.9 Span ℓ of the corrugation (longitudinal section)



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. 23.10 Span ℓ of the corrugation (transverse section)

4. Strength criteria

4.1 General

The following criteria are applicable to transverse bulkheads with vertical corrugations, see Fig. 23.9. 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 4.1.1 and 4.1.2. See also B.8.4.

The corrugation angle Φ shown in Fig. 23.9 is not to be less than 55°.

Requirements for local net plate thickness are given in 4.7.

In addition, the criteria as given in 4.2 and 4.5 are to be complied with.

The thicknesses of the lower part of corrugations considered in the application of 4.2 and 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 4.2 and 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 stresses.

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 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. 23.13. 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. 23.14. The supporting floors are to be connected to the inner bottom by either full penetration or deep penetration welds, see Fig. 23.14.

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 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.

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. 23.14. 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.

4.2 Bending capacity and shear stress τ

The bending capacity is to comply with the following relationship:

$$\frac{\mathrm{M} \cdot 10^3}{0,5 \cdot \mathrm{W}_{\mathrm{le}} \cdot \sigma_{\mathrm{a,le}} + \mathrm{W}_{\mathrm{m}} \cdot \sigma_{\mathrm{a,m}}} \leq 0,95$$

M = bending moment [kN m], as given in 3.1

W_{le} = section modulus of one half pitch corrugation [cm^3], at the lower end of corrugations, to be calculated according to 4.3

W_m = section modulus of one half pitch corrugation [cm^3], at the mid-span of corrugations, to be calculated according to 4.4

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

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

In no case is W_m to be taken greater than the lesser of 1,15 · W_{le} and 1,15 · 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:

$$W'_{le} = W_g + 10^3 \cdot \frac{Q \cdot h_g - 0,5 \cdot h_g^2 \cdot e_1 \cdot p_g}{\sigma_a} \quad [cm^3]$$

W_g = section modulus of one half pitch corrugation [cm^3], of the corrugations calculated, according to 4.4, in way of the upper end of shedder or gusset plates, as applicable
Q = shear force [kN], as given in according to 3.2
h_g = height [m], of shedders or gusset plates, as applicable (see Fig. 23.11 and Fig. 23.12)
e_1 = as given in 2.3
p_g = resultant pressure [kN/m^2], as defined in 2.5, calculated in way of the middle of the shedders or gusset plates, as applicable
σ_a = allowable stress [N/mm^2], as given in according to 4.5

Stresses τ are obtained by dividing the shear force Q by the shear area. The shear area is to be reduced in order to account for possible non-perpendicularity between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by (sin Φ), Φ being the angle between the web and the flange (see Fig. 23.9).

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 4.3 and 4.4.

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 4.6.1.

If the corrugation webs are not supported by local brackets below the stool top (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30 % effective.

a) Provided that effective shedder plates, as defined in 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 [cm^2], may be increased by :

$$\Delta A_f = 2,5 \cdot b \cdot \sqrt{t_f \cdot t_{sh}} \quad [cm^2] \quad \text{(not to be taken greater than 2,5} \cdot b \cdot t_f)$$

b = width [m], of the corrugation flange, see Fig. 23.9

t_{sh} = net shedder plate thickness [mm]

t_f = net flange thickness [mm]

b) Provided that effective gusset plates, as defined in 4.2, are fitted (see Fig. 23.12), when calculating the section modulus of corrugations at the lower end (cross-section ① in Fig. 23.12), the area of flange plates [cm^2], may be increased by :

$$\Delta A_r = 7 \cdot h_g \cdot t_f \qquad [\mathrm{cm}^2]$$

h_g = height of gusset plate [m], see Fig. 23.12, with :

$$h_g \leq \frac{10}{7} \cdot a_{gu} \quad [\mathrm{m}]$$

a_{gu} = width of the gusset plates

$$a_{gu} = 2 \cdot e_1 - b \quad [\mathrm{m}]$$

t_f = net flange thickness [mm], based on the as built condition

c) 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 b) above. No credit can be given to shedder plates only.

For angles less than 45°, the effectiveness of the web may be obtained by linear interpolation between 30% for 0° and 100% for 45°.

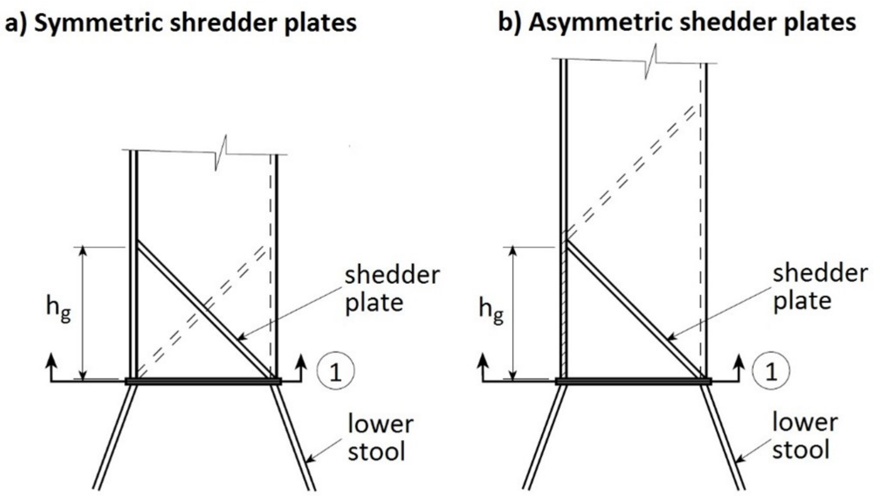


Fig. 23.11 Shedder plates

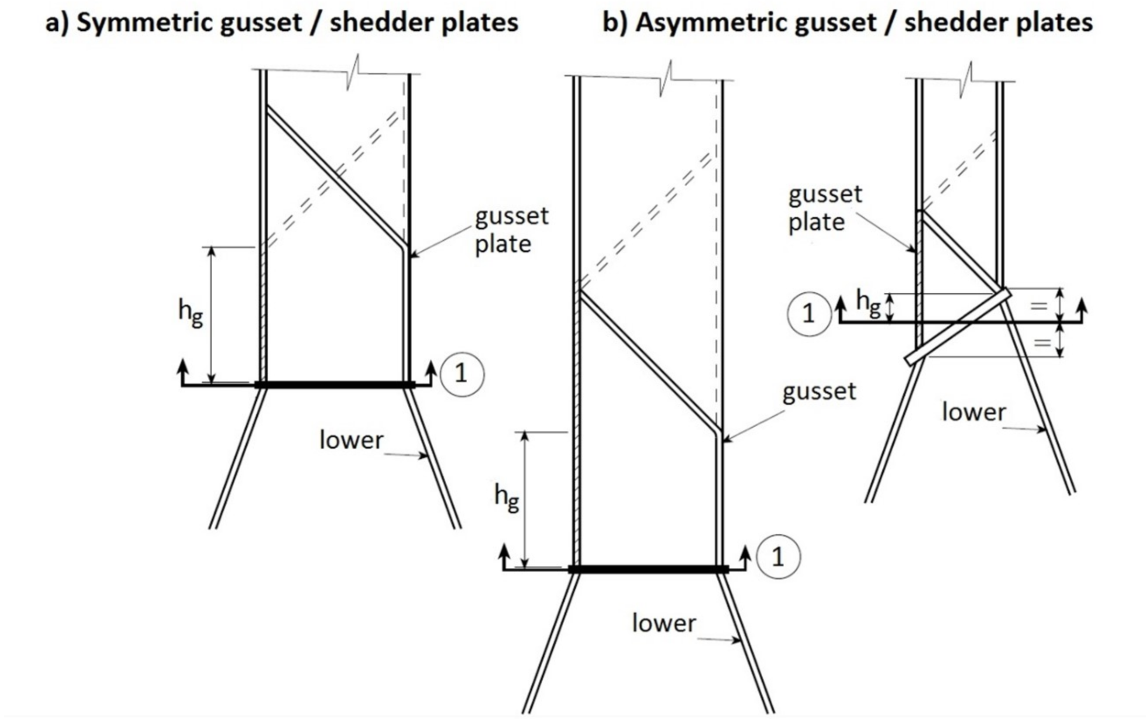


Fig. 23.12 Gusset plates and shedder plates

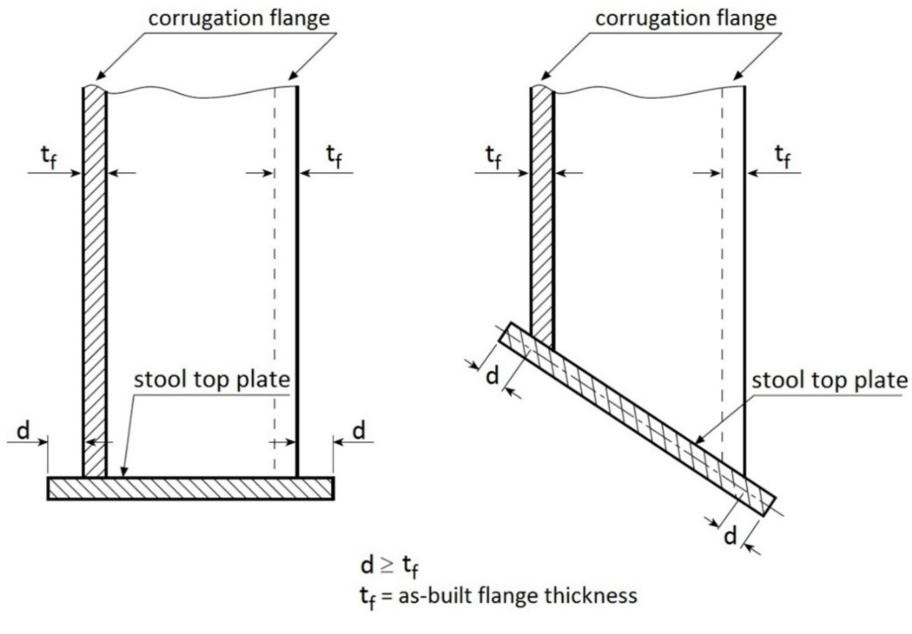
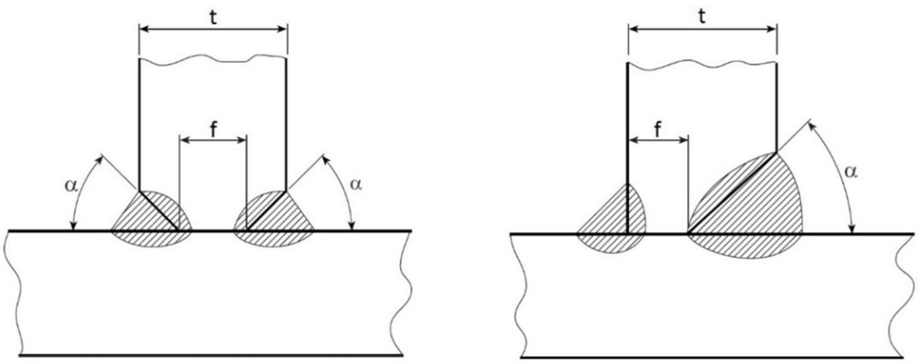


Fig. 23.13 Excess end d of the stool top plate



Root face f : 3 mm to t/3 mm

Groove angle α : 40° to 60°

Fig. 23.14 Connection by deep penetration welds

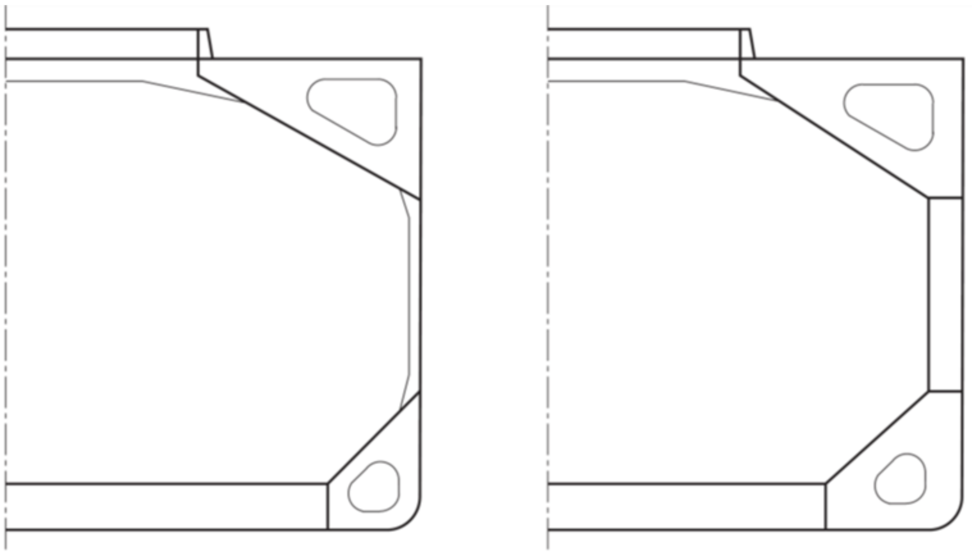


Fig. 23.15 Single and double side skin bulk carrier

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 4.6.1.

4.5 Allowable stress check

The normal and shear stresses ς and τ are not to exceed the allowable values τ_a and σ_a [N/mm^2], given by:

$$\sigma_a = R_{eH}$$

$$\tau_a = 0,5 \cdot R_{eH}$$

R_{eH} = the minimum upper yield stress [N/mm^2], of the hull structural steel

4.6 Effective compression flange width and shear buckling check

4.6.1 Effective width of the compression flange of corrugations

The effective width b_{ef}, of the corrugation flange is given by:

$$b_{ef} = C_e \cdot b$$

where:

$C_e = \dfrac{2,25}{\beta} - \dfrac{1,25}{\beta^2}$ for $\beta > 1,25$

C_e = 1,0 for $\beta \leq 1,25$

$\beta = 10^3 \cdot \dfrac{b}{t_f} \cdot \sqrt{\dfrac{R_{eH}}{E}}$

t_f = net flange thickness, in mm

b = width, in m, of the corrugation flange (see Fig. 23.9)

R_{eH} = minimum upper yield stress, in N/mm^2, of the material

E = modulus of elasticity of the material, in N/mm^2, to be assumed equal to 2,06 × 10^5 for steel

(IACS UR S18.4.6.1)

4.6.2 Shear buckling

The buckling check for the web plates at the corrugation ends is to be performed according to Section 3, F.

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 4.2 and the safety factor S is 1,05.

4.7 Local net plate thickness

The bulkhead local net plate thickness t_{net} [mm], is given by :

$$t_{net} = 14,9 \cdot a_w \cdot \sqrt{\frac{1,05 \cdot p}{R_eH}}$$

a_w = plate width [m], to be taken equal to the width of the corrugation flange or web, whichever is the greater, see Fig. 23.9

p = resultant pressure [kN/m^2], as defined in 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 $t_{net,n}$ [mm], is to be determined by the following formula: given by :

$$t_{net,n} = 14,9 \cdot a_n \cdot \sqrt{\frac{1,05 \cdot p}{R_eH}}$$

a_n = the width [m], of the narrower plating, see Fig. 23.9

The net thickness of the wider plating [mm], is not to be taken less than the maximum of the following values t_{w1} and t_{w2}:

$$t_{w1} = 14,9 \cdot a_w \cdot \sqrt{\frac{1,05 \cdot p}{R_eH}}$$

$$t_{w2} = \sqrt{\frac{440 \cdot a_w^2 \cdot 1,05 \cdot p}{R_{eH}} - t_{np}^2}$$

t_{np} are actual net thickness of the narrower plating, $t_{np} \le t_{w1}$.

5. Local detail

As applicable, the design of local details is to comply with the BKI requirements for the purpose of transferring the corrugated bulkhead forces and moments to the boundary structures, in particular to the double bottom and cross-deck structures.

The thickness and stiffening of effective gusset and shedder plates, as defined in 4.3, is to determined according to Section 12, B. on the basis of the load model in 2.

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the BKI requirements.

6. Corrosion addition and steel renewal

The corrosion addition t_K is to be taken equal to 3,5 mm.

F. Design Loading Conditions for BC-A, BC-B and BC-C Notations

(IACS UR S25 deleted)

BC-A, **BC-B** and **BC-C** are mandatory additional notations for bulk carriers having **CSR** notation and length **L** ≥ 150 m, therefore the Rules for Bulk Carrier and Oil Tankers (Pt.1, Vol.XVII) must be applied.

As request by Owner, the notation of **BC-A, BC-B** and **BC-C** may be assigned for other bulk carriers, excluding those mentioned above. Only design loading condition requirements in the Rules for Bulk Carriers and Oil Tankers (Pt. 1, Vol.XVII.B) Sec. 1.3.1 are to be applied and included in the longitudinal strength calculation according to Section 5.

G. Fitting of Forecastle of Bulk Carrier, Ore Carriers and Combination Carriers

1. Application

All bulk carriers, ore carriers and combination carriers are fitted with an enclosed fore castle on the freeboard deck.

The structural arrangements and scantlings of the fore castle are to comply with the requirements of Section 16.

(IACS UR S28.1)

2. Dimensions

The forecastle is to be located on freeboard deck with its aft bulkhead fitted in way or aft of the forward bulkhead of the foremost hold (see Fig 23.16).

The forecastle height, H_F above the main deck is not to be less than the grater of :

— the standard height of a superstructure as specified in the ICLL, or

— H_C + 0,5 [m]

H_C = height [m] of the forward transverse hatch coaming of cargo hold No.1 [m]

In order to use the reduced design load 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 23.16) :

$$\ell_F = 5 \cdot \sqrt{H_F - H_C} \quad [m]$$

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 comply with the following (see Fig. 23.16) :

$$\ell_B \geq 2{,}75 \cdot H_B \quad [m]$$

H_B = is the water height of the breakwater above the forecastle.

(IACS UR S28.2)

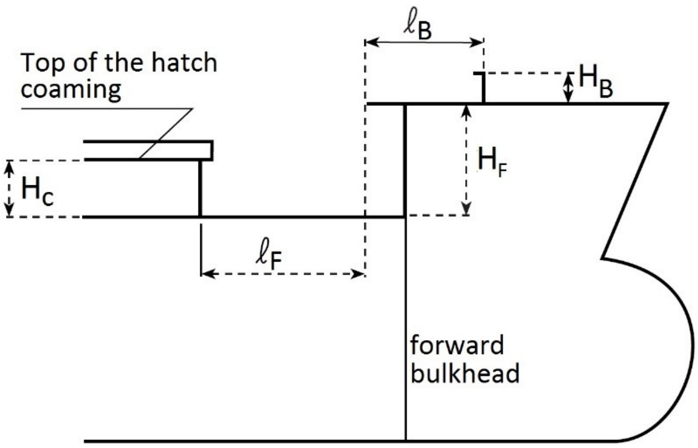


Fig. 23.16 Dimensions of forecastle

H. Transport of Steel Coils in Multi-Purpose Dry Cargo Ships

1. General

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.

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 2 and 3 may be used, if a direct determination based on stowing arrangement plans is not possible.

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.

2. Inner bottom plating

The plate thickness t of inner bottom is not to be less than determined by the following formula:

$$t = 1{,}15 \cdot K_1 \cdot \sqrt{\frac{P}{\sigma_{P\ell}}} + t_k \quad [mm]$$

K_1 = coefficient, defined as:

$$= \sqrt{\frac{1{,}7 \cdot a \cdot b \cdot K_2 - 0{,}73 \cdot a^2 \cdot K_2^2 - (b - c)^2}{2 \cdot c \cdot (2 \cdot a + 2 \cdot b \cdot K_2)}}$$

K_2 = coefficient, defined as:

$$= -\frac{a}{b} + \sqrt{\left(\frac{a}{b}\right)^2 + 1{,}37 \cdot \left(\frac{b}{a}\right)^2 \cdot \left(1 - \frac{c}{b}\right)^2 + 2{,}33}$$

c = distance [m] between outermost patch loads in a plate field, defined as:

$= (n_2 - 1) \cdot \dfrac{\ell}{n_3} + c_d \cdot \ell_c \cdot (n_4 - 1)$

n_1 = number of tiers of coils, defined as:

= 1,4 for one tier, secured with key coils

n_2 = number of patch loads per plate field, see also Fig. 23.17, defined as:

$= n_3 \cdot \left(\dfrac{b}{\ell_c} - c_d \cdot (n_4 - 1)\right)$ in general

$= n_3 \cdot n_4$ for $(n_3 - n_1) \cdot \dfrac{\ell}{n_3} < b - (1 + c_d) \cdot \ell_c \cdot (n_4 - 1)$

n_2 has to be rounded up to the next integer

n_3 = number of dunnages per coil, see Fig. 23.17

n_4 = number of coils per plate field, see Fig. 23.17, where at

$= \dfrac{b}{(1 + c_d) \cdot \ell_c}$

n_4 has to be rounded up to the next integer

P = mass force [N] including acceleration addition, defined as:

$= F_p \cdot (1 + a_v)$ [N]

F_p = mass force [N] acting on one plate field [N], defined as:

$= 9,81 \cdot \dfrac{W \cdot n_1 \cdot n_2}{n_3}$ [N]

$\sigma_{p\ell}$ = permissible local design stress [N/mm^2], defined as

$= \sqrt{\sigma_{perm}^2 - 0,786 \cdot \sigma_{perm} \cdot \sigma_{L,i} - 3 \cdot \tau_L^2} - 0,062 \cdot \sigma_{L,i}$

Note:

As a first approximation $\sigma_{L,i}$ and τ_L may be taken as follows:

$\sigma_{L,i} = \dfrac{12,6 \cdot \sqrt{L}}{k}$ *[N/mm^2] for **L** < 90 m*

$= \dfrac{120}{k}$ *[N/mm^2] for **L** > 90 m*

$\tau_L = 0$ *[N/mm^2]*

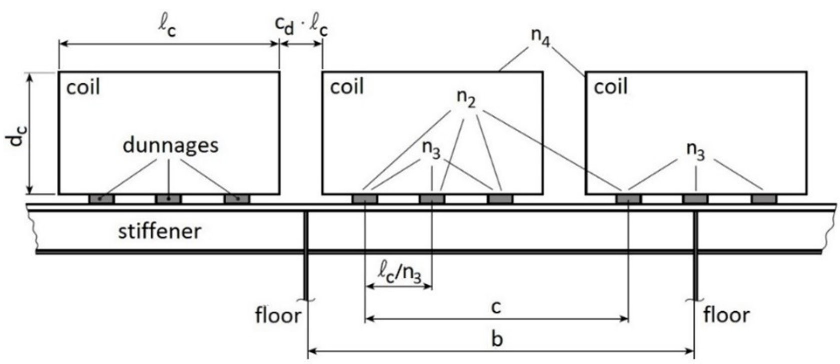


Fig. 23.17 Exemplary arrangement for determination of n_2, n_3 and n_4

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:

$$t = K_1 \cdot \sqrt{\frac{P^*}{\sigma_{P\ell}}} + t_k \text{ [mm]}$$

K_1 = coefficient according to 2

p^* = mass force [N] including acceleration addition, defined as:

$= F_p^* \cdot (a_y = \mu \cdot \cos\varphi)$ [N]

F_p^* = mass force [N] acting on one plate field, defined as:

$= 9,81 \cdot \dfrac{W \cdot n_2 \cdot n_5}{n_3}$ [N]

n_2 = number of patch loads per plate field according to 2

n_3 = number of dunnages per coil, see Fig. 23.17

n_5 = number of coils in row athwardships, defined as:

$= \dfrac{B_H}{d_c} + n_6$

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 $n_1 = 3$

σ_{pl} = permissible local design stress [N/mm^2], defined as

$= \sqrt{\sigma_{perm}^2 - 0,786 \cdot \sigma_{perm} \cdot \sigma_{L,l} - 3 \cdot \tau_L^2} - 0,062 \cdot \sigma_{L,l}$ [N/mm^2]

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 $\sigma_{L,i}$ and τ_L may be taken as follows:

$\sigma_{L,l} = 0,76 \cdot \sigma_{L,i}$ [N/mm^2]

$\tau_L = \dfrac{55}{k}$ [N/mm^2]

$\sigma_{L,i}$ = *see* 2.

4. Scantlings of longitudinal stiffeners

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.

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 2 and 3 can be made as follows:

Inner bottom:

- Acting mass per dunnage = F_P / n_2, accelerated by av according to Section 4, C.1.

Side structure:

- Acting mass per dunnage = F_P* / n_2, accelerated by (a_y – μ · cosφ), see also 3

The stresses caused by global ship deflections have to be superposed.

4.3 Permissible stresses

The permissible stresses of Section 9, B.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.

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. Evaluation of Scantlings of the Transverse Watertight Corrugated Bulkhead between Cargo Holds Nos. 1 and 2, with Cargo Hold No. 1 Flooded, for Existing Bulk Carriers

1. Application and definitions

These requirements apply to all bulk carriers of 150 m in length and above, in the foremost hold, intending to carry solid bulk cargoes having a density of 1,78 t/m^3, or above, with single deck, topside tanks and hopper tanks, fitted with vertically corrugated transverse watertight bulkheads between cargo holds No. 1 and 2 where:

- the foremost hold is bounded by the side shell only for ships which were contracted for construction prior to 1 July 1998, and have not been constructed in compliance with sub section E.
- the foremost hold is double side skin construction of less than 760 mm breadth measured perpendicular to the side shell in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 July 1999 and have not been constructed in compliance with IACS Unified Requirement S18 (Rev. 2, Sept. 2000).

The net scantlings of the transverse bulkhead between cargo holds Nos. 1 and 2 are to be calculated using the loads given in 2, the bending moment and shear force given in 3. and the strength criteria given in 4.

Where necessary, steel renewal and/or reinforcements are required as per 6.

In these requirements, homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for the two foremost cargo holds, does not exceed 1,20, to be corrected for different cargo densities.

2. Load model

2.1 General

The loads to be considered as acting on the bulkhead are those given by the combination of the cargo loads with those induced by the flooding of cargo hold No.1.

The most severe combinations of cargo induced loads and flooding loads are to be used for the check of the scantlings of the bulkhead, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions;
- non homogeneous loading conditions.

Non homogeneous part loading conditions associated with multiport loading and unloading operations for homogeneous loading conditions need not to be considered according to these requirements.

2.2 Bulkhead corrugation flooding head

The flooding head h_f (see Fig. 23.8) is the distance, in m, measured vertically with the ship in the upright position, from the calculation point to a level located at a distance d_f, in m, from the baseline equal to:

a) in general:

   - **H**

b) for ships less than 50000 t deadweight with Type B freeboard:

   - $0{,}95 \cdot \mathbf{H}$

   H being the distance, in m, from the baseline to the freeboard deck at side amidship (see Fig. 23.8).

c) for ships to be operated at an assigned load line draught Tr less than the permissible load line draught **T**, the flooding head defined in a) and b) above may be reduced by $\mathbf{T} - T_r$.

2.3 Pressure in the flooded hold

2.3.1 Bulk cargo loaded hold

Two cases are to be considered, depending on the values of d_1 and d_f, d_1 (see Fig. 23.8) being a distance from the baseline given, in m, by:

$$d_1 = \frac{M_c}{\rho_c \cdot l_c \cdot \mathbf{B}} + \frac{V_{LS}}{l_c \cdot \mathbf{B}} + (h_{HT} - h_{DB}) \cdot \frac{b_{HT}}{\mathbf{B}} + h_{DB}$$

where:

M_c	=	mass of cargo [ton], in hold No. 1
ρ_c	=	bulk cargo density [t/m^3]
l_c	=	length of hold No. 1 [m]
B	=	ship's breadth amidship [m]
V_{LS}	=	volume [m^3], of the bottom stool above the inner bottom
h_{HT}	=	height of the hopper tanks amidship [m], from the baseline
h_{DB}	=	height of the double bottom [m]
b_{HT}	=	breadth of the hopper tanks amidship [m]

At each point of the bulkhead located at a distance between d_1 and d_f from the baseline, the pressure $p_{c,f}$, in kN/m^2, is given by following condition:

- if $d_f \ge d_1$, see E.2.4.1.a)
- if $d_f < d_1$, see E.2.4.1.b)

2.3.2 Empty hold

At each point of the bulkhead, the hydrostatic pressure p_f induced by the flooding head h_f is to be considered. The force F_f, in kN, acting on a corrugation is given in E.2.4.2

2.4 Pressure in the non-flooded bulk cargo loaded hold

At each point of the bulkhead, the pressure p_c, in kN/m^2, and the force F_c, in kN, is given in E.2.3

2.5 Resultant pressure

The resultant pressure and the resultant force of homogeneous and non-homogeneous loading conditions at each point of the bulkhead structures are to be considered for the scantlings of the bulkhead, see E.2.5.

3. Bending moment and shear force in the bulkhead corrugations

The bending moment M and the shear force Q in the bulkhead corrugations are obtained using the formulae given in E.3.1 and E.3.2. The M and Q values are to be used for the checks in 4.

4. Strength criteria

4.1 General

The following criteria are applicable to transverse bulkheads with vertical corrugations (see Fig. 23.9).

Requirements for local net plate thickness are given in 4.7.

In addition, the criteria given in 4.2 and 4.5 are to be complied with.

Where the corrugation angle Φ shown in Fig. 23.9 if less than 50°, an horizontal row of staggered shedder plates is to be fitted at approximately mid depth of the corrugations (see Fig. 23.9) to help preserve dimensional stability of the bulkhead under flooding loads. The shedder plates are to be welded to the corrugations by double continuous welding, but they are not to be welded to the side shell.

The thicknesses of the lower part of corrugations considered in the application of 4.2 and 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 considered in the application of 4.2 and 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 $0{,}3 \cdot \ell$

4.2 Bending capacity and shear stress τ

The bending capacity is to comply with the following relationship:

$$\frac{M \cdot 10^3}{0,5 \cdot W_{le} + \sigma_{a,le} + W_m \cdot \sigma_{a,m}} \leq 1,0$$

where:

M	=	bending moment [kN m], as given in E.3.1
W_{le}	=	section modulus of one half pitch corrugation [cm^3], at the lower end of corrugations, to be calculated according to 4.3
W_m	=	section modulus of one half pitch corrugation [cm^3], at the mid-span of corrugations, to be calculated according to 4.4
$\sigma_{a,le}$	=	allowable stress [N/mm^2], as given in 4.5, for the lower end of corrugations
$\sigma_{a,m}$	=	allowable stress [N/mm^2], as given in 4.5, for the mid-span of corrugations

In no case is W_m to be taken greater than the lesser of 1,15 · W_{le} and 1,15 · W'_{le} for calculation of the bending capacity W'_{le} being defined below.

In case effective shedders plates are fitted which:

- are not knuckled
- are welded to the corrugations and the top of the lower stool by one side penetration welds or equivalent
- are fitted with a minimum slope of 45° and their lower edge is in line with the stool side plating
- have 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, the formula see E.4.2

Stresses τ are obtained by dividing the shear force Q by the shear area. The shear area is to be reduced in order to account for possible non-perpendicularity between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by (sin φ), φ being the angle between the web and the flange.

When calculating the section moduli and the shear area, the net plate thicknesses are to be used.

The section moduli of corrugations are to be calculated on the basis of the requirements given in 4.3 and 4.4.

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, bef, not larger than as given in 4.6.1.

a) Provided that effective shedder plates, as defined in 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, in cm^2, may be increased by

$$\left(2,5 \cdot a \cdot \sqrt{t_f \cdot t_{sh}} \cdot \sqrt{\frac{\sigma_{Fsh}}{\sigma_{Ffl}}}\right) \qquad \text{(not to be taken greater than 2,5} \cdot a \cdot t_f\text{)}$$

where:

a = width [m], of the corrugation flange (see Fig. 23.9)

t_{sh} = net shedder plate thickness [mm]

t_f = net flange thickness [mm]

σ_{Fsh} = minimum upper yield stress [N/mm^2], of the material used for the shedder plates

σ_{Ffl} = minimum upper yield stress [N/mm^2], of the material used for the corrugation flanges.

b) Provided that effective gusset plates, as defined in 9.4.2, are fitted (see Fig. 23.12), when calculating the section modulus of corrugations at the lower end (cross-section ① in Fig. 23.12), the area of flange plates, in cm^2, may be increased by (7 · hg · t_{gu}) where:

h_g = height of gusset plate [m], see Fig. 23.12, not to be taken greater than : $\left(\frac{10}{7} \cdot s_{gu}\right)$

s_{gu} = width of the gusset plates [m]

t_{gu} = net gusset plate thickness [mm], not to be taken greater than t_f

t_f = net flange thickness [mm], based on the as built condition.

c) If the corrugation webs are welded to a sloping stool top plate, which is at an angle not less than 45° with the horizontal plane, the section modulus of the corrugations may be calculated considering the corrugation webs fully effective. In case effective gusset plates are fitted, when calculating the section modulus of corrugations the area of flange plates may be increased as specified in b) above. No credit can be given to shedder plates only.

For angles less than 45°, the effectiveness of the web may be obtained by linear interpolation between 30% for 0° and 100% for 45°.

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 4.6.1.

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 [N/mm^2], given by:

$$\sigma_a = R_{eH}$$

$$\tau_a = 0{,}5 \cdot R_{eH}$$

R_{eH} = minimum upper yield stress [N/mm^2], of the material.

4.6 Effective compression flange width and shear buckling check

4.6.1 Effective width of the compression flange of corrugations

The effective width bef, in m, of the corrugation flange, see E.4.6.1

4.6.2 Shear

The buckling check for the web plates at the corrugation ends is to be performed according to Section 3, F.

The buckling factor is to be taken as follows:

$$K = 6{,}34$$

The shear stress τ has to be taken according to 4.2 and the safety factor S is 1,05.

4.7 Local net plate thickness

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

$$t_{net} = 14{,}9 \cdot a_w \cdot \sqrt{\frac{p}{R_{eH}}}$$

a_w, p = see E.4.7

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 $t_{net,n}$ [mm], is to be determined by the following formula given by :

$$t_{net,n} = 14{,}9 \cdot a_n \cdot \sqrt{\frac{p}{R_{eH}}}$$

a_n = see E.4.7

The net thickness of the wider plating [mm], is not to be taken less than the maximum of the following values t_{w1} and t_{w2}:

$$t_{w1} = 14{,}9 \cdot a_w \cdot \sqrt{\frac{p}{R_{eH}}}$$

$$t_{w2} = \sqrt{\frac{440 \cdot a_w^2 \cdot p}{R_{eH}} - t_{np}^2}$$

t_{np} are actual net thickness of the narrower plating, $t_{np} \leq t_{w1}$.

5. Local details

Requirements for local detail, see E.5.

6. Corrosion addition and steel renewal

See Rules for Classification and Surveys (Pt.1, Vol.I) Annex B.6.5.

K. Evaluation of Allowable Hold Loading of Cargo Hold No. 1 with Cargo Hold No. 1 Flooded, for Existing Bulk Carriers

1. Application and definitions

These requirements apply to all bulk carriers of 150 m in length and above, in the foremost hold, intending to carry solid bulk cargoes having a density of 1,78 t/m^3, or above, with single deck, topside tanks and hopper tanks, where:

- the foremost hold is bounded by the side shell only for ships which were contracted for construction prior to 1 July 1998, and have not been constructed in compliance with sub section D.
- the foremost hold is double side skin construction less than 760 mm breadth measured perpendicular to the side shell in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 July 1999 and have not been constructed in compliance with IACS Unified Requirement S20 (Rev. 2, Sept. 2000).

Early completion of a class renewal survey coming due after 1 July 1998 to postpone compliance is not allowed.

The loading in cargo hold No. 1 is not to exceed the allowable hold loading in the flooded condition, calculated as per 4, using the loads given in 2. and the shear capacity of the double bottom given in 3.

In no case, the allowable hold loading in flooding condition is to be taken greater than the design hold loading in intact condition.

2. Load model

2.1 General

The loads to be considered as acting on the double bottom of hold No. 1 are those given by the external sea pressures and the combination of the cargo loads with those induced by the flooding of hold No. 1.

The most severe combinations of cargo induced loads and flooding loads are to be used, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions;
- non homogeneous loading conditions;
- packed cargo conditions (such as steel mill products).

For each loading condition, the maximum bulk cargo density to be carried is to be considered in calculating the allowable hold limit.

2.2 Inner bottom flooding head

The flooding head h_f (see Fig. 23.5) is the distance, in m, measured vertically with the ship in the upright position, from the inner bottom to a level located at a distance d_f, in m, from the baseline equal to:

- **H** in general
- 0,95 · **H** for ships less than 50000 t deadweight with Type B freeboard.

H being the distance, in m, from the baseline to the freeboard deck at side amidship (see Fig. 23.5).

3. Shear capacity of the double bottom of hold No. 1

The shear capacity C of the double bottom of hold No. 1 is defined as the sum of the shear strength at each end of:

- all floors adjacent to both hoppers, less one half of the strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted (see Fig. 23.6)
- all double bottom girders adjacent to both stools, or transverse bulkheads if no stool is fitted.

The strength of girders or floors which run out and are not directly attached to the boundary stool or hopper girder is to be evaluated for the one end only.

Note that the floors and girders to be considered are those inside the hold boundaries formed by the hoppers and stools (or transverse bulkheads if no stool is fitted). The hopper side girders and the floors directly below the connection of the bulkhead stools (or transverse bulkheads if no stool is fitted) to the inner bottom are not to be included.

When the geometry and/or the structural arrangement of the double bottom are such to make the above assumptions inadequate, to the BKI discretion, the shear capacity C of the double bottom is to be calculated according to the BKI criteria.

In calculating the shear strength, the net thicknesses of floors and girders are to be used. The net thickness t_{net}, in mm, is given by:

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

where:

t	=	as built thickness, in mm, of floors and girders
t_c	=	corrosion diminution, equal to 2,0 mm, in general; a lower value of t_c may be adopted, provided that measures are taken, to the BKI satisfaction, to justify the assumption made.

3.1 Floor shear strength

Requirements for floor shear strength, see D.3.1.

For allowable shear stress, τ_a, [N/mm^2], to be taken equal to $\frac{R_{eH}}{\sqrt{3}}$.

3.2 Girder shear strength

Requirements for girder shear strength, see D.3.2.

For allowable shear stress, τ_a, [N/mm^2], to be taken equal to $\frac{R_{eH}}{\sqrt{3}}$

4. Allowable hold loading

Calculating the allowable hold loading HL [t], the condition in D.4 are to be complied. For factor F, are defined as following condition:

- General = 1,05
- For steel mill products = 1,00

L. Renewal Criteria for Side Shell Frames and Brackets in Single Side Skin Bulk Carriers and Single Side Skin OBO Carriers not Built in accordance with UR S12 Rev.1 or subsequent revisions

See Rules for Classification and Surveys (Pt.1, Vol.I) Annex B.11.

Section 24 Tankers

A. General

1. Scope

1.1 The following regulations 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.

Unless specially mentioned in this Section the regulations of Section 1 - 22 and stability requirements of Section 36 apply.

For double hull oil tankers and product tankers with **L** ≥ 150 m and being self-propelled ship with unrestricted navigation, the Rules for Bulk Carriers and Oil Tankers (Pt. 1, Vol. XVII) are applicable in lieu of B to F.

1.2 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).

1.3 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.

1.4 Products listed in the Product List 2 (at the end of this Section) are permitted to be carried in tankers complying with the regulations 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 Rules for Machinery Installations (Pt. 1, Vol.III) Sec.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.*

1.5 The regulations 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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.12 and 15.

1.6 Requirements for ships intended to carry dry cargo or oil in bulk see G.

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. as per 4.4, 4.5, 9. 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.

1.8 Where cargo is intended to be heated Section 12, A.6 is also to be observed.

1.9 Oil or other flammable liquids are not permitted to be carried in fore- or afterpeak.

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.

2. Character of Classification

2.1 Tankers, built in accordance with the requirements of this Section will have the following Notations affixed to their Character of Classification: **OIL TANKER** if engaged in the trade of carrying "oil" as defined in 1.2 or **PRODUCT TANKER** if engaged in the trade of carrying oil other than "crude oil" as defined in 1.3 or **NLS TANKER** if engaged in trade of carrying the products list Category Z of the IBC Code Chapter 17 as defined in 1.4.

Oil tankers or product tankers or NLS tankers will be assigned the symbol □ for characterizing proof of damage stability according to Section 36, C

2.2 Ships intended to alternatively carry dry cargo or liquids in bulk having a flashpoint (closed cup test) not exceeding 60°C may have one of the following Notations affixed to their Character of Classification: **"BULK CARRIER OR OIL TANKER", "ORE CARRIER OR OIL TANKER"**, "ORE CARRIER OR PRODUCT TANKER" etc.

The regulations specified in G. are to be observed.

2.3 Tankers intended to carry liquids of different properties and presenting hazards different from the criteria of liquids mentioned in 1.2 will be specially considered as "tankers for special cargoes". These tankers may have the Notation:

"SPECIAL TANKER", "ASPHALT TANKER", "EDIBLE OIL TANKER", etc. affixed to their Character of Classification.

2.4 Where it is intended to carry liquids having a flash point (closed cup test) above 60°C only, the following remark will be entered in the Certificate:

"FP > 60°C"

2.5 Where special structural measures (separation of piping, tank coating, etc) permit simultaneous carriage of various oils and oil products, the following remark may be entered in the Certificate:

"Suitable for the carriage of various oil products".

2.6 Where the cargo tanks are not segregated from other spaces in fore and aft ship (see 4.3.6) the following remark will be entered in the Certificate:

"No cofferdams at the forward and/or aft ends".

3. Cargo Tank Arrangement

3.1 General

3.1.1 Every oil tanker of 600 tdw and above shall comply with the double hull requirements of MARPOL 73/78, Annex I, Reg. 19.

3.1.2 Tanks or spaces within the double hull required in accordance with the provisions of 3.2 and 3.3 are not to be used for the carriage of cargo and fuel oil.

3.1.3 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 shall not be less than the capacity of segregated ballast tanks necessary to meet the requirements of MARPOL 73/78, Annex 1, Regulation 18. Wing tanks, spaces and double bottom tanks used to meet the requirements of MARPOL 73/78, Annex 1, Regulation 18 shall be located as uniformly as practicable along the cargo tank length. For inerting, ventilation and gas measurement see Rules for Machinery Installations (Pt.1, Vol.III) Sec.15.

3.2 Double hull requirements for oil tankers of 5000 tdw and above

3.2.1 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.

3.2.2 Double Side

Wing tanks or spaces are to extend for the entire cargo tank length and 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 (see Fig. 24.1):

$$w = 0,5 + \frac{\text{tdw}}{20000} \text{ or } 2,0 \text{ [m] ; whichever is the lesser}$$

$$w_{min} = 1,0 \text{ m.}$$

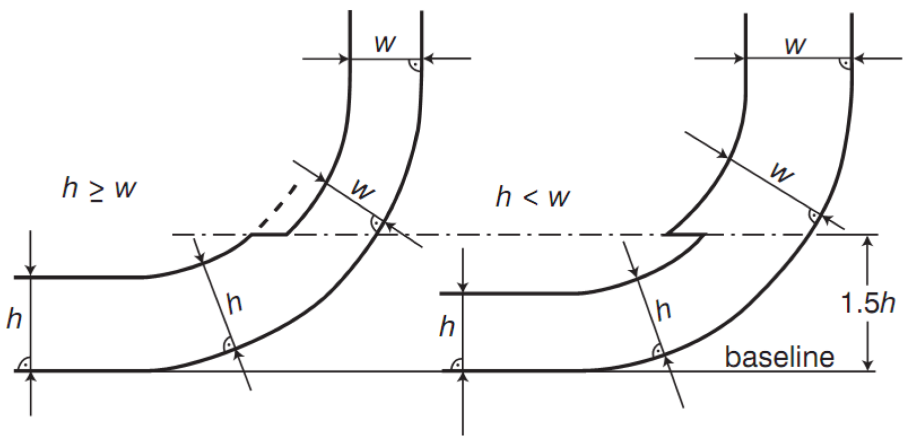


Fig. 24.1 Cargo Tank Boundary Lines

3.2.3 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 specified below (see Fig. 24.2):

$$h = \frac{B}{15} \text{ [m] or}$$
$$= 2{,}0 \text{ m, whichever is the lesser}$$
$$h_{min} = 1{,}0 \text{ m}$$

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 shall have preference at levels exceeding 1,5 h above the baseline. For details see MARPOL 73/78, Annex I, Reg. 19.3.3.

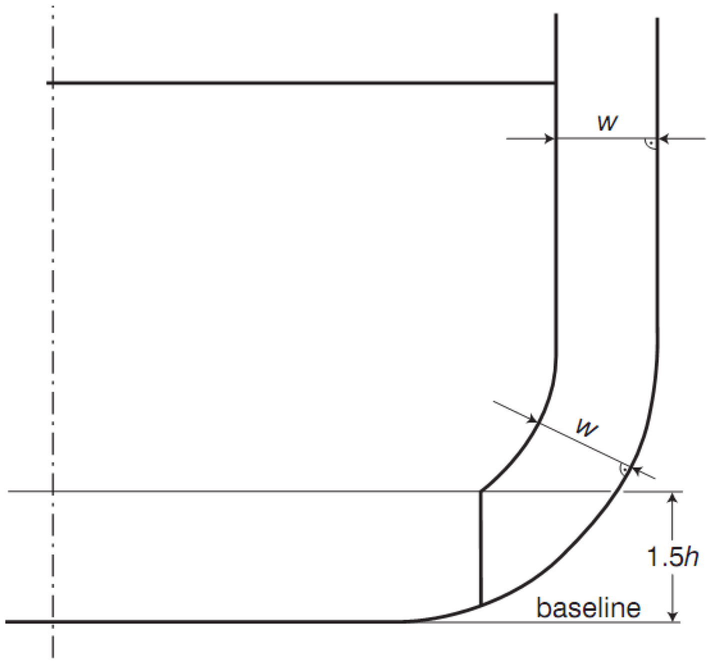


Fig. 24.2 Cargo Tank Boundary Lines

3.2.4 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 bottom shell plating is not less than 0,5 h.

3.2.5 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.

3.2.6 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 3.2.3.

Note:

For pump rooms, the bottom plate of which is above this minimum height, see 22.3 of MARPOL 73/78, Annex I

3.3 Double hull requirements for oil tankers of less than 5000 tdw

3.3.1 Double Bottom

Oil tankers of less than 5000 tdw are at least to be fitted with double bottom tanks or spaces having such a depth that the distance h specified in 3.2.3 complies with the following (see Fig. 24.3):

$$h = \frac{\mathbf{B}}{15} \quad [m] \text{ or}$$

$$h_{min} = 0{,}76 \text{ m}$$

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.

(MARPOL 73/78 Annex I Reg. 13F)

For suction wells in cargo tanks, the provisions of 3.2.4 apply accordingly.

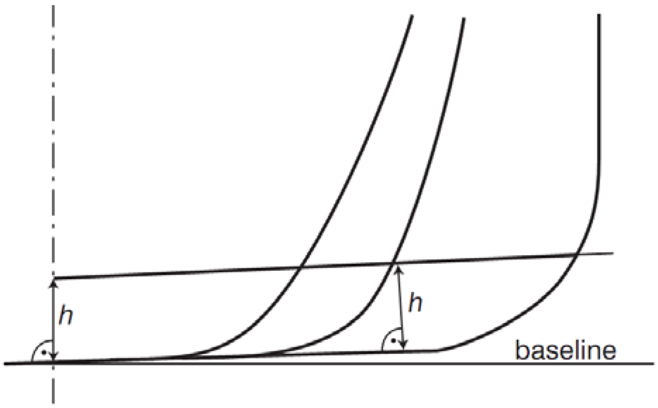


Fig. 24.3 Cargo tank boundary lines

3.3.2 Limitation of cargo tank capacity

The capacity of a each cargo tank of ships of less than 5000 tdw is limited to 700 m3, unless wing tanks or spaces are arranged in accordance with 3.2.2 complying with:

$$w = 0{,}4 + \frac{2{,}4 \cdot \text{tdw}}{20000} \quad [m]$$

$$w_{min} = 0{,}76 \text{ m}$$

3.4 Limitation of cargo tank length

3.4.1 For oil and product tankers of less than 5000 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.

3.4.2 Where the tank length exceeds 0,1**L** and/or the tank breadth exceeds 0,6**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 1, Regulation 23, concerning limitation of cargo tank sizes

Table 24.1 Permissible length of cargo tanks

<table>
<tr><th>Number of longitudinal bulkheads within the cargo tank</th><th colspan="3">Permissible length</th></tr>
<tr><td>-</td><td>$\ell_{ct} = \left(\frac{b_i}{2\,\mathbf{B}} + 0,1\right) .\mathbf{L_C}$</td><td colspan="2">With $\ell_{ct,max}$ = 0,2 · $\mathbf{L_C}$</td></tr>
<tr><td>1</td><td>$\ell_{ct} = \left(\frac{b_i}{4\,\mathbf{B}} + 0,15\right) .\mathbf{L_C}$</td><td colspan="2">With $\ell_{ct,max}$ = 0,2 · $\mathbf{L_C}$</td></tr>
<tr><td rowspan="5">2 and more</td><td colspan="3">Centre tanks :</td></tr>
<tr><td>$\ell_{ct} = 0,2 \cdot \mathbf{L_C}$</td><td colspan="2">if $\frac{b_i}{\mathbf{B}} \geq 0,2$</td></tr>
<tr><td>$\ell_{ct} = \left(\frac{b_i}{2\,\mathbf{B}} + 0,15\right) .\mathbf{L_C}$</td><td>if $\frac{b_i}{\mathbf{B}} < 0,2$</td><td>and centreline longitudinal bulkhead is provided.</td></tr>
<tr><td>$\ell_{ct} = \left(\frac{b_i}{4\,\mathbf{B}} + 0,15\right) .\mathbf{L_C}$</td><td>if $\frac{b_i}{\mathbf{B}} < 0,2$</td><td>and a centreline longitudinal bulkhead is provided.</td></tr>
<tr><td colspan="3">Wing cargo tanks:
$\ell_{ct} = 0,2 \cdot \mathbf{L_C}$</td></tr>
<tr><td colspan="4">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</td></tr>
</table>

4. Ship Arrangement

4.1 General

The requirements according to 4.3.2 - 4.3.4, 4.3.8- 4.3.10 and 4.4.1 - 4.4.3 apply to ships of 500 tons gross tonnage and over.

4.2 Definitions

Unless expressly stated otherwise following definitions apply in the context of this Section.

4.2.1 Flashpoint

Flashpoint is the temperature in degrees Celsius [°C] at which a product will give off enough flammable vapour to be ignited.

4.2.2 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.

4.2.3 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 space 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.

4.2.4 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.

4.2.5 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.

4.2.6 Cargo pump room

Cargo pump room is a space containing pumps and their accessories for the handling of products covered by this Section.

4.2.7 Hold space

Hold space is a space enclosed by the ship’s structure in which an independent cargo tank is situated.

4.2.8 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.

4.2.9 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.

4.2.10 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.

4.2.11 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.

4.2.12 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).

4.2.13 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.

4.2.14 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.

4.2.15 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.

4.2.16 Slop tank

Slop tank is a tank for the retention of oil residues and oily wash water residues according to Reg. 1.16 of Annex I of MARPOL 73/78.

4.3 Location and separation of spaces

4.3.1 Cargo tanks are to be segregated by means of cofferdams from all spaces which are situated outside the cargo area (see also 4.3.5 - 4.3.7).

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.

4.3.2 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 25000 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.

4.3.3 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 4.3.2 need not be taken into account when the position of these spaces is being determined.

4.3.4 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.

4.3.5 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.

4.3.6 Where it is intended to carry products with a flashpoint (closed cup test) above 60°C only, the cofferdams according to 4.3.1 - 4.3.5 need not be arranged (see also 1.7 and 2.6).

4.3.7 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.

4.3.8 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 2,0 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.

4.3.9 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 (approx. 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.

4.3.10 For exterior boundaries of superstructures, see Section 22, F.2.1.

4.4 Arrangement of doors, windows and air inlets

4.4.1 Entrances, air inlets and outlets and openings to accommodation spaces, service spaces, control stations and machinery spaces shall not face the cargo area. They are to be located on the transverse bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse at a distance of at least 0,04 L* but not less than 3,0 m from the end of the superstructure or deckhouse facing the cargo area. This distance need not exceed 5,0 m.

4.4.2 Access doors may be permitted in boundary bulkheads facing the cargo area or within the limits specified in 4.4.1, 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 shall 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 4.4.1. Wheelhouse doors and wheelhouse windows may be located within the limits specified in 4.4.1 so long as they are designed to ensure that the wheelhouse can be made rapidly and efficiently gas and vapour tight.

4.4.3 Windows and side scuttles facing the cargo area and on the sides of the superstructures and deckhouses within the limits specified in 4.4.1 shall be of the fixed (non-opening) type. Such windows and side scuttles, except wheelhouse windows, shall be constructed to "A-60" class standard and shall be of an approved type.

4.5 Pipe tunnels in double bottoms

4.5.1 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 shall 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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.15).

4.6 Slop tanks

Subject to the provisions of paragraph 4 of Reg. 3 of Revised Annex I of MARPOL 73/78 in the followings is referred as Annex, oil tankers of 150 gross tonnage and above shall be provided with slop tank arrangements in accordance with the requirements of paragraphs 4.6.1 to 4.6.3 of this sub section. In oil tankers delivered on or before 31 December 1979 as defined in Reg. 1.28.1 of the Annex, any cargo tank may be designated as a slop tank.

4.6.1 Adequate means shall be provided for cleaning the cargo tanks and transferring the dirty ballast residue and tank washings from the cargo tanks into a slop tank approved by Administration.

4.6.2 In this system arrangements shall be provided to transfer the oily waste into a slop tank or combination of slop tanks in such a way that any effluent discharged into the sea will be such as to comply with the provisions of Reg. 34 of the Annex.

4.6.3 The arrangements of the slop tank or combination of slop tanks shall have a capacity necessary to retain the slop generated by tank washings, oil residues and dirty ballast residues.

The total capacity of the slop tank or tanks shall not be less than 3% of the oil carrying capacity of the ship, except that Administration may accept:

- 2% for such oil tankers where the tank washing arrangement are such that once the slop tank or tanks are charged with washing water, this water is sufficient for tank washing and, where applicable, for providing the driving fluid for eductors, without the introduction of additional water into the system;
- 2% where segregated ballast tanks or dedicated clean ballast tanks are provided in accordance with Reg. 18 of the Annex, or where a cargo tank cleaning system using crude oil washing is fitted in accordance with regulation 3 of this Annex. This capacity may be further reduced to 1,5% for such oil tankers where the tank washing arrangements are such that once the slop tank or tanks are charged with washing water, this water is sufficient for tank washing and, where applicable, for providing the driving fluid for eductors, without the introduction of additional water into the system; and .
- 1% for combination carriers where oil cargo is only carried in tanks with smooth walls. This capacity may be further reduced to 0,8% where the tank washing arrangements are such that once the slop tank or tanks are charged with washing water, this water is sufficient for tank washing and, where applicable, for providing the driving fluid for eductors, without the introduction of additional water into the system.

4.6.4 Slop tanks shall be so designed particularly in respect of the position of inlets, outlets, baffles or weirs where fitted, so as to avoid excessive turbulence and entrainment of oil or emulsion with the water.

4.7 Oil tankers of 70000 tonnes deadweight and above delivered after 31 December 1979, as defined in Reg. 1.28.2 of the Annex, shall be provided with at least two slop tanks.

5. Bow or stern loading and unloading arrangements

5.1 Subject to special approval, cargo piping may be fitted to permit bow or stern loading or unloading. Portable piping is not permitted.

5.2 Outside the cargo area bow and stern loading and unloading lines are to be arranged on the open deck.

5.3 When stern loading and unloading arrangements are in use, openings and air inlets to enclosed spaces within a distance of 10 m from the cargo shore connection are to be kept closed.

5.4 The provisions of 4.3.9, 4.3.10, 4.4.1, 4.4.2 and 4.4.3 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.

5.5 Tankers equipped for single point offshore mooring and bow loading arrangements should in addition to the provision of 5.1 to 5.4 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.

5.6 For piping details and for the fire extinguishing systems the provisions of Rules for Machinery Installations (Pt.1, Vol.III) Sec.15 apply.

6. Superstructures

6.1 According to Regulation 39 of ICLL, a minimum bow height above the waterline is required at the forward perpendicular.

6.2 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 shall be taken from ICLL, Reg.26.

The end bulkheads are to have scantlings as required in Section 16.

Machinery casing may be exposed if there are no openings giving direct access from the freeboard deck to the machinery space. A door complying with the requirement of Regulation 12 of ICLL, is accepted in the machinery casing. Provided that it leads to a space or passageway which is as strongly constructed as the casing and is separated from the stairway to the engine room by a second weathertight door of steel or other equivalent material.

6.3 Openings in superstructure end bulkheads are to be provided with weathertight closing appliances. Their sills are not to be less than 380 mm in height. Reference is made to the respective requirements of the ICLL.

7. Gangways, bulwarks

7.1 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) shall be provided between the deckhouse and the forecastle on or near the centre line of the ship.

For these the following conditions shall be observed:

- The clear width shall be between 1,0 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 shall be provided. Each shelter shall 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 shall be fitted with guard rails and a footstop on either side. The guard rails shall have a height of not less than 1,0 m and shall be fitted with two courses and with a handrail. The intermediate opening to the lowest course shall not exceed 230 mm and between the other courses it shall not exceed 380 mm. Stanchions shall be fitted at intervals of not more than 1,5 m. Every third stanchion shall be fitted with a support.

- At all the working areas, but at least every 40 m, there shall be access to the deck.
- The construction of the gangway shall be of suitable strength, shall be fire resistant and the surface shall 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 2000 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.

7.2 Type "A' ships with bulwarks are to have open rails fitted for at least half the length of the exposed parts of the weather deck or other effective 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.

8. Ventilators

8.1 Ventilators for spaces under the freeboard deck are to be of strong construction, or to be efficiently protected by superstructures or other equivalent means.

8.2 Pump rooms, cofferdams and other rooms adjacent to cargo tanks are to be fitted with ventilation arrangements, as per Rules for Machinery Installations (Pt.1, Vol.III) Sec.15.

8.3 The dangerous zones as per Rules for Electrical Installations (Pt.1, Vol.IV) Sec.1.K are to be observed.

9. Anchor equipment

9.1 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 3,0 m from the cargo tank boundaries, if liquids having a flashpoint (closed cup test) not exceeding 60°C are intended to be carried.

9.2 For distances from cargo tank vent outlets etc. the relevant requirements of Rules for Machinery Installations (Pt.1, Vol.III) Sec.15 are to be observed.

10. Cathodic protection

10.1 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.

10.2 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.

10.3 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 horizontal surfaces such as bulkhead girders and stringers not less than 1,0 m 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.

10.4 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.

11. Aluminium paints

The use of aluminium coatings containing greater than 10 percent aluminium by weight in the dry film is prohibited in cargo tanks, cargo tank deck area, pump rooms, cofferdams or any other area where cargo vapour may accumulate.

(IACS UR F2 Rev. 2)

12. Minimum Plate Thicknesses in Cargo and Ballast Tanks within the Cargo Area

12.1 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 the following minimum value:

$$t_{min} = 6{,}5 + 0{,}02\,\mathbf{L} \quad [mm]$$

where **L** need not be taken greater than 250 m. For secondary structures such as local stiffeners t_{min} need not be taken greater than 9,0 mm.

The minimum thickness is not permitted to be reduced for restricted service.

12.2 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, A.7 apply, however, with an upper limit of t_{min} = 11 mm.

For aft peak tanks the requirements of Section 12, A.7.3 apply.

12.3 In way of cargo tanks the thickness of side shell is not to be taken less than:

$$t_{min} = \sqrt{\mathbf{L} \cdot k} \quad [mm]$$

12.4 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·**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**B**.

13. Corrosion protection

"The requirements of Section 38 apply, as far as applicable".

14. Testing of cargo and ballast tanks

For testing of cargo and ballast tanks has to be in compliance with Section 3, M.

B. Strength of Girders and Transverses in the Cargo Tank Area

1. General

1.1 Girders and transverses may be predesigned according to Section 12, B.3. Subsequently, a stress analysis according to 2. is to be carried out. All structural elements exposed to compressive stresses are to be subjected to a buckling analysis according to Section 3, F.

1.2 Brackets fitted in the corners of transverses and tripping brackets fitted on longitudinals are to have smooth transitions at their toes.

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 shall be placed near the constraint points of stiffeners and girders and near the toes of brackets.

1.4 Transverses are to be effectively supported to resist loads acting vertically on their webs.

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 according to Fig. 24.4 and Fig. 24.5 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 BKI.

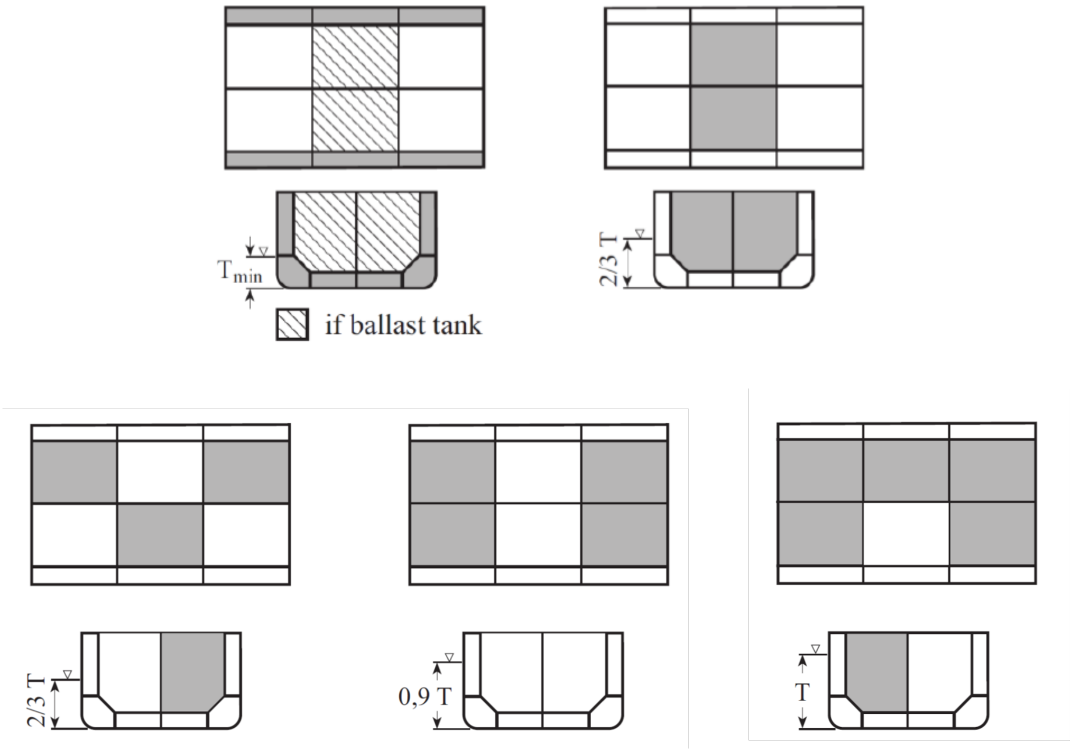


Fig. 24.4 Loading conditions for tankers with one centreline longitudinal bulkhead

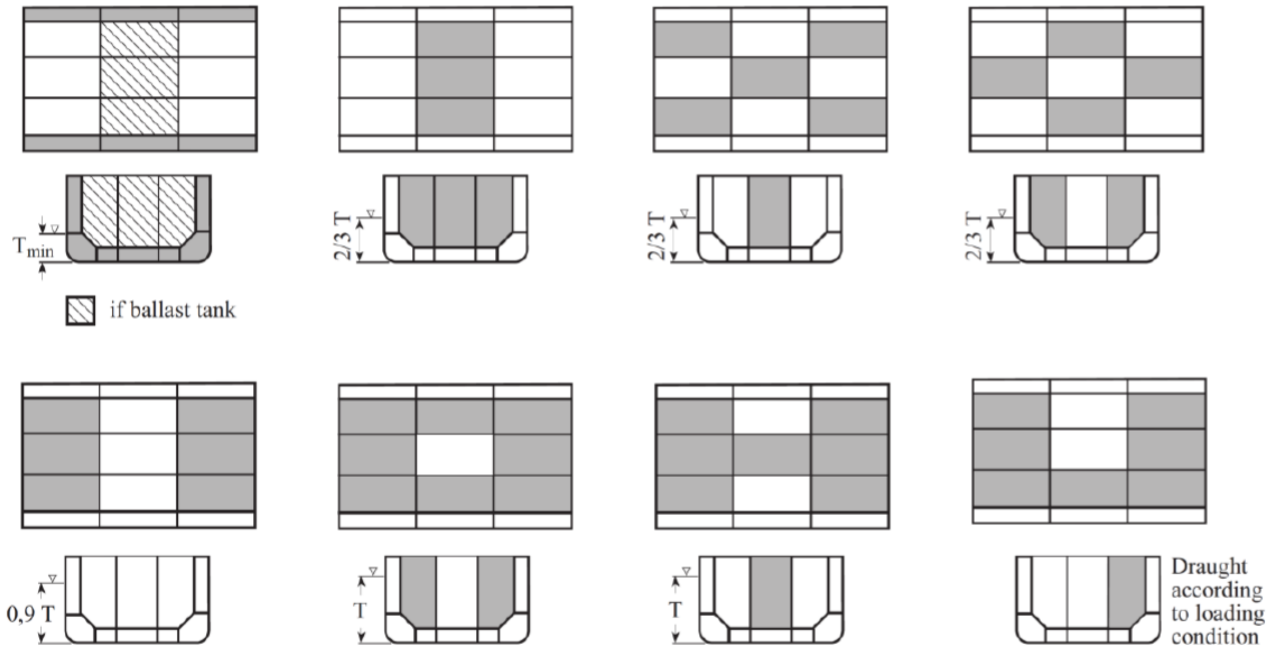


Fig. 24.5 Loading conditions for tankers with two longitudinal bulkheads

2.1 Structural modeling

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, BKI reserve the right to require examination of structural details by means of local FE models.

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 $\varphi$is to be considered.

The internal pressure in the cargo tanks is to be determined in accordance with the formula for p_1 as per Section 4, D.1.1.

2.3 Permissible stresses

2.3.1 Transverse members

Under load assumption according to 2. the following stress values are not to be exceeded in the transverses and in the bulkhead girders :

bending and axial stresses :

$$\sigma_x \leq \frac{150}{k} \quad [N/mm^2]$$

shear stress :

$$\tau \leq \frac{100}{k} \quad [N/mm^2]$$

equivalent stress:

$$\sigma_v = \sqrt{\sigma_x^2 + 3 \cdot \tau^2} \leq \frac{180}{k} \quad [N/mm^2]$$

σ_x = stress in longitudinal direction of the girder.

k = material factor according Section 2, B.2.

The stress values as per Section 12, B.3.2 are not to be exceeded when the load p_2 as per Section 4, D.1.2 is applied.

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].

2.4 Fatigue strength

A fatigue strength analysis according to Section 20 is to be carried out. Analogously it shall be based on 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.

2.5 Cross ties

The cross sectional area of the cross ties due to compressive loads is not to be less than:

$$A_k = \frac{P}{9,5 - 4,5 \cdot 10^4 \cdot \lambda^2} \quad [\text{cm}^2] \qquad \text{for } \lambda \le 100$$

$$= \frac{P \cdot \lambda^2}{5 \cdot 10^4} \quad [\text{cm}^2] \qquad \text{for } \lambda > 100$$

λ = $\frac{\ell}{i}$ = degree of slenderness

ℓ = unsupported span [cm]

i = radius of gyration = $\sqrt{\frac{I}{A_k}}$ [cm^4]

I = smallest moment of inertia [cm^4]

For the first approximation,

$P = A \cdot p$ [kN],

A = area supported by one cross tie [m^2].

p = load p_1 or p_d [kN/m^2] as per Section 4, D.

Finally the sectional area A_k is to be checked for the load P resulting from the transverse strength calculation.

C. Oiltight Longitudinal and Transverse Bulkheads

1. Scantlings

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 as per A.13. For stress and buckling analysis the requirements of B.1.1 apply.

1.2 The top and bottom strakes of the longitudinal bulkheads are to have a width of not less than 0,1**H**, and their thickness is not to be less than:

— top strake of plating:

t_{min} = 0,75 x deck thickness

— bottom strake of plating:

t_{min} = 0,75 x bottom thickness

1.3 The section modulus of horizontal stiffeners of longitudinal bulkheads is to be determined as for longitudinals according to Section 9, B, however, it is not to be less than W_2 according to Section 12, B.3.

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 τ_{perm} = 100/k [N/mm^2].

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. For cofferdam bulkheads not serving as tank bulkheads, e.g. pump-room bulkheads, the scantlings for watertight bulkheads as required by Section 12 are sufficient.

D. Swash Bulkheads

1. General

1.1 The total area of perforation in swash bulkheads is to be approximately 20% of the bulkhead area.

1.2 The scantlings of the top and bottom strakes of plating of a perforated centre line bulkhead are to be as required by C.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.

2. Scantlings

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]. Beyond that, the buckling strength of plate panels is to be examined. The plate thickness is not to be less than the minimum thickness according to A.13.

2.2 The stiffeners and girders are to be determined as required for an oiltight bulkhead. The pressure p_d according to Section 4, D.2 is to be substituted for p.

E. Hatches

1. Tank hatches

1.1 Oiltight tank hatches are to be kept to the minimum number and size necessary for access and venting.

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**L** amidships. Where this is not practicable, compensation is to be provided for lost cross sectional area.

1.3 Coaming plates are to have a minimum thickness of 10 mm.

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 oiltight.

1.5 Other types of oiltight covers may be approved if found to be equivalent.

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 weathertight steel covers, the strength of which is to be in accordance with Section 17, C.

F. Structural Details at the Ship's End

1. General

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.

1.2 For the fore- and afterpeak, the requirements of Section 9, A.5 apply.

2. Fore body

2.1 Floor plates are to be fitted at every frame. The scantlings are to be determined according to Section 8, A.1.2.3.

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.

2.3 The sides may be framed transversely or longitudinally in accordance with Section 9.

3. Aft body

3.1 Between the aft cofferdam bulkhead and the afterpeak bulkhead the bottom structure is to comply with Section 8.

3.2 The sides may be framed transversely or longitudinally in accordance with Section 9.

4. Emergency towing arrangements

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 20000 tdw and above shall be fitted with an emergency towing arrangement in the bow and stern areas of the upper deck.

4.2 Requirements for the arrangements and components

4.2.1 General

The emergency towing arrangements shall be so designed as to facilitate salvage and emergency towing operations on tankers primarily to reduce the risk of pollution. The arrangements shall at all times 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. 24.6 shows typical arrangements which may be used as reference.

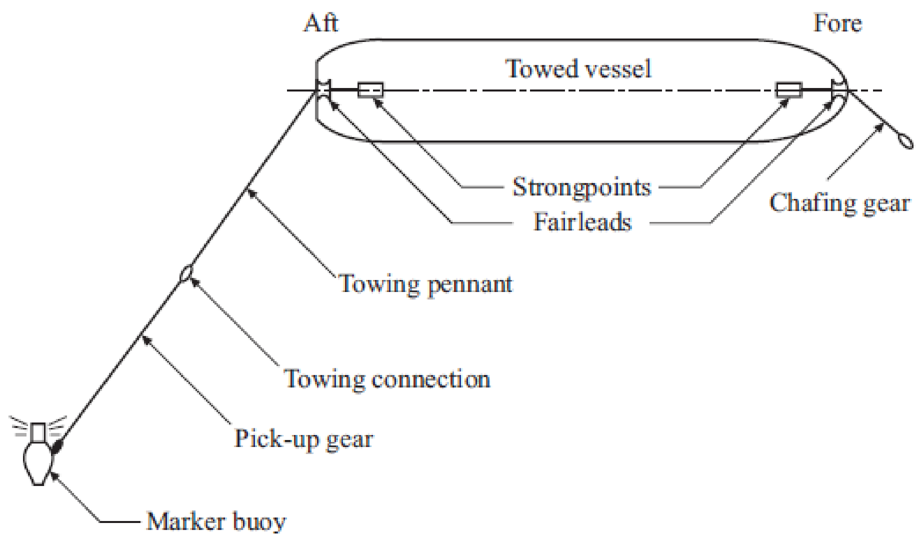


Fig. 24.6 Loading conditions for tankers with two longitudinal bulkheads

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

4.2.3 Strength of the towing components

Towing components shall have a Safe Working Load (SWL) of at least 1000 kN for tankers of 20000 tdw and over but less than 50000 tdw, and at least 2000 kN for tankers of 50000 tdw and over. The SWL is defined as one half of the minimum breaking load of the towing pennant. The strength shall 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.

4.2.4 Length of towing pennant

The towing pennant shall have a length of at least twice the lightest seagoing ballast freeboard at the fairlead plus 50 m.

4.2.5 Location of strongpoint and fairlead

The strong points and fairleads shall each be located in the bow and stern areas at the centerline.

4.2.6 Strongpoint

The inboard end fastening shall 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.

4.2.7 Fairleads

The bending ratio (towing pennant bearing surface diameter to towing pennant diameter) of the fairlead shall not be less than 7 to 1. Otherwise a chafing gear (stud link chain) is required.

4.2.8 Chafing gear

.1 The chafing gear shall 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 3,0 m beyond the fairlead shall meet this criterion.

.2 One end of the chafing chain shall be suitable for connection to the strongpoint. The other end shall be fitted with a standard pear-shaped open link allowing connection to a standard bow shackle.

4.2.9 Towing connection

The towing pennant shall have a hard eye-formed termination allowing connection to a standard bow shackle.

4.2.10 Testing

The breaking load of the towing pennant shall be demonstrated. All components such as chafing gear, shackles and standard pear-shaped open links shall be tested in the presence of a BKI surveyor under a proof load of 1420 kN or 2640 kN respectively, corres-ponding to a SWL of 1000 kN or 2000 kN (see 4.2.3).

The strong points of the emergency towing arrangements shall be prototype tested before the installation on board under a proof load of 2 x SWL.

On board, the rapid deployment in accordance with 4.3 shall be demonstrated.

4.3 Ready availability of towing arrangements

Emergency towing arrangements shall comply with the following criteria:

4.3.1 The aft emergency towing arrangement shall be pre-rigged and be capable of being deployed in a controlled manner in harbour conditions in not more than 15 minutes.

4.3.2 The pick-up gear for the aft towing pennant shall 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 shall be protected against the weather and other adverse conditions that may prevail.

4.3.3 The forward emergency towing arrangement shall be capable of being deployed in harbour conditions in not more than one hour.

4.3.4 All emergency towing arrangements shall be clearly marked to facilitate safe and effective use even in darkness and poor visibility

G. Ships for the Carriage of Dry Cargo or Oil in Bulk

1. General

1.1 For ships covered by this Sub-Section 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. For the character of classification see A.2.2.

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 3.

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.

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.

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.

2. Reinforcements

2.1 In cargo holds for dry cargo in bulk or oil the following reinforcements are to be carried out.

2.2 Framing

2.2.1 The scantlings of frames in the cargo holds for oil are to be determined according to Section 9, A.2.2. Tripping brackets according to Section 9, A.5.5 are to be fitted at suitable intervals.

2.2.2 In cargo holds which may be partly filled frames may be required to be strengthened, depending on the filling ratio.

2.3 Cargo hold bulkheads

2.3.1 The scantlings of cargo hold bulkheads are to be determined according to Section 23, B.8 as well as according to the requirements for oil tankers and according to the requirements of Sub-Section C.

2.3.2 In cargo holds which may be partly filled the bulkheads may be required to be strengthened, depending on the filling ratio.

2.4 Hatchways

2.4.1 The scantlings of the hatchway covers are to be determined according to Section 17.

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.

2.4.3 The scantlings of the hatchway coamings are to be checked for the load according to Section 17, C.2.

2.4.4 The form and size of hatchway covers and the sealing system shall be adapted to each other in order to avoid leakages caused by possible elastic deformations of the hatchways.

3. Slop tanks

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.

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 shall be under the control of the responsible Ship's Officer

H. Small Tankers

1. General

1.1 The following requirements apply to small tankers of less than 90 m in length. Small tankers for the purpose of this Section are coastal tankers, bunkering boats and water tankers. Unless otherwise mentioned in this Section, the requirements of A - G are applicable.

1.2 Small tankers may be framed either longitudinally or transversely, or a combined system may be adopted with the ship's sides being framed transversely and the bottom and strength deck longitudinally. For the strength deck, the longitudinal framing system is recommended.

1.3 The strength deck may extend from side to side, or may consist of a main deck and a raised trunk deck. In the case of trunk deckers the permissible **L/H** values for the various service ranges (see Section 1, A.1) are to be related to the following fictitious depth **H'** :

$$\mathbf{H'} = e_B + e'_D$$

e_B and e'_D see Section 5, A.5 and C.4.1.

1.4 Two oiltight longitudinal bulkheads, or else one oiltight centre line bulkhead, may be fitted, extending continuously through all cargo tanks from cofferdam to cofferdam.

1.5 For tankers of more than 24 m in length proof is to be provided of sufficient bow height as per A.6.1.

1.6 A trunk of sufficient height may serve as fore and aft gangway as per A.7.

2. Girders and transverses

2.1 Girders and transverses are to be determined according to Section 12, B.3. If deemed necessary a stress and buckling analysis according to B.1.1 is to be carried out.

2.2 Deductions for restricted service range are not permitted for girders and transverses.

3. Transverse framing

3.1 Scantlings

3.1.1 The section modulus of the transverse frames in the cargo tank area is not to be less than:

$$W_1 = k \cdot 0,55 \cdot a \cdot \ell^2 \cdot p \qquad [cm^3]$$

or

$$W_2 = k \cdot 0,44 \cdot a \cdot \ell^2 \cdot p_2 \qquad [cm^3]$$

k, ℓ, p and p_2 see Section 12, B.1.

3.1.2 The scantlings of the frame section are to be maintained throughout the whole depth **H**.

3.2 End attachment and connections

3.2.1 At their ends, the transverse frames are to be provided with flanged brackets according to Section 3, D.2. The bilge bracket is to fill the entire round of the bilge and is to be connected to the adjacent bottom longitudinal.

The bracket at the upper end of the frame is to be attached to the adjacent deck longitudinal.

3.2.2 Where the unsupported span is considerable, flats or brackets are to be fitted to support the frame against tripping.

The transverse frames are to be attached to the stringers by means of flats or brackets extending to the face plate of the stringer in such a way that the force of support can be transmitted.

4. Deck

4.1 The plate thickness is not to be less than:

$$\text{for longitudinal framing : } t_{krit} = \frac{\mathbf{a} \cdot 10^3}{85 - 0,15\mathbf{L}} \qquad [mm]$$

$$\text{for transverse framing : } t_{krit} = \frac{\mathbf{a} \cdot 10^3}{65 - 0,2\mathbf{L}} \qquad [mm]$$

The thickness of deck plating is not to be less than the minimum thickness as given under A.13 or the thickness required for tank bulkhead plating.

4.2 For trunk deckers, designing of the deck is to be based upon the fictitious depth **H'** according to 1.3. The thickness of deck plating so obtained applies to the main deck and the trunk deck. Where the thickness obtained for the deck exceeds that for the bottom - provided the framing system and the frame spacing are equal in deck and bottom – the mean value of the two different thicknesses is to be taken for deck and bottom.

4.3 The trunk side plating is to have the same thickness as the side shell plating at the ends, taking into account the frame spacing, however, it is not to be less than the minimum thickness according to A.13 or the thickness required for tank bulkhead plating.

4.4 The stiffening of the trunk side plating is to be similar to that of a deck. The transverses are to be determined according to 2. like deck transverses, with a span equal to the depth of trunk; the section modulus is not to be less than that of the adjoining deck transverses.

5. Shell plating

The thickness of the shell plating is to be determined according to Section 6. For trunk deckers the thickness is to be based upon the fictitious depth H' according to 1.3. The thickness of the shell plating is not to be less than the minimum thickness according to A.13 or the thickness required for tank bulkhead plating.

J. Product List 1

List of Oils [1)]

Asphalt solutions

- Blending stocks
- Roofers flux
- Straight run residue

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

Oils

- Penetrating oil
- Spindle oil
- Turbine oil

Distillates

- Straight run
- Flashed feed stocks

Gas oil

- Cracked

Gasoline blending stocks

- Alkylates - fuel
- Reformates
- Polymer – fuel

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

Jet fuels

- Kerosene
- Mineral spirit

Naphtha

- Solvent
- Petroleum
- Heartcut distillate oil

[1)] This list of oils shall not necessarily be considered as comprehensive.

K. 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	:	Z = pollution category assigned under **MARPOL 73/78**, Annex II
(column c)		I = Product to which a pollution category X, Y or Z has not been assigned.
Flashpoint	:	Values in ( ) are "open cup values", all other values are "closed cup values".
(column e)		– = non-flammable product

Note:

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 data included therein have been taken from different publications.

Product name	UN number	Category	Density [kg/m^2]	Flashpoint [°C]
a	b	c	d	e
Acetone	1090	Z	790	-18
Alcoholic beverages, n.o.s.	3065	Z	< 1000	> 20
Apple juice		I	< 1000	-
n-Butyl alcohol	1120	Z	810	29
sec-Butyl alcohol	1120	Z	810	24
Butyl stearate		I	860	160
Clay slurry		I	$\approx$2000	-
Coal slurry		I	$\approx$2000	-
Diethylene glycol		Z	1120	143
Ethyl alcohol	1170	I	790	13
Ethylene carbonate		I	1320	143
Glucose solution		I	1560	-
Glycerine		Z	1260	160
Glycerol monooleate		Z	950	224
Hexamethylenetetramine solutions		Z	$\approx$1200	-
Hexylene glycol		Z	920	96
Isopropyl alcohol	1219	Z	790	22
Kaolin slurry		I	1800 – 2600	-
Magnesium hydroxide slurry		Z	$\approx$1530	-
N-Methylglucamine solution (70% or less)		Z	1150	> 95
Molasses		I	1450	> 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	1190 – 1300	-
Potassium formate solutions		Z	$\approx$1570	> 93
Propylene carbonate		Z	1190	135
Propylene glycol		Z	1040	99
Sodium acetate solutions		Z	1450	
Sodium sulphate solutions		Z		> 60
Tetraethyl silicate monomer/oligomer (20% in ethanol)		Z		
Triethylene glycol		Z	1130	166
Water		I	1000	–

L. Additional Requirements for Tankers in Shuttle Service

1. General requirements and instructions

1.1 General

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 shall 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.

1.1.2 Reference to other rules and guidelines

The following BKI Rules shall be applied in addition:

- Section 1 to 22
- Rules for Machinery Installations (Pt.1, Vol.III)
- Rules for Electrical Installations (Pt.1, Vol.IV)
- Rules for Dynamic Positioning Systems (Pt.4, Vol.II)
- Rules for Single Point Mooring (Pt.5, Vol.IX)

1.2 Exemptions

Any kind of new or different design may be accepted by BKI provided that an equivalent level of safety is demonstrated.

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 1.4 and have to comply with the requirements set out in 2.

For further Notations refer to Rules for Dynamic Positioning Systems (Pt.4, Vol.II).

1.4 Definitions

SPM Single point mooring arrangement of basic design, fitted with local control for mooring to single point mooring complying with 2.1.1

SPM1 Single point mooring arrangement of basic design, fitted with local control for mooring and cargo loading manifold complying with 2.1, 2.3.1 to 2.3.4 and 2.4.1.3 to 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 2.1, 2.3 and 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 2.1, 2.3, 2.4 and Dynamic Positioning Systems

STL Submerged turret loading arrangement of specific design combined with a Dynamic Positioning System (DPS) complying with 2.2 and Rules for Dynamic Positioning Systems (Pt.4, Vol.II).

1.5 Documents for approval

In addition to the documents required for regular Class (as per 1.1.2 above) the following documentation is to be submitted for approval as applicable:

Single point mooring arrangement:

- plans showing the mooring arrangement with position of bow fairleads, bow chain stoppers, winches and capstans, possible pedestal rollers, and winch storage drum
- detailed of bow fairleads and their attachment to the bulwark
- details of attachment to deck and supporting structure of the bow chain stoppers, winch or capstans, possible pedestal rollers, and winch storage drum
- a product certificate for the bow chain stoppers and bow fairleads, confirming compliance with 2.1.1
- documentation for maximum Safe Working Load (SWL) from manufacturer (works certificate) for winches or capstans, confirming compliance with 2.1.1.8.
- documentation for maximum Safe Working Load (SWL) from manufacturer (works certificate) for pedestal roller (if fitted), confirming necessary structural strength to withstand the forces to which it will be exposed when the winch or capstan are lifting with maximum capacity

Bow loading arrangement:

- plans showing the bow loading and mooring arrangements
- detailed drawings and data sheets of quick release hose coupling, if fitted
- cargo and vapour return systems, if fitted
- arrangement of fairleads, chain stopper, winches including drawings of their substructures and bow control station
- arrangement and details of fire protection equipment in the bow area
- ventilation of spaces in the bow area incl. bow control room
- electrical systems and location of equipment
- hydraulic systems
- arrangement of forward spaces incl. accesses, air inlets and openings
- plan of hazardous areas
- operation manual

Submerged turret loading:

- plans showing the STL room arrangement including hull constructional details and mating platform
- detailed drawings of loading manifold with cargo piping, couplings and hoses
- plans for hydraulically operated components with hydraulic systems
- fire protection arrangement of the STL room
- ventilation arrangement of the STL room
- location and details of all electrical equipment
- arrangement, foundation, substructure and details of hoisting winch.

2. System requirements

2.1 Requirements for Single Point Mooring (SPM)

2.1.1 Bow chain stoppers and fairleads

.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 Mooring of Ships at Single Point Moorings"). Number and capacity of the chain stoppers are to be in accordance with Table 24.2.

.2 The design of the chain stopper shall be of an approved type, in accordance with the Rules for Machinery Installations (Pt.1, Vol.III) Sec.14.D. The chafing chain shall be secured when the chain engaging pawl or bar is in closed position. When in open position, the chain and associated fittings shall be capable to pass freely.

.3 Stoppers are to be fitted as close as possible to the deck structure and shall be located 2,7 m to 3,7 m inboard of the fairleads. Due consideration shall be given to proper alignment between the fairlead and pedestal lead or drum of the winch or capstan.

.4 For the structural strength of the supporting structure underneath the chain stoppers the following permissible stresses are to be observed:

$$\sigma_x \le \frac{200}{k} \quad [N/mm^2] \quad \text{for bending and axial stresses}$$

$$\tau \le \frac{120}{k} \quad [N/mm^2] \quad \text{for shear stresses}$$

$$\sigma_v = \sqrt{\sigma_x^2 + 3 \cdot \tau^2} \le \frac{220}{k} \quad [N/mm^2] \quad \text{for equivalent stresses}$$

For strength assessment using FEM the following permissible equivalent v. Mises stress is to be observed:

$$\sigma_v \le \frac{230}{k} \quad [N/mm^2]$$

The acting forces are to be twice the SWL according to Table 24.2.

.5 Upon installation, bow stoppers are to be load tested to the equivalent Safe Working Load (SWL). A copy of the installation test certificate shall be available for inspection on board the ship.

Alternatively, the ship shall 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 shall also indicate the yield stress of the bow chain stoppers. Loads that induce this yield stress shall not be less than twice the SWL.

Applicable strength of the supporting structures underneath the chain stoppers shall be documented by adequate analyses.

BKI will issue a declaration confirming that an evaluation verifying sufficient support strength has been carried out. A copy of the declaration shall be available for inspection on board the ship. Bow chain stoppers and supporting structures underneath the chain stoppers shall be subject to Periodic Class Survey.

.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 2.1.1.4. The design force is to be considered at angles of 90° to the sides and 30° upwards or downwards.

.7 Single fairleads should be arranged at the centreline, where two fairleads are fitted they should be arranged 1,0 to 1,5 m from the centreline on either side. Two bow fairleads are recommended for ships fitted with two bow chain stoppers.

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]
≤ 100000	76	1	1	2000
> 100000 ≤ 150000	76	1	1	2500
> 150000	76	2	2	3500

.8 Winches or capstans are to be positioned to enable a direct pull to be achieved on the continuation of the direct lead line between bow fairleads and bow stoppers. Alternatively a pedestal roller fairlead is to be positioned between the stopper and the winch or capstan. Winches or capstans are to be capable of lifting at least 15 tonnes.

.9 If a winch storage drum is used to stow the pick-up rope, it shall be capable to accommodate 150 m rope of 80 mm in diameter.

.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 2.1.1.4.

.11 The SWL according to Table 24.2 is to be marked (by weld bead or equivalent) on the chain stoppers and fairleads.

2.1.2 Bow loading arrangements

.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.

.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 shall be provided.

.3 The bow loading connection shall 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.

.4 Materials and pipe scantlings shall be in compliance with Rules for Machinery Installations (Pt.1, Vol.III) Sec.11.

2.1.3 Fire fighting arrangements

.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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.12.K.
- one portable foam branch pipe for protecting the cargo line forward of the cargo area

.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 shall 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.

2.1.4 Electrical equipment

Electrical equipment in hazardous areas and spaces as well as within a radius of 3,0 m from the cargo loading connection/manifold or any other vapour outlet shall be of certified safe type, meeting the requirements stated in Rules for Electrical Installations (Pt.1, Vol.IV) Sec. 15.

2.2 Requirements for Submerged Turret Loading (STL)

2.2.1 The STL room with mating recess shall 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.) shall 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.

2.2.2 Access to the STL room is only permitted from open deck.

2.2.3 A permanent mechanical extraction type ventilation system providing at least 20 changes of air per hour shall be fitted. Inlets and outlets shall be arranged at least 3,0 m above the cargo tank deck, and the horizontal distance to safe spaces shall not be less than 10 m. Design of fans shall conform to Rules for Machinery Installations (Pt.1, Vol.III) Sec.15.

The air inlet shall 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 2,0 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.

2.2.4 A fixed fire extinguishing system in accordance with Rules for Machinery Installations (Pt.1, Vol.III) Sec.12.D is to be provided.

2.2.5 A connection for the supply of Inert Gas (IG) shall be fitted. The connection may be arranged fixed or portable. If fixed, the connection to the IG-System inlet shall be provided with a blank flange.

2.2.6 Electrical equipment shall be of certified safe type in compliance with Rules for Electrical Installations (Pt.1, Vol.IV) Sec.15. Where equipment needs to be installed for submerged use, the protection class shall be IP 68; otherwise, the installation is to be located well above the deepest waterline. Electric lighting of the STL room shall be interlocked with the ventilation such that lights can only be switched on when the ventilation is in operation.

Failure of ventilation shall not cause the lighting to extinguish. Emergency lighting shall not be interlocked.

2.2.7 A fixed gas detection system shall be fitted with sampling points or detector heads located at the lower portions of the room. At least one sampling point/detector shall be fitted above the deepest waterline. Visual and audible alarms shall 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).

2.3 Arrangement of forward spaces

2.3.1 General

Hazardous zones, areas and spaces shall be defined on basis of Rules for Electrical Installations (Pt.1, Vol.IV) Sec.15.

2.3.2 Air vent pipes from fore peak tanks are to be located as far as practicable away from hazardous areas.

2.3.3 Access openings, air inlets and outlets or other openings to service, machinery and other gas safe spaces shall not face the bow loading area and shall be arranged not less than 10 m away from the bow loading connection. These spaces shall have no connection to gas dangerous spaces and are to be equipped with fixed ventilation systems.

2.3.4 Spaces housing the bow loading connection and piping are to be considered as gas dangerous spaces and shall preferably be arranged semi-enclosed. In case of fully enclosed spaces, a fixed extraction type ventilation providing 20 changes of air per hour shall be fitted. Design of fans shall be according to Rules for Electrical Installations (Pt.1, Vol.IV) Sec.15.

2.3.5 A bow control station for SPM or STL loading operations may be arranged. Unless agreed otherwise and approved, this space shall 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 shall 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 shall be considered during design. Fire protection standards according to "A–60" class shall be applied for bulkheads, decks, doors and windows in relation to adjacent spaces and areas.

2.4 Functional requirements for bow and STL loading systems

2.4.1 Control systems, communication

.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 shall 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.

.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 a 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

.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 shall 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 shall be provided.

.4 Communication

Means of communication between ship and offshore loading terminal shall be provided, certified as ”Safe for use in gas dangerous atmosphere”. Procedures for emergency communication shall be established.

2.4.2 Operation manual

The tanker shall 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

3. Surveys and tests

3.1 Tests of components

Couplings/connectors intended for bow or STL loading operations shall 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 shall in general be in compliance with the current BKI Rules as applicable, see 1.1.2. Cargo transfer hoses and hoses used in hydraulic or other systems shall be type approved.

3.2 Tests after installation

All systems and equipment used for SPM, bow loading and STL shall be function tested at the shipyard prior to commissioning. During the first offshore loading operation, an inspection shall be carried out by a local Surveyor. The inspection shall include all relevant operational procedures and verification of the operation manual.

3.3 Periodical inspections

To maintain the Class Notations assigned for the SPM and STL installations, annual/intermediate and renewal surveys shall be carried out in conjunction with regular class surveys. The scope of surveys shall be based on the principles laid down in Rules for Classification and Surveys (Pt.1, Vol.I) Sec.4.I.B.

Section 25 Ships Carrying Dangerous Chemical in Bulk

The requirements for the construction of ships carrying dangerous chemicals in bulk, see Rules for Ships Carrying Dangerous Chemicals in Bulk (Pt.1, Vol.X).

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Section 26 Ships Carrying Liquefied Gases in Bulk

The requirements for the construction of ships carrying liquefied gases in bulk, see Rules for Ships Carrying Liquefied Gases in Bulk (Pt. 1, Vol.IX).

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Section 27 Tugs

A. General

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

IACS UR A1 Rev.8

IACS UR M79 Rev.1

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

1. Scope, application

1.1 The following requirements apply to vessels primarily designed for towing and/or pushing operations or assisting other vessels or floating objects in manoeuvring. Combination with other purposes is possible and will be noted accordingly in the Class Certificate, see 2.2.

1.2 Unless specially mentioned in this Section, the requirements of Sections 1 – 22 apply.

1.3 Special designs not covered by the following rules will be considered from case to case.

1.4 For instructions regarding towing operations in general, see Guidelines for Safe Ocean Towing (Pt.1, Vol.12).

2. Classification, Notations

2.1 Ships built in accordance with the requirements of this Section will have the Notation **TUG** affixed to their Character of Classification.

2.2 Where towing services are to be combined with other duties such as offshore supply or ice breaking, corresponding additional Class Notations may be assigned if the relevant requirements are met.

2.3 Additional requirements for the combined pusher/barge unit, see Annex 2.

3. Approval documents, documentation

3.1 In addition to the documents listed in the rules mentioned under 1.2 above, the following design documentation shall be submitted in form of soft copy (electronic), for approval and/or information:

- general arrangement of the towing gear including winch(es), if provided,
- design drawings and material specifications of towing hook and accessory towing gear, towrope guide and/or of the towing winch including winch drives, brakes and fastening elements, for examination of towing gear with towing winch, the direction of the towrope has to be indicated on the drawings,

- slip device(s) including hydraulic/pneumatic systems and electric circuits, and/or "weak link" for towrope on winch drum,
- required bollard pull (design value),
- towrope specification,
- in special cases, intended tow configuration(s).

3.2 The reliable function of the towing gear has to be proven during the initial tests on board.

3.3 If a bollard pull test has to be carried out and will be certified by BKI, it shall correspond to the procedure given in Guidelines for Safe Ocean Towing (Pt.1, Vol.12). The test results shall be documented and kept on board together with the Certificate of bollard pull testing and the Classification documents.

3.4 Materials

BKI material certificates will generally be required for:

- towing hook and attached load transmitting elements, including slip device,
- towing winch: frame, drum shaft(s), couplings, brakes, and gear(s),
- towrope(s), including certification of breaking force.

Material Certificates according to DIN 50049-3.1B or equivalent standard may be accepted for standard items, if the manufacturer is recognized by BKI.

B. Hull Structures

1. Scantlings, general

For the determination of hull structure scantlings the draught **T** is not to be taken less than 0,85**H**.

2. Deck structure

2.1 On tugs for ocean towage, the deck, particularly in the forward region, shall be suitably protected or strengthened against sea impact.

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 C.1.5.

3. Fore body, bow structure

3.1 On tugs for ocean towage, strengthening in way of the forebody (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.

3.2 For (harbour) tugs frequently engaged in berthing operations, the bow shall be suitably protected by fendering and be structurally strengthened.

3.3 The bulwark shall be arranged with an inward inclination in order to reduce the probability and frequency of damages. Square edges are to be chamfered.

3.4 The bow structure of pusher tugs for sea service will be specially considered. For pusher tugs for Inland Navigation see Rules for Inland Waterway Vessels – Hull Construction (Pt.2, Vol.II).

4. Stern frame, bar keel

4.1 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.3.

4.2 Where a bar keel is provided, its scantling are to be determined by the following formulae:

height h $= 1{,}1 \cdot \mathbf{L} + 110$ [mm]

thickness t $= 1{,}1 \cdot \mathbf{L} + 12$ [mm]

Minor deviations from these values are admissible provided the required sectional area is maintained.

5. Side structure

5.1 The side structure of areas frequently subjected to impact loads shall 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.

5.2 A continuous and suitable strong fender shall be arranged along the upper deck.

5.3 For ice strengthening see 8.

6. Engine room casing, superstructures and deckhouses

6.1 The plate thickness of the casing walls and casing tops is not to be less than 5,0 mm. The thickness of the coamings is not to be less than 6,0 mm. The coamings shall extend to the lower edges of the beams.

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.

6.3 Regarding height of the casing and closing arrangements as well as exits see also F.1.1.

6.4 The following requirements have to be observed for superstructures and deckhouses of tugs assigned for the restricted services ranges L and P or for unlimited range of service:

- The plate thickness of the external boundaries of superstructures and deckhouses is to be increased by 1,0 mm above the thickness as required in Section 16, C.3.2
- The section modulus of stiffeners is to be increased by 50% above the values as required in Section 16, C.3.1

7. Foundations of towing gear

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, shall be thoroughly connected to the ship's structure, considering all possible directions of the towrope, see C.3.5.

7.2 The stresses in the foundations and fastening elements shall not exceed the permissible stresses shown in Table 27.2, 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 C.3.5 and C.5.3.

8. Ice strengthening

8.1 Ice strengthening, where necessary according to the intended service, shall be provided according to the requirements of Section 15.

8.2 Tugs with the notation "**ICEBREAKER**" to be specially considered.

C. Towing Gear/Towing Arrangement

1. General design requirements

1.1 The towing gear shall be arranged in such a way as to minimize the danger of capsizing; the towing hook/working point of the towing force is to be placed as low as practicable, see also F.

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, see 3.5.

1.3 The attachment point of the towrope shall be arranged closely behind the centre of buoyancy.

1.4 On tugs equipped with a towing winch, the arrangement of the equipment shall be such that the towrope is led to the winch drum in a controlled manner under all foreseeable conditions (directions of the towrope). Means shall be provided to spool the towrope effectively on the drum, depending on the winch size and towing gear configuration.

1.5 Towrope protection sleeves or other adequate means shall be provided to prevent the directly pulled towropes from being damaged by chafing/abrasion.

2. Definition of loads

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 A.3.3 and Guidelines for Safe Ocean Towing (Pt.1, Vol.12).

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 27.1.

Table 27.1 Design force T and test force PL

Design force T [kN]	Test force PL [kN]
T ≤ 500	2 · T
500 < T ≤ 1500	T + 500
1500 < T	1,33 · T

2.3 The minimum breaking force of the towrope is based on the design force, see 4.3.

2.4 The winch holding capacity shall be based on the minimum breaking force, see 5.3, the rated winch force is the hauling capacity of the winch drive when winding up the towrope, see 6.1.3.3.

2.5 For forces at the towing hook foundation see 3.5.4.

3. Towing hook and slip device

3.1 The towing hook shall be fitted with an adequate device guaranteeing slipping (i.e., quick release) of the towrope in case of an emergency. Slipping shall 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.

3.2 The towing hook has to be equipped with a mechanical, hydraulic or pneumatic slip device. The slip device shall be designed such as to guarantee that unintentional slipping is avoided.

3.3 A mechanical slip device shall be designed such that the required release force under test force PL does not exceed either 150 N at the towing hook or 250 N when activating the device on the bridge. In case of a mechanical slip device, the releasing rope shall be guided adequately over sheaves. If necessary, slipping should be possible by downward pulling, using the whole body weight.

3.4 Where a pneumatic or hydraulic slip device is used, a mechanical slip device has to be provided additionally.

3.5 Dimensioning of towing hook and towing gear

3.5.1 The dimensioning of the towing gear is based on the test force PL, see 2.2.

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 ≤ 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

3.5.3 Assuming the test force PL acting in any of the directions described in 3.5.2, the permissible stresses in the towing equipment elements defined above shall not exceed the values shown in Table 27.2.

3.5.4 For the towing hook foundation it has to be additionally proven that the permissible stresses given in Table 27.2 are not exceeded assuming a load equal to the minimum breaking force F_{min} of the towrope.

Table 27.2 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	$\sigma_V = 0,85 \cdot R_{eH}$
R_{eH} = yield strength or 0,2% (proof stress)	

4. Towropes

4.1 Towrope materials shall correspond to the Rules for Materials (Pt.1, Vol.V) Sec.14. All wire ropes should have as far as possible the same lay.

The suitability of fibre ropes as towropes is to be separately demonstrated to BKI.

4.2 The length of the towrope shall 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 Guidelines for Safe Ocean Towing (Pt.1, Vol.12).

4.3 The required minimum breaking force F_{min} of the towrope is to be on the basis of the design force T and a utility factor K, as follows:

$$F_{min} = K \cdot T \quad [kN]$$

K = 2,5 for T ≤ 200 kN and

K = 2,0 for T ≥ 1000 kN

For T between 200 and 1000 kN, K may be interpolated linearly.

4.4 For ocean towages, at least one spare towrope with attachments shall be available on board.

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.

5. Towing winches

5.1 Arrangement and control

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 3.5.2.

5.1.2 The winch must 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 shall be freely visible; where this is not ensured, the winch shall be provided with a self-rendering device.

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.

5.1.4 Operating levers shall, when released, return into the stop position automatically. They are to be capable of being secured in the stop position.

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.

5.1.6 If, during normal operating conditions, the power for the towing winch is supplied by a main engine shaft generator, another generator shall be available to provide power for the towing winch in case of main engine or shaft generator failure.

5.1.7 All towing winches are to be provided with an emergency release system as described in 5.6.

(IACS UR M79.4.2)

5.2 Winch drum

5.2.1 The towrope shall be fastened on the winch drum by a breaking link.

5.2.2 The winch drum shall be capable of being declutched from the drive.

5.2.3 The diameter of the winch drum is to be not less than 14 times the towrope diameter. However, for all towline types, the towline bending radius should not be less than specified by the towline manufacturer.

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.

5.2.5 To ensure security of the rope end fastening, at least 3 dead turns must remain on the drum.

5.2.6 At the ends, drums shall have disc sheaves whose outer edges shall 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.

5.2.7 If a multi-drum winch is used, then each winch drum shall be capable of independent operation.

5.2.8 Each towing winch drum shall have sufficient capacity to stow the length of the provided towrope. 5.2.3 to 5.2.5 are not applicable to towropes of austenitic steels and fibre ropes. In case these towrope materials are utilized, dimensioning of the wind drum is subject to BKI approval.

5.2.9 The in-board end of the towline shall be attached to the winch drum with a weak link or similar arrangement that is designed to release the towline at low load.

(IACS UR M79.4.1)

5.3 Holding capacity/dimensioning

5.3.1 The holding capacity of the towing winch (towrope in the first layer) shall correspond to 80% of the minimum breaking load Fmin of the towrope.

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 shall not give way under this load.

5.4 Brakes

5.4.1 If the drum brakes are power-operated, manual operation of the brake shall be provided additionally.

5.4.2 Drum brakes shall be capable of being quickly released from the control stand on the bridge, as well as from any other control stand. The quick release shall be possible under all working conditions, including failure of the power drive.

5.4.3 The operating levers for the brakes are to be secured against unintentional operation.

5.4.4 Following operation of the quick release device, normal operation of the brakes shall be restored immediately.

5.4.5 Following operation of the quick release device, the winch driving motor shall not start again automatically.

5.4.6 Towing winch brakes shall be capable of preventing the towrope from paying out when the vessel is towing at the design force T and shall not be released automatically in case of power failure.

5.5 Tricing winches

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 shall be available on the bridge.

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 safe guarded. For tricing ropes, see 4.5.

5.6 Emergency release systems

5.6.1 Scope

.1 This Sub-Section defines minimum safety standards for winch emergency release systems provided on towing winches that are used on towing ships within close quarters, ports or terminals.

.2 This Sub-Section is not intended to cover towing winches on board ships used solely for long distance ocean towage, anchor handling or similar offshore activities.

(IACS UR M79.1)

5.6.2 Purpose

The purpose of this Sub-Section is to provide requirements to prevent the capsize of a tug when in the act of towage as a result of the towline force acting transversely to the tug (in beam direction) as a consequence of an unexpected event (could be loss of propulsion/steering or otherwise), whereby the resulting couple generated by offset and opposing transverse forces (towline force is opposed by thrust or hull resistance force) causes the tug to heel and, ultimately, to capsize. This capsize may be referred to as “girting”, “girthing”, “girding” or “tripping”. See Fig.27.1 which shows the forces acting during towage operations.

(IACS UR M79.2)

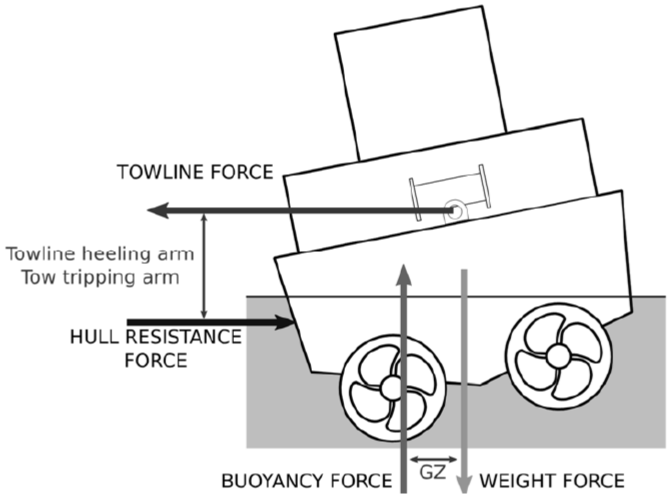

Fig. 27.1 Force during towing

(IACS UR M79.Fig. 1)

5.6.3 Definitions

.1 **Emergency release system** refers to the mechanism and associated control arrangements that are used to release the load on the towline in a controlled manner under both normal and black out conditions.

.2 **Maximum design load** is the maximum load that can be held by the winch as defined by the manufacturer (the manufacturer's rating).

.3 **Fleet angle** is the angle between the applied load (towline force) and the towline as it is wound onto the winch drum, see Fig. 27.2.

(IACS UR M79.3)

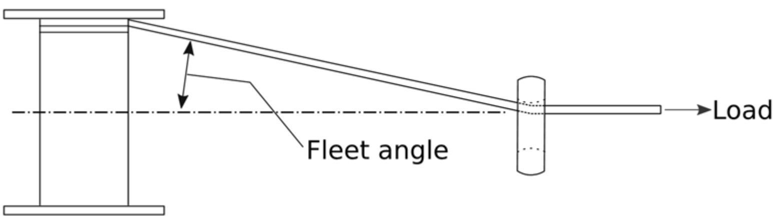

Fig. 27.2 Towline fleet angle

(IACS UR M79.Fig. 2)

5.6.4 Performance requirements

.1 The emergency release system is to operate across the full range of towline load, fleet angle and ship heel angle under all normal and reasonably foreseeable abnormal conditions (these may include, but are not limited to, the following: vessel electrical failure, variable towline load (for example due to heavy weather), etc.).

.2 The emergency release system shall be capable of operating with towline loads up to at least 100% of the maximum design load.

.3 The emergency release system is to function as quickly as is reasonably practicable and within a maximum of three seconds after activation.

.4 The emergency release system is to allow the winch drum to rotate and the towline to pay out in a controlled manner such that, when the emergency release system is activated, there is sufficient resistance to rotation to avoid uncontrolled unwinding of the towline from the drum. Spinning (free, uncontrolled rotation) of the winch drum is to be avoided, as this could cause the towline to get stuck and disable the release function of the winch.

.5 Once the emergency release is activated, the towline load required to rotate the winch drum is to be no greater than:

a) the lesser of 49 kN (5 t) or 5% of the maximum design load when two layers of towline are on the drum, or

b) 15% of the maximum design load where it is demonstrated that this resistance to rotation does not exceed 25% of the force that will result in listing sufficient for the immersion of the lowest unprotected opening.

.6 Emergency release of the towline is to be possible in the event of a blackout. For this purpose, where additional sources of energy are required, such sources are to comply with .7.

.7 The sources of energy required by .6 are to be sufficient to achieve the most onerous of the following conditions (as applicable):

a) Sufficient for at least three attempts to release the towline (i.e. three activations of the emergency release system). Where the system provides energy for more than one winch it is to be sufficient for three activations of the most demanding winch connected to it.

b) Where the winch design is such that the drum release mechanism requires continuous application of power (e.g. where the brake is applied by spring tension and released using hydraulic or pneumatic power), sufficient power is to be provided to operate the emergency release system (e.g. hold the brake open and allow release of the towline) in the event of a blackout for a minimum of five minutes. This may be reduced to the time required for the full length of the towline to feed off the winch drum at the load specified in .5 if this is less than five minutes.

(IACS UR M79.5.1)

5.6.5 Operational requirements

.1 Emergency release operation must be possible from the bridge and from the winch control station on deck. The winch control station on deck is to be in a safe location. A position in close proximity to the winch is not regarded as “safe location”, unless it is documented that the position is at least protected against towline break or winch failure.

.2 The emergency release control is to be located in close proximity to an emergency stop button for winch operation, if provided and shall be clearly identifiable, clearly visible, easily accessible and positioned to allow safe operability.

.3 The emergency release function is to take priority over any emergency stop function Activation of the winch emergency stop from any location is not to inhibit operation of the emergency release system from any location.

.4 Emergency release system control buttons are to require positive action to cancel, the positive action may be made at a different control position from the one where the emergency release was activated. It must always be possible to cancel the emergency release from the bridge regardless of the activation location and without manual intervention on the working deck.

.5 Controls for emergency use are to be protected against accidental use.

.6 Indications are to be provided on the bridge for all power supply and/or pressure levels related to the normal operation of the emergency release system. Alarms are to activate automatically if any level falls outside of the limits within which the emergency release system is fully operational.

.7 Wherever practicable, control of the emergency release system is to be provided by a hard-wired system, fully independent of programmable electronic systems.

.8 Computer based systems that operate or may affect the control of emergency release systems are to meet the requirements for Rules for Electrical Installations (Pt.1, Vol. IV) Sec. 10.

.9 Components critical for the safe operation of the emergency release system are to be identified by the manufacturer.

(IACS UR M79.5.2)

6. Testing

6.1 Workshop testing

6.1.1 Towing hook and slip device

.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 shall be tested likewise; the release force has to be measured and shall not exceed 150 N, see 3.3.

.2 When towing hooks are provided with a pneumatic slip device, both the pneumatic and the mechanical slip device required by 3.4 have to be tested according to 6.1.1.1.

.3 Also towing hooks with a hydraulic slip device have to be tested according to 6.1.1.1, but the slip device itself need not be subjected to the test load. If a cylinder tested and approved by BKI 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.

6.1.2 Certification and stamping of towing hook Following each satisfactory testing at manufacturer's, a Certificate will be issued by the attending Surveyor and shall be handed on board, together with the towing hook.

6.1.3 Towing winches

.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 6.2.4.

.2 Components exposed to pressure are to be pressure-tested to a test pressure PD of

$$P_D = 1{,}5 \cdot p$$

where:

p = admissible working pressure or opening pressure of the safety valves [bar]. 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.

.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 shall 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 6.2.4.

In that case only the operational trials without applying the prescribed loads will be carried out at the manufacturers.

.4 Emergency release systems

1) All testing within 5.6 is to be witnessed by surveyor
2) For each emergency release system or type thereof, the performance requirements of 5.6.4 are to be verified either at the manufacturer's works or as part of the commissioning of the towing winch when it is installed on board. Where verification solely through testing is impracticable (e.g. due to health and safety), testing may be combined with inspection, analysis or demonstration in agreement with BKI.
3) The performance capabilities as well as instructions for operation of the emergency release system are to be documented by the manufacture and made available on board the ship on which the winch has been installed.
4) Instructions for surveys of the emergency release system are to be documented by the manufacturer, agreed by BKI and made available on board the ship on which the winch has been installed.
5) Where necessary for conducting the annual and class renewal surveys of the winch, adequately sized strong points are to be provided on deck.

(IACS UR M79.6.1)

6.1.4 Accessory towing gear components, Towropes

.1 Accessories subjected to towing loads, where not already covered by 6.1.1.1, shall generally be tested to test force PL at the manufacturer.

.2 For all accessories Test Certificates, Form LA 3, and for the towrope, Form LA 4, have to be submitted.

.3 BKI reserve the right of stipulating an endurance test to be performed at towing gear components, where considered necessary for assessment of their operability.

6.2 Initial testing

6.2.1 Towing gear on board The installed towing gear has to be tested on the tug using the bollard pull test to simulate the towrope pull.

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 BKI, see Guidelines for Safe Ocean Towing (Pt.1, Vol.12).

6.2.3 Towing hooks

.1 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.

.2 The surveyor certifies the initial board test by an entry into the Test Certificate for Towing Hooks.

6.2.4 Test of towing winches on board

.1 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 6.2.2.

.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.

.3 Emergency release systems

a) The full functionality of the emergency release system is to be tested as part of the shipboard commissioning trials to the satisfaction of the surveyor. Testing may be conducted either during a bollard pull test or by applying the towline load against a strong point on the deck of the tug that is certified to the appropriate load.
b) Where the performance of the winch in accordance with 5.6.4 has previously been verified, the load applied for the installation trials is to be at least the lesser of 30% of the maximum design load or 80% of vessel bollard pull.

(IACS UR M79.6.2)

6.3 Recurrent tests

The following tests will be applied to all tugs classed by BKI unless otherwise required by the Administration.

The Surveyor certifies the satisfactory recurrent test in the Test Certificate for Towing Hooks.

6.3.1 Towing hooks

.1 The functional safety of towing hook and slip device shall be checked by the ship's master at least once a month.

.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 27.1. Slipping has to be effected whilst both tugs are pulling with full test force.

.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.

.4 Particular attention has to be paid to the proper functioning of all gear components.

D. Steering Gear/Steering Arrangement

1. Steering stability

Steering stability, i.e. stable course maintaining capability of the tug, shall be ensured under all normally occurring towing conditions. Rudder size and rudder force shall be suitable in relation to the envisaged towing conditions and speed.

2. Rudder movement

Regarding the time to put the rudder from one extreme position to the other, the requirements of Rules for Machinery Installations (Pt.1, Vol.III) Sec.14.A shall be observed for tugs exceeding 500 GT. Special rudder arrangements may be considered in the particular case, see also 4.

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.

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.

E. Anchoring/Mooring Equipment

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 (Z) the term $2 \cdot h \cdot \mathbf{B}$ may be substituted by the term

$$2\ (a \cdot \mathbf{B} + \sum h_i \cdot b_i)$$

where:

$a, \sum h_i$	=	distance and height according to Section 18, B.1
b_i	=	is the breadth [m], of the widest superstructure or deckhouse of each tier having a breadth greater than **B**/4.

(IACS UR A1.3.1)

2. General requirements

2.1 The equipment of tugs for restricted service range is to be determined as for vessels in the "**L**" (Coasting Service) range, see Section 18, A.3. For tugs in the service range "**T**" (Service in Sheltered Waters), see Section 30 ,E.

For tugs under 45 m in length intended for towing service only, one anchor may be used onboard provided that the second anchor and its relevant chain cable holds readily available to be installed. In case of loss of anchor, the tug is to remain in port until replace anchor equipment is installed onboard.

(IACS UR A1.3.1)

2.2 For tugs engaged only in berthing operations, one anchor is sufficient, if a spare anchor is readily available on land.

2.3 The stream anchor specified in Table 18.2 is not required for tugs.

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.

F. Weathertight Integrity and Stability

1. Weather deck openings

1.1 Openings (skylights) above the machinery space shall be arranged with coamings not less than 900 mm high, measured from the upper deck. Where the height of the coamings is less than 1,8 m, the casing covers are to be of specially strong construction, see also G.1.

1.2 The head openings of ventilators and air pipes are to be arranged as high as possible above the deck.

1.3 For companion ways to spaces below deck to be used while at sea, sills with a height not less than 600 mm shall be provided. Weathertight steel doors are to be provided which can be opened/closed from either side.

1.4 Deck openings shall be avoided in the sweep area of the towing gear, or else be suitably protected.

2. Stability

2.1 The intact stability must comply with the following requirements:

- the intact stability, see Section 1, E.1 and IMO IS Code 2008, Part A, paragraph 2.2 or see Guidelines on Intact Stability (Pt.6, Vol.3) Sec.2.
- alternatively, if applicable, the intact stability requirement of IMO IS Code 2008, Part B, paragraph 2.4 or see Guidelines on Intact Stability (Pt.6, Vol.3) Sec.3.I.3.

2.2 Additionally, the vessel's stability shall be assessed when the vessel is subjected to forces related to towing operations, based on the following requirements:

— **Stability criteria, stern freeboard and towing heeling levers (effective from 1st July 2025)**

Vessels engaged in harbour, coastal or ocean-going towing shall in the applicable loading conditions in the stability manual comply with the criteria of IMO IS Code, 2008, Part B, paragraphs 2.8.4.2, 2.8.4.3 and 2.8.6.2, assuming towing heeling levers according to paragraph 2.8.2.

— **Loading conditions (effective from 1st July 2025)**

In addition to the standard loading conditions for cargo ships in Guidelines on Intact Stability (Pt.6, Vol.3) Section 4, D, standard loading conditions given in the IMO IS Code, 2008, Part B, paragraph 3.4.1.8, shall apply, including the assumptions of paragraph 3.4.2.9.

— **Additional information in stability manual (effective from 1st July 2025)**

The vessel's stability manual shall contain detailed information on the calculated heeling levers with all applied parameters. The heeling lever curves shall be plotted together with the GZ curve for all intended towing conditions. The manual shall additionally contain information as given in IMO IS Code, 2008, Part B, paragraph 3.6.4.

G. Escape Routes and Safety Measures

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 shall 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.

2. Companionways

Companionways to spaces below deck see F.1.3.

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 shall be designed according to the requirements of F.1, particularly F.1.4.

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.

5. Safe handling of towing gear

See requirements under C.1, C.3 and C.5.

6. Fire safety

6.1 Structural fire protection measures shall be as outlined in Section 22, as applicable according to the size of the vessel. The fire fighting equipment shall conform to Rules for Machinery Installations (Pt.1, Vol.III) Sec.12, as applicable.

6.2 Additional or deviating regulations of the competent Administration may have to be observed.

H. Additional Requirements for Active Escort Tugs

1. Scope, application

1.1 The following requirements apply to vessels specially intended for active escort towing. This includes steering, braking and otherwise controlling a vessel in restricted waters during speeds of up to 10 knots by means of a permanent towline connection with the stern of the escorted vessel, see 4.3.

1.2 The requirements for the Notation "**TUG**" given in A. to G. are also valid, if applicable, for Active Escort Tugs.

2. Classification, Notations

2.1 Ships built in accordance with the following requirements will have the special notation "**ACTIVE ESCORT**" affixed to their Character of Classification.

2.2 Ships which not comply with the requirements 3. will have the special notation "**ESCORT**" affixed to their Character of Classification.

3. Characteristics of Active Escort Tugs

3.1 The following escort characteristics are to be determined by approved full scale trials:

— maximum steering force T_{Ey} [kN] at a test speed of advance Vt [kn], normally 8 to 10 knots

— manoeuvring time t [s]

— manoeuvring coefficient K = 31 / t or 1,0, whichever is less

3.2 A test certificate indicating the escort characteristics is issued on successful completion of such trials.

4. Definitions

4.1 Active Escort Tug is a tug performing the active escort towing.

4.2 Assisted vessel is the vessel being escorted by an Active Escort Tug.

4.3 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 T_{Ey} [kN] is provided by the hydrodynamic forces acting on the Active Escort Tug's hull, see Fig. 27.3.

4.4 Test speed V_t [kn] is the speed of advance (through the water) of the assisted vessel during full scale trials.

4.5 The manoeuvering 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.27.3. 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°.

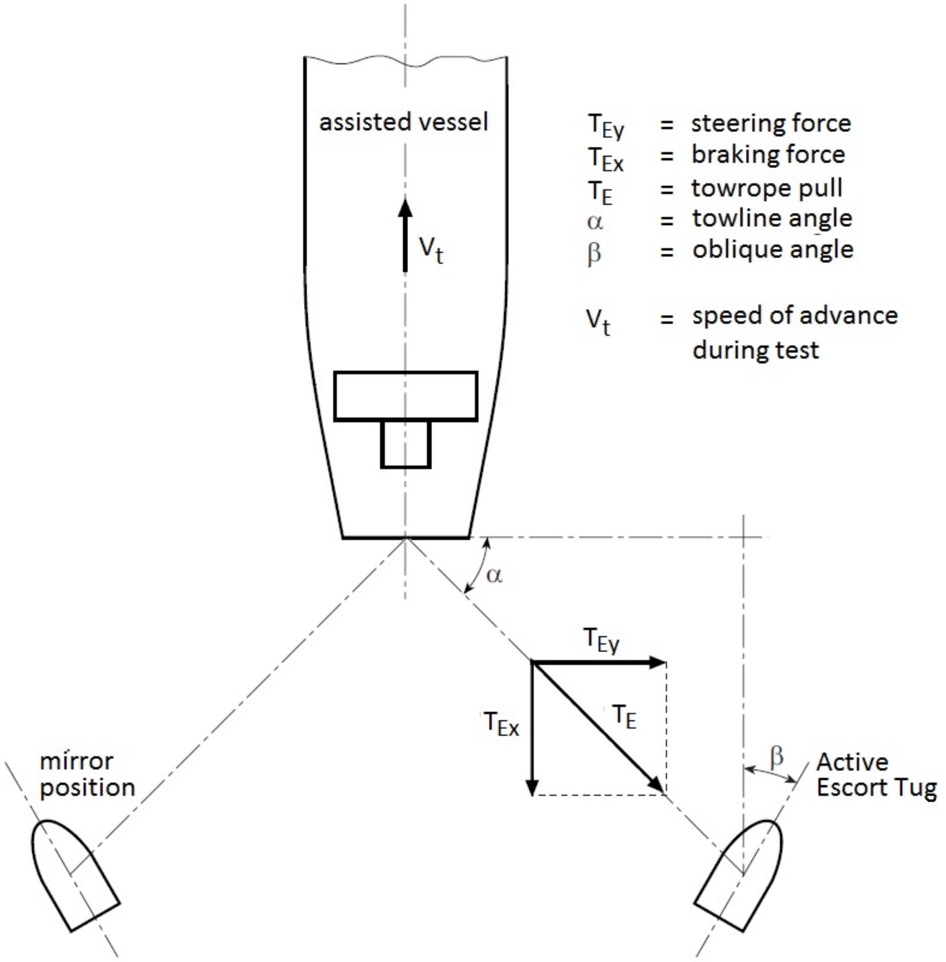

Fig. 27.3 Typical working mode of an Active Escort Tug

5. Documentation

The following documents shall be submitted in form of electronic format in addition to those of A.3.1, for approval:

- BKI Material Certificates for all load transmitting elements (e.g. motor, drive) of the towing winch
- circuit diagrams of the hydraulic and electrical systems of the towing winches
- one copy of a description of the towing winch including the safety devices
- preliminary calculation of the maximum steering force T_{Ey} [kN] and maximum towrope pull T_E [kN] at the intended test speed V_t [kn] with indication of propulsion components necessary for balancing the Active Escort Tug at anoblique angular position at the stern of the assisted vessel.

6. Arrangement and design

6.1 Hull

6.1.1 The hull of the Active Escort Tug is to be designed to provide adequate hydrodynamic lift and drag forces whenin indirect towing mode. Hydrodynamic forces, towline pull and propulsion forces shall be in balance during active escorttowing thereby minimizing the required propulsion force itself.

6.1.2 Freeboard is to be provided in such a way, that excessive trim at higher heeling angles is avoided.

6.1.3 A bulwark is to be fitted all around the weather deck.

6.2 Towing winch

6.2.1 The equipment for measuring the pulling force in the towrope, recommended in C.5.1.5, is to be provided in anycase for towing winches of Active Escort Tugs.

6.2.2 In addition to the requirements given in C.5 towing winches of escort tugs are to be fitted with a load dampingsystem which prevents overload caused by dynamic impacts in the towrope.

The towing winch shall 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 towingwinch's rope drum.

6.2.3 The towing winch shall automatically spool a slack towrope. The requirement C.5.2.4 may be waived, if an impeccable spooling of towrope under load is guaranteed by design measures (e.g. spooling device).

6.3 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.

7. Stability of Active Escort Tugs

In addition to the general stability criteria in F.2, stability criteria for vessels engaged in escort operations shall in the applicable loading conditions in the stability manual comply with the criteria of the IMO IS Code, 2008, Part B, paragraphs 2.8.4.4 and 2.8.6.2, assuming heeling levers according to paragraph 2.8.3, effective from 1st July 2025.

8. Full Scale Trials

8.1 Procedure

8.1.1 A documented plan, describing all parts of the trial shall be submitted for approval before the 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 T_{Ey} [kN]

8.1.2 Full scale trials shall be carried out in favourable weather and sea conditions which will not significantly influence the trial results.

8.1.3 The size of the assisted vessel shall be sufficiently large to withstand the transverse steering forces of the tug without using too large rudder angles.

8.2 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 28 Fishing Vessels

The requirements for the construction of Fishing Vessels, see the Rules for Fishing Vessels (Pt. 1, Vol.XII).

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Section 29 Passenger and Special Purpose Ships

I. Passenger Ship

A. General

1. The requirements given in Sections 1 - 22 and 36 apply to passenger ships unless otherwise mentioned in this Section. The various special regulations for passenger ships contained in the Rules for Machinery Installations (Pt.1, Vol. III) and Rules for Electrical Installations (Pt.1, Vol.IV) are to be observed.

2. A passenger ship as defined in this Section is a ship carrying more than 12 passengers on board.

3. The Notation "**PASSENGER SHIP**" will be affixed to the Character of Classification of ships complying with the Construction Rules for the carriage and/or accommodation of passengers and with the applicable requirements of the Chapters II-1 and II-2 of SOLAS as amended.

4. Exemptions from the requirements may be granted only within the frame work of options given therein and are subject to approval by the competent Administration.

5. Passenger ship will be assigned the symbol ☐ for characterizing proof of damage stability according to the relevant requirements in Section 36, C.

6. Passenger vessels, which due to their overall design are only suitable for trade in defined waterways (e.g. "Shaltered Water Service") may in no case be assigned an extended Navigation Notation to the Character of Classification, even if the strength of the hull is sufficient for a wider range of service (e.g. "Coasting Service"). In that event, this may be expressed in the Certificate by adding the following note: "The strength of the hull structural elements complies with the service range ...".

7. The terms used in this Section are the same as those of SOLAS as amended.

B. Documents for Approval

In addition to those specified in Section 1, G the documents according to Section 36, A are to be submitted.

C. Watertight Subdivision

1. For location of collision bulkhead and stern tube see Section 11, A.2.

2. Openings in watertight bulkheads below the bulkhead deck, see Chapter II-1 Reg. 13 of SOLAS as amended.

D. Double Bottom

A double bottom shall 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. The arrangement shall comply with Chapter II-1 of SOLAS as amended and Section 36.

E. Superstructure

1. In general the requirements of Section 16 have to be observed. If a corresponding weight calculation can be provided, the deck load pAD in cabin areas according to Section 4, C.3 may be reduced to:

$$P_{AD} = 2.5 \cdot 1 + a_v \qquad [kN/m^2]$$

a_v = acceleration addition according to Section 4, C.1.1

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.

F. Openings in the Shell Plating

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.

2. The arrangement and efficiency of the means for closing any opening in the shell plating shall be consistent with its intended purpose and the position in which it is fitted and generally to the satisfaction of the Administration.

3. Arrangement, position and type of side scuttles and associated deadlights are to be in accordance with the requirements of Chapter II-1 Reg. 15 of SOLAS as amended and with Regulation 23, ICLL.

4. Doors in the shell plating below the bulkhead deck are to be provided with watertight closures. Their lowest point is not to be located below the deepest subdivision load line. The corresponding requirements of the ICLL (Reg. 21) have also to be observed. Regarding pilot doors additional requirements are given in Chapter V Reg. 23 of SOLAS as amended.

5. The inboard openings of ash- and rubbish shoots, etc., are to be fitted with efficient covers. If the inboard openings are situated below the margin line, the covers are to be watertight and, in addition, automatic non-return valves are to be fitted in the shoots above the deepest subdivision load line. Equivalent arrangements may be approved.

G. 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.

H. Cross-Flooding Arrangements

For cross-flooding arrangements refer to Section 36, H.

J. Pipe Lines

1. Where pipes are carried through watertight bulkheads, Chapter II-1 Reg. 12 and 13 of SOLAS as amended is to be observed.

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**B** from the ship's side (**B** is the greatest breadth of the ship at the subdivision load line level).

3. Where the pipe lines cannot be placed inboard of the line 0,2**B** from the ship's side, the bulkhead is to be kept intact by the means stated in 4 - 6.

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.

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 shall 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.

6. Where overflow pipes from tanks which are situated in various watertight compartments are connected to a common overflow system, they shall either 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 shall 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.

7. The means of closing described in 4 and 5 should be avoided where possible by the use of suitably installed piping. Their fitting may only be approved by BKI in exceptional circumstances.

K. Side Scuttles and Windows

1. Depending on the arrangement of side scuttles and windows, the following tests are to be performed.

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.

1.2 Side walls and aft facing walls of superstructures from the 2nd to the 4th 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.

1.3 Side walls and aft facing walls of superstructures 5th 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 5th tier and higher for all areas, except unprotected fronts, can be set to 3,6 kN/m^2.

II. Special Purpose Ships

A. General

1. Application

1.1 Special-purpose ships are subject to the requirements of Sections 1 - 21 and Section 29.I unless otherwise mentioned in this Section.

1.2 A special purpose ship as defined in this Section means a ship of not less than 500 gross tonnage which carries more than 12 special personnel, i.e. persons who are specially needed for the particular operational duties of the ship and are in addition to those persons required for the normal navigation, engineering and maintenance of the ship or engaged to provide services for the persons carried on board, e.g. ships engaged in research, training and Seismic Surveys, Fish Carrier, Hospital, as well as Diving Support ships.

Application of these provisions to special purpose ships of less than 500 gross tonnage and to special purpose ships constructed before 13 May 2008 may also be considered by BKI as far as reasonable and practicable.

1.3 The Special purpose ship shall be accordance with IMO Resolution MSC.266(84) : Code Of Safety Special Purpose Ship (SPS Code 2008), as amended.

2. Character of Classification

2.1 Special purpose ship will be assigned the symbol ☐ for characterizing proof of damage stability according to Section 36, C.

2.2 Notation

Special purpose ships, built in accordance with the requirements of this section will have the Qualifier Notation "**SPS**" affixed to their Character of Classification.

B. Documents for Approval

The following documents are to be submitted in form of electronic format in addition to those specified in Section 1, G, for approval.:

1) intact and damage stability calculation in accordance with SPS Code 2008, as amended.

2) drawings showing the external openings and the closing devices thereof.

3) drawings showing the watertight subdivision as well as internal openings and the closing devices thereof.

4) a damage control plan and damage control booklet containing all data essential for maintaining the survival capability.

Section 30 Ships for Sheltered Water Service

A. General

1. The requirements given in Sections 1 – 22 apply to ships sailing in sheltered unless otherwise mentioned in this Section.

2. Ships sailing in sheltered complying with the requirements of this Section will have the Notation ”**T**” ”**SHELTERED WATER SERVICE**” affixed to the Character of Classification.

3. The deck load is to be taken as p = 6 kN/m^2 unless a greater load is required by the Owner.

B. Shell Plating

1. The thickness of bottom plating is not to be less than determined by the following formula:

$$t = 1,3 \cdot \frac{\mathbf{a}}{a_0} \cdot \sqrt{\frac{\mathbf{L} \cdot \mathbf{T}}{\mathbf{H}}} \quad [mm]$$

a_0 = standard frame spacing [m], defined as:

= 0,002 · **L** + 0,48 [m]

2. For ships having flat bottoms the thickness is to be increased by 0,5 mm.

3. The thickness of the side shell plating within 0,4 **L** may be 0,5 mm less than the bottom plating according to 1.

4. The thickness within 0,05**L** from the forward and aft end of the length **L** may be 1,0 mm less than the value determined according to 1.

5. The thickness of the shell plating is nowhere to be less than 3,5 mm.

6. Strengthening of the bottom forward according to Section 6, E is not required.

7. The plate thickness of sides of superstructures is to be determining according to 4 and 5 analogously.

C. Watertight Bulkheads and Tank Bulkheads

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.

The thickness is, however, not to be less than the following minimum values :

for the lowest plate strake

t_{min} = 3,5 [mm]

for the remaining plate strakes

t_{min} = 3,0 [mm]

2. The scantlings of tank bulkheads and tank walls are to be determined according to Section 12. The thickness of plating and stiffener webs is not to be less than:

t_{min} = 5,0 [mm]

D. Deck Openings

1. Hatchways

1.1 The height hhc above deck of hatchway coamings is not to be less than[1)]:

on decks in Pos. 1 = 600 mm

on decks in Pos. 2 = 380 mm

1.2 The thickness tc of coamings is to be determined according to the following formulae:

longitudinal coaming :

$$t_{\ell} = 4,5 + \frac{\ell}{6} \quad [mm]$$

transverse coaming :

$$t_q = 2,75 + \frac{b}{2} \quad [mm]$$

ℓ = length of hatchway [m]

b = breadth of hatchway [m]

1.3 For hatch covers the requirements of Section 17 and Section 21, R.

2. Casings, companionways

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 3,0 mm. Coamings are not to be less in height than 350 mm and they are not to be less in thickness than 4,0 mm.

2.2 The height h_c above deck of companionway coamings h_{cc} is not to be less than[1)]:

on decks in Pos. 1 = 600 mm

on decks in Pos. 2 = 380 mm

E. Equipment

1. The equipment of anchors, chain cables and recommended ropes is to be determined according to Section 18.

2. The anchor mass may be 60% of the value required by Table 18.2. The chain diameter may be determined according to the reduced anchor mass.

[1)]For ship which the Flag entitled to fly, National Regulation to be observed.

3. For anchor masses of less than 120 kg, the chain cable diameter of grade K1 steel is to be calculated according to the following formula:

$$d = 1,15 \cdot \sqrt{P} \quad [mm]$$

P = anchor mass [kg]

Short link chain cables are to have the same breaking load as stud link chain cables.

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 Table 18.2.

5. The length of the ropes is recommended to be 50% of the length given in Table 18.2 (see also Section 18, F).

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Section 31 Barges and Pontoons

A. General

1. Design

1.1 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.

1.2 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.

2. Validity

The requirements given in Sections 1 - 24 and the stability requirements of the Section 36 apply to barges and pontoons unless otherwise mentioned in this Section.

3. Character of Classification

3.1 Ships built in accordance with the requirements of this Section will have the Notation "**BARGE**" or "**PONTOON**" affixed to the Character of Classification.

3.2 Barges and pontoon built for the carriage of special cargo (e.g. liquid or ore cargo) will have the respective Notations affixed to the Characters of Classification (see also Guidance for Class Notation (Pt.0, Vol.B) Sec.2.M.

3.3 For barges having the Notation "**BARGE, HOPPER**" including split hopper barges see Section 32.

3.4 For Barges intended to operate combined pusher/barge units, additional requirements in Annex 2 are to be applied.

4. General indication

Where barges are intended to operate as linked push barges proper visibility from the tug forward is to be ensured.

5. Deck cargo load

The load for deck cargo, unless greater load is required by the Owner, is to be taken as p = 25 [kN/m^2]. For deck cargo more than 25 kN/m^2 will have additional notation **DL** maximum deck loading ton/m^2.

Note:

Cargo retaining arrangements (side boards, coamings, etc.) fitted on deck of deck cargo barge to have adequate strength and to be provided with sufficient freeing arrangements.

B. Longitudinal Strength

1. The scantlings of the longitudinal hull structures for barges of 65 m in length and more and for pontoons of 90 m in length and more are to be determined on the basis of longitudinal bending moments and shear forces calculations according to Section 5.

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, C.2 is to be fulfilled.

2. The midship section modulus may be 5% less than required according to Section 5.

3. 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 Volume. The minimum thickness and critical thickness specified in those Sections are, however, to be adhered to.

4. 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:

$$\text{bending stress} : \sigma_b = \frac{150}{k} \quad [\text{N/mm}^2]$$

$$\text{shear stress} : \tau = \frac{100}{k} \quad [\text{N/mm}^2]$$

k = material factor according to Section 2, B

Special attention is to be paid to the transmission of lifting forces into the barge structure.

5. 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 given under 4. are not to be exceeded.

C. Watertight Bulkheads and Tank Bulkheads

1. For barges and pontoons, the position of the collision bulkhead is to be determined according to Section 11, A.2.

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.

2. On barges intended to operate as linked push barges, depending on the aft ship design, a collision bulkhead may be required to be fitted in the aft ship.

3. 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.

4. 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, D.1 is to be inserted in the formulae for determining the pressures P_1 and P_2.

D. Structural Details at the Ends

1. Where barges have typical ship-shape fore and aft ends, the scantlings of structural elements are to be determined according to Section 8, A.1.2 and Section 9, A.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.

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.

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. In the forward ends, the girders shall be spaced not more than 2,4 m apart. The girders shall be scarphed into the midship structure. A raked fore-end with a flat bottom is to be strengthened according to Section 6, E.

4. In pontoons which are not assigned a Notation for restricted service range or which are assigned the Notation P (Restricted Ocean Service), 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. Rudder

The rudder stock diameter is to be determined according to Section 14, C.1. The ship's speed $\mathbf{v}_0$ is not to be taken less than 7 knots.

F. 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 not to be exceeded:

bending and normal stresses:

$$\sigma = \frac{100}{k} \quad [\text{N/mm}^2]$$

shear stresses:

$$\tau = \frac{60}{k} \quad [\text{N/mm}^2]$$

equivalent stresses:

$$\sigma_v = \sqrt{\sigma^2 + \tau^2} = \frac{120}{k} \quad [\text{N/mm}^2]$$

G. Equipment

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 shall 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 Rules for Machinery Installations (Pt 1, Vol. III) Sec.14.D. are to be observed.

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.

3. The equipment numeral Z for determining the equipment according to Table 18.2, is to be determined for pontoons carrying lifting equipment, rams etc. by the following formula:

$$Z = D^{2/3} + \mathbf{B} \cdot f_b + f_w$$

D = displacement of the pontoon [t] at maximum anticipated draught

f_b = distance [m] between pontoon deck and waterline

f_w = wind area of the erections on the pontoon deck [m^2] which are exposed to the wind from forward, including houses and cranes in upright position.

4. 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 Table 18.2.

5. If necessary for a special purpose, upon Owner's request, for barges and pontoons mentioned under 4, the anchor mass may be further reduced by up to 20%. In such cases the equipment Notation in the Character of Classification is to be **II**.

Upon Owner's request the anchoring equipment may be dispensed with. In such cases the anchoring equipment will not be assigned in the Character of Classification.

6. If a wire rope shall be provided instead of a chain cable, the following is to be observed:

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.

6.2 Between anchor and wire rope, a chain cable is to be fitted the length of which is 12,5 m or equal to the distance between the anchor in stowed position and the windlass. The smaller value is to be taken.

6.3 A winch has to be provided which is to be designed in accordance with the requirements for windlasses (see also Rules for Machinery Installations (Pt 1, Vol.III) Sec.14.D).

7. Push barges not operating at the forward or aft end of pushed or towed units need not have any equipment.

8. Anchor equipment fitted in addition to that required herein (e.g. for positioning purposes) is not part of Classification.

Section 32 Dredgers

A. General

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

IACS UR A1 Rev.8

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

1. For the purposes of this Section, ”dredgers” means hopper dredgers, barges, hopper barges and similar vessels which may be self-propelled and non-self-propelled and which are designed for all common dredging methods (e.g. bucket dredgers, suction dredgers, grab dredgers etc.)

Dredgers intended for unusual dredging methods and ships of unusual form will be specially considered.

2. The requirements given in Sections 1 - 22 and Stability requirement of Section 36 apply to dredgers covered by this Section unless otherwise mentioned hereinafter.

3. Dredgers built in accordance with the requirements of this Section, will have the special notation “**BUCKET**”, “**SUCTION**”, “**GRAB**”, or ”**HOPPER**”, affixed to the Character of Classification.

4. Dredgers engaged in international service are to comply with the requirements of the ICLL.

5. Dredgers with a restricted service area operating exclusively in national waters shall comply, as far as possible, with the requirements of the ICLL. The height of companion way coamings above deck is not to be less than 300 mm.

Note:

For dredgers with a restricted service range as per Section 1, B operating exclusively in national waters, a special ”Dredger Freeboard” is assigned by some Administrations.

6. Dredgers intended to work in conjunction with other vessels are to be fitted with strong fenders.

7. 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 BKI such members may alternatively be constructed of special abrasion resistant materials.

8. 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 Rules for Electrical Installations (Pt.1, Vol.IV), are to be observed.

B. Documents for Approval

To ensure conformity with the Rules, the following drawings and documents are to be submitted in form of electronic format in addition to those stipulated in Section 1, G.

1. General arrangement plan, showing also the arrangement of the dredging equipment.

2. Longitudinal and transverse hopper bulkheads, with information regarding density of the spoil and height of overflow.

3. Arrangement and scantlings of substructures attached to or integrated into main structural members, such as gantries, gallows etc. or their seats, seats of dredging machinery and pumps, hopper doors and their gear with seats, positioning equipment and other dredging equipment and devices and their seats.

4. Longitudinal strength calculations for ships of 100 m in length and more.

For ships of less than 100 m in length of unusual design and with unusual load distribution, longitudinal strength calculations may be required.

C. Principal Dimensions

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, H.

2. Where a "Dredger Freeboard" is assigned in accordance with A.5, the length **L**, draught **T** and block coefficient $\mathbf{C_B}$ as per Section 1, H are to be determined for this freeboard.

D. Longitudinal Strength

1. For dredgers with **L** ≥ 100 m, the longitudinal strength requirements as per Section 5 apply in general.

For dredgers classed for particular service areas, dispensations may be approved.

2. For hopper dredgers and hopper barges of less than 100 m in length, the minimum midship section modulus according to Section 5 is to be fulfilled and longitudinal strength calculations may be required in special instances.

3. Irrespective of their length, for split hopper barges longitudinal strength calculations are to be carried out for the unloading condition according to J.

4. At the ends of the hopper, the longitudinal strength members are to be carefully scarphed into the adjacent compartments (see also H.1.3).

E. Shell Plating

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.

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 baseline 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.

3. On non-self-propelled dredgers and on self propelled dredgers with the restricted service range Notation "**L**" or "**T**" affixed to their Character of Classification, strengthening of the bottom forward in accordance with Section 6, E is not required.

4. 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 1. are also to be observed.

5. The corners of hopper door openings and of dredging gear wells generally are, to comply with Section 7, A.3. The design of structural details and welded connections in this area is to be carried out with particular care.

F. Deck

1. The deck thickness is to be determined in accordance with Section 7.

On vessels of less than 100 m in length, the rule deck plating is to be fitted at least in the following areas: Above engine and boiler rooms, in way of engine and boiler casings, adjacent to all deck openings exceeding 0,4**B** in breadth and in way of the supporting structure for dredging gear, dredging machinery and bucket ladders, etc.

Where wood sheathing is fitted, the deck plating thickness required in Section 7, A.7 is sufficient unless greater thicknesses are required on account of strength calculations.

2. At the ends of the hopper space continuity of strength is to be maintained by fitting strengthened corner plates.

The corners are to be carried out in accordance with the requirements of Section 7, A.3.

G. Bottom Structure

1. Single bottom transversely framed

1.1 Abreast of hoppers and centreline dredging wells, the floors are to be dimensioned in accordance with Section 8, A.1.2.1 where R_{min} is not to be taken less than 0,4**B**. The depth of floor is not to be less than:

$$h = 45 \cdot \mathbf{B} - 45 \quad [\mathrm{mm}]$$

$$h = 180 \ \mathrm{mm}$$

1.2 Floors, longitudinal girders etc. below dredging machinery and pump seats are to be adequately designed for the additional loads.

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.

1.4 Where the unsupported span of floors exceeds 3,0 m, one side girder in accordance with Section 8, A.2.2.2 is to be fitted.

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.

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, F.1.

2. Single bottom longitudinally framed

2.1 The spacing of bottom transverses generally is not to exceed 3,6 m. Section modulus and web cross sectional area are not to be less than:

$$W = k \cdot c \cdot e \cdot \ell^2 \cdot p \quad [cm^3]$$

$$A_W = k \cdot 0,0061 \cdot e \cdot \ell \cdot p \quad [cm^2]$$

k	=	material factor according to Section 2, B
c	=	$0,9 - 0,002 \cdot \mathbf{L}$ for **L** ≤ 100 mm
	=	0,7 for **L**> 100 mm
e	=	spacing of bottom transverses between each other or from bulkheads [m]
ℓ	=	unsupported span [m], any longitudinal girders not considered
p	=	load p_B or pl as per Section 4, B.3 or D.1; the greater value to be taken

The web depth is not to be less than the depth of floors according to 1.1.

2.2 The bottom longitudinals are to be determined in accordance with Section 9, B.

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. They are to be flanged or fitted with face bars.

2.4 Where longitudinal bulkheads and the side shell are framed transversely, the brackets as per 2.3 are to be fitted at every frame and are to extend to the bilge.

2.5 The bottom transverses are to be stiffened by means of flat bar stiffeners at every longitudinal. The depth shall approximately be equal to the depth of the bottom longitudinals, however, it need not exceed 150 mm.

2.6 The bottom structure of dredgers intended or expected to operate with aground is to be dimensioned as follows:

2.6.1 The spacing of the bottom transverses as per 2.1 is not to exceed 1,8 m. The webs are to be stiffened as per 1.6.

2.6.2 The Section modulus of the bottom longitudinals as per 2.2 is to be increased by 50

2.7 The requirements of 1.2, 1.3, 1.4 and 1.5 are to be applied analogously.

3. Double bottom

3.1 Double bottoms need not be fitted adjacent to the hopper spaces.

3.2 In addition to the requirements of Section 8, B.6, plate floors are to be fitted in way of hopper spaces intended to be unloaded by means of grabs.

3.3 Where brackets are fitted in accordance with Section 8, B.7.4, the requirements as per 2.3 and 2.4 are to be observed where applicable.

3.4 The bottom structure of dredgers intended or expected to operate while aground is to be strengthened in accordance with Section 8, B.1.7. Where applicable, 2.6 is to be applied analogously.

H. Hopper and Well Construction

1. The scantlings of the boundaries of hopper spaces and wells are to be determined as follows:

1.1 Plating

$$t = 1,21 \cdot \mathbf{a} \cdot \sqrt{p \cdot k} + t_K \quad [mm]$$

t_{min} = as per Section 24, A.12

k = see G.2.1

$\mathbf{a}$, a_ℓ = spacing of stiffeners [m]

p = $10 \cdot \rho \cdot h\,(1 + a_v)$ [kN/m^2]

h = distance of lower edge of plating or of the load centre of the respective member to the upper edge of overflow [m]

a_v = see Section 4, C.1.1

ρ = density of the spoil [t/m^3]

ρ_{min} = 1,2 [t/m^3]

t_K = corrosion addition according to Section 3, K

1.2 Stiffeners

1.2.1 transverse stiffeners of longitudinal bulkheads and stiffeners of transverse bulkheads:

$$W_y = k \cdot 0,6 \cdot \mathbf{a} \cdot \ell^2 \cdot p \quad [cm^3]$$

1.2.2 longitudinal stiffeners:

$$W_x = W_\ell$$

W_ℓ see Section 9, B.3, but not less than W_y.

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.

2. In hoppers fitted with hopper doors, transverse girders are to be fitted between the doors the spacing of which shall normally not exceed 3,6 m.

3. The depth of the transverse girders spaced in accordance with 2. shall not be less than 2,5 times the depth of floors as per Section 8, A.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 in accordance with 1. At the upper edge, a plate strengthened by at least 50% is to be fitted.

4. Vertical stiffeners spaced not more than 900 mm apart are to be fitted at the transverse girders.

5. The transverse bulkheads at the ends of the hoppers are to extend from board to board.

6. Regardless of whether the longitudinal or the transverse framing system is adopted, web frames in accordance with Section 12, B.3 are to be fitted in line with the transverse girders as per 2.

The density of the spoil is to be considered when determining the scantlings.

7. Strong beams are to be fitted transversely at deck level in line with the web frames as per 6. The scantlings are to be determined, for the actual loads complying with an equivalent stress σ_v = 150/k (N/mm^2). 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 as per Section 10, C at the box keel, if fitted.

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.

J. Box Keel

1. The scantlings are to be determined as follows:

1.1 Plates

1.1.1 Bottom plating

— where the box keel can serve as a docking keel, the requirements for flat plate keels as per Section 6, B.5 apply,

— where the box keel cannot serve as a docking keel (see also E.2), the requirements for bottom plating as per Section 6, B.1-3 apply.

1.1.2 Remaining plating

— outside the hopper space, the requirements for bottom plating as per Section 6, B.1-3 apply,

— within the hopper space the requirements for hopper space plating as per H.1.1 apply. The thickness of the upper portion particularly subjected to damage is to be increased by not less than 50%.

1.2 Floors

The requirements as per G.1 and G.2 respectively apply.

1.3 Stiffeners

The requirements for hopper stiffeners as per H.1.2 apply.

2. Strong webs of plate floors are to be fitted within the box keel in line with the web frames as per H.6 to ensure continuity of strength across the vessel.

3. With regard to adequate scarphing at the ends of a box keel, H.1.3 is to be observed.

K. Stern Frame and Rudder

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.

2. Where dredgers are fitted with auxiliary propulsion and their speed does not exceed 5,0 kn at maximum draught, the value $\mathbf{v}_0$ = 7,0 kn is to be taken for determining the rudder stock diameter.

L. Bulwark, Overflow Arrangements

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.

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 cutouts 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.

3. Dredgers with restricted service range Notation may have overflow arrangements which permit discharge of excess water during dredging operations onto the deck.

M. Self-Unloading Barges

1. Self-unloading barges covered by this Sub Section are split hopper barges the port and starboard portions of which are hinged at the hopper end bulkheads to facilitate rotation around the longitudinal axis when the bottom is to be opened.

2. Longitudinal strength calculations are to be carried out for self-unloading barges, irrespective of their length, for the unloading condition. The bending moments and the stresses related to the inertia axis y' - y' and z' - z' are to be determined according to the following formula:

$$\sigma = \frac{M'_y \cdot e'_z}{I_y} + \frac{M'_z \cdot e'_y}{I_z} \quad [\mathrm{kN/mm^2}]$$

M'_y, M'_z = bending moment 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, B.2 and Section 5, B.3.

The horizontal still water bending moment within the hold length is to be calculated on the basis or 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 :

$$M_z = \frac{\ell^2}{24} \cdot \left[10 \cdot \mathbf{T}^2 - \frac{(10 \cdot \mathbf{T} - p_0)^2}{10 \cdot \mathbf{T} + p_0} \cdot \mathbf{T}\right] \quad [\mathrm{kN.m}]$$

p_0 = see Section 4, A.2, with f = 1,0

ℓ = spacing between hinges [m]

The stresses are not to exceed the following values:

- in still water:

$$\sigma_{sw} = 15 \cdot \frac{\sqrt{\mathbf{L}}}{k} \leq \frac{150}{k} \quad [\mathrm{N/mm^2}]$$

- in the seaway:

$$\sigma_p \leq \frac{175}{k} \quad [\mathrm{N/mm^2}]$$

BKI may approve reduced vertical wave bending moments if the vessel is intended for dumping within specified service ranges or in sheltered waters only.

3. The bearing seating and all other members of the hinge are to be so designed as not to exceed the following permissible stress values when loading as per Fig. 32.1:

$$\sigma_b \leq \frac{90}{k} \quad [N/mm^2]$$

$$\tau \leq \frac{55}{k} \quad [N/mm^2]$$

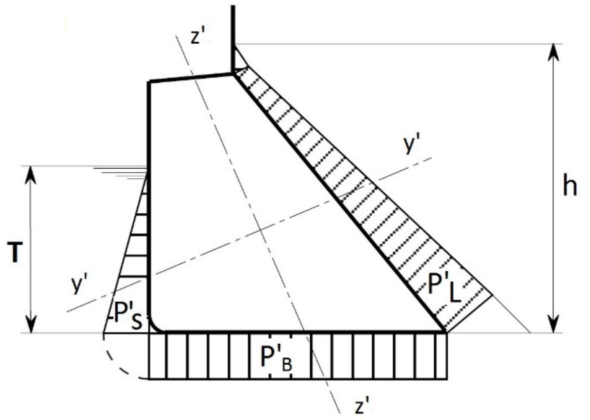

Fig. 32.1 Static loads on a self-unloading barge, loaded

p_S' and p_B'	=	water pressure	[kN/m^2]	at the draught **T**
p_L'	=	cargo pressure	[kN/m^2]	as per the following formula:
	=	$10 \cdot \rho \cdot h$	[kN/m^2]	
ρ and h	=	see H.1.1		

N. Equipment

1. The equipment of anchors, chain cables, wires and recommended ropes for dredgers for unrestricted service range 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 range of service is to be determined as for vessels with the Notations **L** (Coasting Service).

For dredgers with Notation “**T**”, see Section 30, E.

Dredgers with unusual design of the underwater part of the hull are not covered by alternative methodology using direct force calculation for anchoring equipment described in Guidance for Marine Industry (Pt.1, Vol.AC) Sec.1, R-10, Appendix B.

(IACS UR A1.3.2)

2. The equipment of non-self propelled dredgers is to be determined as for barges, in accordance with Section 31, G.

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.

Section 33 Special Rules of Floating Docks

The requirements for the construction of Floating Docks, see the Rules for Floating Docks (Pt 3, Vol.II).

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Section 34 Supply Vessels

A. General

1. Application, character of classification

1.1 Ships intended to get Notations of **SUPPLY VESSEL** or **WORK SHIP** are to be in compliance with this section.

SUPPLY VESSEL is Ships intended for supply/replenishment of islands and ships of similar use.

WORK SHIP is ships intended to special working ships (e.g. buoy tender, etc.)

1.2 The requirements of Sections 1-22 and stability requirements of Section 36 apply to supply vessels unless otherwise mentioned in this Section.

1.3 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 Rules for Ship Carrying Dangerous Chemical in Bulks (Pt.1, Vol.X) Sec.20).

2. Documents for approval

The following documents are to be submitted in form of electronic format in addition to those specified in Section 1, G:

2.1 drawings showing the external openings and the closing devices thereof.

2.2 drawings showing the watertight subdivision as well as internal openings and the closing devices thereof.

2.3 damage stability calculation in accordance with IMO-Res. A.469 or A.673.

2.4 damage control plan containing all data essential for maintaining the survival capability.

2.5 stability information.

B. Shell Plating, Frames

1. Shell plating

1.1 The thickness of the side shell plating including bilge strake is not to be less than :

$$t = 7,0 + 0,004 \cdot \mathbf{L} \quad [\mathrm{mm}]$$

1.2 Flat parts of the ship's bottom in the stern area are to be efficiently stiffened.

1.3 Where the stern area is subjected to loads due to heavy cargo, sufficient strengthenings are to be provided.

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

1. The scantlings of the weather deck are to be based on the following design load:

$$p = p_L + c \cdot p_D \quad [kN/m^2]$$

p_L	=	cargo load as defined in Section 4, C.1
p_{Lmin}	=	15 $[kN/m^2]$
p_D	=	deck load according to Section 4, B.1
c	=	$1,28 - 0,0032 \cdot p_L$ for $p_L < 40$ kN/m^2
	=	0 for $p_L \geq 40$ kN/m^2

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.

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:

$$\text{bending stress}: \sigma_b \leq \frac{120}{k} \quad [N/mm^2]$$

$$\text{shear stress}: \tau \leq \frac{80}{k} \quad [N/mm^2]$$

k = material factor according to Section 2, B

4. The thickness of the bulwark plating is not to be less than 7,5 mm.

5. Air pipes and ventilation are to be fitted in protected positions in order to avoid damage by cargo and to minimize the possibility of flooding other spaces.

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

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, C.3.2.

2. The section modulus of stiffeners is to be increased by 50% above the values as required in Section 16, C.3.1.

E. Access to Spaces

1. Access to the machinery space

1.1 Access to the machinery spaces 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.

1.2 Due regard is to be given to the position of the machinery space ventilators. Preferably they should be fitted in position above the superstructure deck or above an equivalent level.

2. Access to spaces below the exposed cargo deck

Access to spaces below the exposed cargo deck shall preferably 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, D.

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Section 35 Strengthening Against Collisions

A. General

1. Application

1.1 Ships, the side structures of which are specially strengthened in order to resist collision impacts, may be assigned the additional notations "**COLL**", with index numbers **1- 6**, e.g. "**COLL 2**", 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 35.1 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 "**COLL 6**" may be assigned if justified by the design and construction of the ship.

Table 35.1 COLL - Notation

C^*	"COLL"-Notation
2	**COLL 1**
3	**COLL 2**
4	**COLL 3**
6	**COLL 4**
10	**COLL 5**
20	**COLL 6**

1.2 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.

The critical speed v_{cr} is defined as being the speed of the striking ship; if this speed is exceeded, a critical situation may be expected.

1.3 The definition of the critical situation is entered into the Certificate.

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.

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.

1.5 A "**COLL**"-Notation will be assigned under the provision that the ship has a sufficient residual longitudinal strength in the damaged condition.

B. Calculation of the Deformation Energy

1. The deformation energy has to be calculated by procedures recognized by BKI. 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 BKI.

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 RUC to be assumed is the mean value of the minimum nominal upper yield point and the tensile strength, as follows:

$$R_{UC} = \frac{1}{2}\left(R_{eH} + R_m\right)$$

R_{eH} = minimum nominal upper yield point of the hull structural steel applied as per Section 2, B.

R_m = tensile strength of the hull structural steel applied.

The elongation at fracture of the shell is to be taken as 5%.

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.

Two (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.

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.

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 $\Delta\mathbf{T}$ of the ships involved in the collision, see Fig. 35.1

The following draught differentials are to be considered:

Collision case 1:

$$\Delta \mathbf{T}_1 = \mathbf{T}_{2max} - \frac{3 \cdot \mathbf{T}_{1min} + \mathbf{T}_{1max}}{4}$$

Collision case 2:

$$\Delta T_2 = T_{2max} - \frac{T_{1min} + 3 \cdot T_{1max}}{4}$$

Collision case 3:

$$\Delta T_3 = \frac{T_{2min} + 3 \cdot T_{2max}}{4} - T_{1max}$$

Collision case 4:

$$\Delta T_4 = \frac{3 \cdot T_{2min} + T_{2max}}{4} - T_{1max}$$

T_{1max} = design draught of the striking ship

T_{1min} = ballast draught of the striking ship

T_{2max} = design draughts of the struck ship

T_{2min} = ballast draught of the struck ship

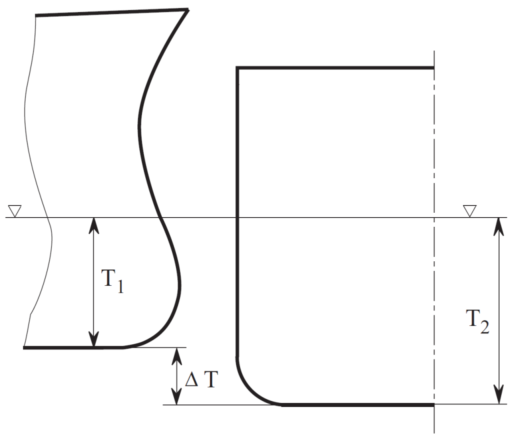

Fig. 35.1 Draught differential ΔT of ships involved in a collision

6. Based on the deformation energies calculated for the strengthened and non-strengthened side structure for the different collision cases defined in 5. above, the mean values of the critical deformation energies are to be evaluated by means of weighting factors.

7. The mean critical deformation energies are to be calculated for the collision cases 1 to 4 and for both bow shapes, in accordance with the following formulae:

for bow shape 1:

$$\overline{E_{01}} = \frac{1}{8}\left[E_{01,1} + 3 \cdot E_{01,2} + 3 \cdot E_{01,3} + E_{01,4}\right]$$

$$\overline{E_{11}} = \frac{1}{8}\left[E_{11,1} + 3 \cdot E_{11,2} + 3 \cdot E_{11,3} + E_{11,4}\right]$$

for bow shape 2:

$$\overline{E_{02}} = \frac{1}{8}\left[E_{02,1} + 3 \cdot E_{02,2} + 3 \cdot E_{02,3} + E_{02,4}\right]$$

$$\overline{E_{22}} = \frac{1}{8}\left[E_{22,1} + 3 \cdot E_{22,2} + 3 \cdot E_{22,3} + E_{22,4}\right]$$

where:

$E_{01,i}$ = deformation energy for the un-strengthened 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 un-strengthened ship, bow shape 2, collision case i, i = 1$\sim$4

$E_{22,i}$ = deformation energy for the strengthened ship, bow shape 2, collision case i, i = 1$\sim$4

8. The ratios of the mean critical deformation energies are to be calculated by the following formulae:

for bow shape 1:

$$\overline{C_1} = \frac{\overline{E_{11}}}{E_{01}}$$

for bow shape 2:

$$\overline{C_2} = \frac{\overline{E_{22}}}{E_{02}}$$

The characteristic ratio for the ship is the mean value resulting from the two weighted ratios and in accordance with the following formula:

$$C* = \frac{1}{2}\left(\overline{C_1} + \overline{C_2}\right)$$

9. The index defined in A.1 will be fixed on the basis of the characteristic ratio C* and the corresponding minimum value for the critical speed v^*_{crmin} according to C.3.

C. Computation of the Critical Speed

1. The critical collision speed is to be determined by the following formula:

$$v_{cr} = 2,75 \cdot \sqrt{\frac{E_{cr}}{m_2}\left[1 + \frac{m_2}{m_1}\right]} \quad [kn]$$

E_{cr} = deformation energy, once the critical speed has been reached [kJ]

m_1 = mass of the striking ship, including 10% hydrodynamical added mass [t]

m_2 = mass of the struck ship, including 40% hydrodynamical added mass [t]

2. When calculating the critical speeds for the collision cases in accordance with B.5, the following draughts are to be assumed:

Collision case 1:

$$\mathbf{T}_1 = \frac{3 \cdot \mathbf{T}_{1min} + \mathbf{T}_{1max}}{4}$$

$$\mathbf{T}_2 = \mathbf{T}_{2max}$$

Collision case 2:

$$\mathbf{T}_1 = \frac{\mathbf{T}_{1min} + 3 \cdot \mathbf{T}_{1max}}{4}$$

$$\mathbf{T}_2 = \mathbf{T}_{2max}$$

Collision case 3:

$$\mathbf{T}_1 = \mathbf{T}_{1max}$$

$$\mathbf{T}_2 = \frac{3 \cdot \mathbf{T}_{2max} + \mathbf{T}_{2min}}{4}$$

Collision case 4:

$$\mathbf{T}_1 = \mathbf{T}_{1max}$$

$$\mathbf{T}_2 = \frac{\mathbf{T}_{2max} + 3 \cdot \mathbf{T}_{2min}}{4}$$

3. For the assignment of a "**COLL**" Notation, in addition to the characteristic ratio C* according to A.1 (Table 35.1), the minimum values for the mean critical speed v^*_{cr} as given in Table 35.2 have to be met.

Table 35.2 Minimum values for the mean critical speed v^*_{cr}

"COLL"-Notation	v^*_{crmin} [kn]
COLL 1	1,0
COLL 2	1,5
COLL 3	2,5
COLL 4	4,0
COLL 5	5,5
COLL 6	7,0
v^*_{cr} see also 4.	

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:

for bow shape 1:

$$\overline{v_{cr1}} = \frac{1}{8}\left[v_{1cr1} + 3 \cdot v_{1cr2} + 3 \cdot v_{1cr3} + v_{1cr4}\right]$$

v_{1cri} = critical speed for bow shape 1, collision case i, i = 1 ÷ 4

for bow shape 2:

$$\overline{v_{cr2}} = \frac{1}{8}\left[v_{2cr1} + 3 \cdot v_{2cr2} + 3 \cdot v_{2cr3} + v_{2cr4}\right]$$

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:

$$v^*_{cr} = \frac{1}{2}\left(\overline{v_{cr1}} + \overline{v_{cr2}}\right) \qquad [\text{kn}]$$

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Section 36 Subdivision and Stability

A. General

1. Application

1.1 All ships within the scope of Table 36.1 and Table 36.2 are to meet the stability and subdivision criteria specified in the following sub-sections, as applicable. In case the criteria listed in this Section are not applicable to a particular ship, the intact and damaged stability are to be reviewed by BKI in accordance with other recognized criteria appropriate to the ship's type, size and intended service.

1.2 Alternative calculations or arrangements will be accepted for a particular or group of ships if they have been acknowledged by the competent administration as providing at least the same degree of safety.

1.3 Where the stability review is conducted and found satisfactory by the flag State Administration, the stability information and calculations specified in the following sections need not be submitted.

2. Character of Classification

Ships with a length of 24 m and above will be assigned class only after it has been demonstrated that their intact stability is adequate for the service intended.

(IACS UR L2)

Ships which meet the requirements of C. will be assigned the symbol ☐ for characterizing proof of damage stability.

Attained subdivision index "A" calculated by BKI in accordance with Regulation II-1/7 of SOLAS 1974 as amended is to be indicated in the Register Book (Appendix of Certificate).

3. Documents for approval

The following documents are to be submitted for examination in form of electronic format in addition to those specified in Section 1, G.

1) Drawings showing the external openings and the closing devices thereof.
2) Drawings showing the watertight subdivision as well as internal openings and the closing devices thereof.
3) Damage stability calculation in accordance with SOLAS as amended and the related Explanatory Notes.
4) Damage control plan and damage control booklet containing all data essential for maintaining the survival capability.

5) Stability information in accordance with B.

4. References

International conventions and codes

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

IACS UR L2

IACS UR S23 Rev.4

ICLL containing all amendments up to 1st July 2010

SOLAS including all amendments up to 1st July 2012

IBC Code, as amended

IGC Code as amended

5. Definitions

Draught (d)

Draught is vertical distance [m] from the moulded baseline at mid-length to the waterline in question.

Deepest subdivision draught (d_S)

Deepest subdivision draught [m] corresponds to the summer load line draught of the ship.

Light service draught (d_L)

Light service draught [m] corresponds to the lightest anticipated loading and associated tankage, including, however, such ballast as may be necessary for stability and / or immersion. Passenger ships should include the full complement of passengers and crew on board.

Partial subdivision draught (d_P)

Partial subdivision draught is the light service draught plus 60% of the difference between the light service draught and the deepest subdivision draught.

$$d_P = d_L + 0,6\ (|d_s - d_L|)$$

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, BKI may define the limits of the machinery spaces.

Mid-length

Mid-length is the mid point of the subdivision length of the ship.

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.

B. Intact Stability

1. General

Ships of applicable size, type and service are to comply with the intact stability criteria as indicated in Table 36.1.

Table 36.1 Intact Stability Criteria

Ship Type	Intact Stability Requirements
All Ships of applicable size, type and service[5]	Regulation 10 of the International Convention on Load Lines (ICLL), intact stability guidance IMO Code on Intact Stability 2008, Part A, as applicable or Guidelines on Intact Stability (Pt.6, Vol.3)
Dry Cargo Ships[1, 2, 5]	IMO Code on Intact Stability 2008, Part A, as applicable or Guidelines on Intact Stability (Pt.6, Vol.3), Sec. 2
Oil Tanker[1, 3, 4, 5]	Regulation 27 in Annex I of the International Convention for Prevention of Pollution from Ships, 1973/1978, as amended. or Guidelines on Intact Stability (Pt.6, Vol.3), Sec. 3, B
Offshore Service Vessel[1, 5]: - Supply Vessels or Work Ships	IMO Code on Intact Stability 2008, Part A, as applicable or Guidelines on Intact Stability (Pt.6, Vol.3), Sec. 3, I

Notes

1 Ships for which load line is not required; however intact stability is performed for classification purpose.

2 Cargo Ships of 24 m in length and over with or without deck cargo

3 Tankers of 5000 deadweight tonnes and above delivered on or after 1 February 2002 or for which the building contract is placed on or after 1 February 1999 or, in the absence of a building contract, the keels of which are laid or which are in a similar stage of construction on or after 1 August 1999.

4 Recommendation for Intact stability of tankers during liquid transfer operations which are not subject to MARPOL, Annex I, Reg. 27 see Guidance for Marine Industry (Pt.1, Vol.AC), Section 3, R-60.

5 The two referenced requirements are considered equivalent for classification purposes. In case of any discrepancy, the more recent rule or requirement shall take precedence.

2. Onboard Stability Information

2.1 The Master shall be supplied with such information satisfactory to the Administration 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 shall be furnished to the Administration.

(SOLAS II-1, B-1, 5-1.1)

2.2 The information should include:

1) Curves or tables of minimum operational metacentric height GM' versus draught which assure 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.

2) Instructions concerning the operation of cross - flooding arrangements.

3) 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)

2.3 The intact and damage stability information required by 2.2 shall be presented as consolidated data and encompass the full operating range of draught and trim. Applied trim values shall coincide in all stability information intended for use on board. Information not required for determination of stability and trim limits should be excluded from this information.

(SOLAS II-1, B-1, 5-1.3)

2.4 If the damage stability is calculated in accordance with regulation 6 to regulation 7-3 and, if applicable, with regulations 8 and 9.8 of part B-1 of SOLAS as amended, a stability limit curve is to be determined using linear interpolation between the minimum required GM assumed for each of the three draughts ds, dp and dl. When additional subdivision indices are calculated for different trims, a single envelope curve based on the minimum values from these calculations shall be presented. When it is intended to develop curves of maximum permissible KG it shall be ensured that the resulting maximum KG curves correspond with a linear variation of GM.

(SOLAS II-1, B-1, 5-1.4)

2.5 As an alternative to a single envelope curve, the calculations for additional trims may be carried out with one common GM for all of the trims assumed at each subdivision draught. The lowest values of each partial index A_s, A_p and A_l across these trims shall then be used in the summation of the attained subdivision index A according to regulation 7.1 of part B-1 of SOLAS as amended. This will result in one GM limit curve based on the GM used at each draught. A trim limit diagram showing the assumed trim range shall be developed.

(SOLAS II-1, B-1, 5-1.5)

2.6 When curves or tables of minimum operational metacentric height GM' or maximum allowable KG versus draught are not provided, the master should 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, 5-1.6)

2.7 The terms used in this Section are the same as those of SOLAS as amended.

C. Damage Stability

1. General

Damage stability calculation is required for ships of applicable size, type and service as indicated in Table 36.2. Ships with proven damage stability will be assigned the symbol ☐.

Table 36.2 Damage Stability Criteria

Ship Type	Damage Stability Criteria
Passenger Ships[1,2]	SOLAS Chapter II-1 Parts B, B-1, and B-2, as amended
Dry Cargo Ships[1]	SOLAS Chapter II-1 Parts B, B-1, and B-2, as amended
Oil Tanker[1]	Regulation 28 in Annex I to MARPOL 73/78, as amended
Gas Carriers[1, 6]	IGC Code 2014, Ch. 2, as amended or Rules for Ship Carrying Liquefied Gas in Bulk (Pt. 1, Vol. IX), Section 2
Chemical Carriers[1, 6]	IBC Code, Ch. 2, as amended by resolution MEPC.225(64) or Rules for Ship Carrying Dangerous Chemical in Bulk (Pt. 1, Vol. X), Section 2
Bulk Carriers[3]	Regulation 27 as per the 1988 Protocol to the ILLC, 1966, as amended The assumed flooding need only take into account flooding of the cargo hold space. The permeability of a loaded hold is to be assumed as 0,9 and the permeability of an empty hold is to be assumed as 0,95, unless permeability relevant to a particular cargo is assumed for the volume of a flooded hold occupied by cargo and permeability of 0,95 is assumed for the remaining empty volume of the hold
Open-top Containerships	MSC/Circ.608/Rev.1

Table 36.2 Damage Stability Criteria *(continued)*

Ship Type	Damage Stability Criteria
Offshore Service Vessel[1,4]: - Supply Vessels or Work Ships	- **L** ≤ 100 m in length - IMO Guidelines for the Design and Construction of Offshore Supply Vessels 2008, as amended - **L** > 100 m in length - SOLAS Chapter II-1, Parts B, B-1, and B-2, as amended
Special Purpose Ships[5]	Damage stability : IMO 2008 SPS Code, Ch.2, as amended by resolution MSC.408(96)

Notes

[1] Ships of applicable size, type and service are to have subdivision and damage stability as required by the International Convention for the SOLAS, 1974, as amended.

[2] Definition of Passenger Ships, refer to Section 29, I

[3] Bulk carriers for which the request for class for new construction is received on or after 1 July 1998.

[4] Offshore Service Vessel of 80 m or more in subdivision length

[5] Special Purpose Ships in carrying more than twelve special personnel or for special purpose

[6] The two referenced requirements are considered equivalent for classification purposes. In case of any discrepancy, the more recent rule or requirement shall take precedence.

2. Damage stability requirements applicable to bulk carriers

Note:

These requirements developed based on the new Regulation XII/4 of SOLAS 1974, as amended, 'Damage Stability Requirements Applicable to Bulk Carriers', are applicable for bulk carriers 150 m in length and above to carry solid bulk cargoes described below:

Construction Date	***Skin Type Single or Double Sin***	***Specific Density ≥ t/m^3***	***Damaged Hold***
on or after 1 July 1999	*Single*	*1,0*	*any one cargo hold*
on or after 1 July 2006	*Double with longitudinal bhd. Located within the lesser of **B**/5 or 11,5m*	*1,0*	*any one cargo hold*
before 1 July 1999	*Single*	*1,78*	*foremost cargo hold*

Note:
***B** is the bulk carrier breadth as defined in the International Convention on Load Lines in force*

The application of the requirements from the Regulation is extended as a condition of classification for consistency with the new strength/structural requirements under flooded conditions specified in Section 23, B.2.2.3 (Longitudinal Strength), Section 23, E (Corrugated Transverse Watertight Bulkheads) and Section 23, D (Permissible Cargo Loads in Holds).

2.1 General

Single side skin bulk carriers of 150 m in length and greater, designed to carry solid bulk cargoes having a density of 1,78 t/m^3 and above, constructed before 1 July 1999, are, when loaded to the summer load line, to be able to withstand flooding of the foremost cargo hold in all loading conditions and remain afloat in a satisfactory condition of equilibrium, as specified in Table 36.2.

Single side skin bulk carriers of 150 m in length and greater, designed to carry solid bulk cargoes having a density of 1,0 t/m^3 and above are, when loaded to the summer load line, to be able to withstand flooding of any one cargo hold of single side skin construction in all loading conditions and remain afloat in a satisfactory condition of equilibrium, as specified in Table 36.2.

Double side Bulk carriers of 150 m in length and upwards in which any part of longitudinal bulkhead is located within **B**/5 or 11,5 m, whichever is less, inboard from ship's side at right angle to the centerline at the assigned Summer Load Line, designed to carry solid bulk cargoes having a density of 1000 kg/m^3 and above, constructed on or after 1 July 2006, shall, when loaded to the Summer Load Line, be able to withstand flooding of any one cargo hold in all loading conditions and remain afloat in a satisfactory condition of equilibrium, as specified in Table 36.2.

2.2 Bulk Carriers which have been assigned a reduced freeboard

Alternatively, bulk carriers which have been assigned a reduced freeboard in compliance with the provisions of paragraph (8) of the regulation equivalent to regulation 27 of the International Convention on Load Lines, 1966, adopted by resolution A.320(IX), as amended by resolution A.514(13), may be considered as complying with 2.1.

On bulk carriers which have been assigned reduced freeboard in compliance with the provisions of regulation 27(8) set out in Annex B of the Protocol of 1988 relating to the International Convention on Load Lines, 1966, the condition of equilibrium after flooding shall satisfy the relevant provisions of that Protocol.

]Ships with assigned reduced freeboards intended to carry deck cargo shall be provided with a limiting GM or KG curve required by SOLAS Chapter II-1, Regulation 5-1.4, based on compliance with the probabilistic damage stability analysis of Part B-1 (see IACS Unified Interpretation LL 65).

2.3 Existing Bulk Carriers[1)]

2.3.1 Bulk carriers which are subject to compliance with Section 23, J and Section 23, K shall, when loaded to the summer load line, be able to withstand flooding of the foremost cargo hold in all loading conditions and remain afloat in a satisfactory condition of equilibrium, as specified in SOLAS regulation XII/4.3 to 4.7.

2.3.2 A ship having been built with an insufficient number of transverse watertight bulkheads to satisfy 2.3.1 may be exempted provided that the ships fulfills the requirement in SOLAS regulation XII/9.

(IACS UR S23.2)

3. Container ships with "Hatchcoverless" notation

3.1 General

The additional class notation **Hatchcoverless** is applicable to container ships designed such that one or more cargo holds are not fitted with hatch covers, and may be assigned under the provision of compliance with MSC/Circ.608/Rev.1.

3.2 Strength requirements in the intact flooded condition

3.2.1 For container ships with the additional class notation **Hatchcoverless** the vertical hull girder bending strength in intact flooded condition shall comply with Section 5, C.8.

3.2.2 The still water bending moment $M_{sw\text{-}f}$ applied in 2.2.1 shall be taken as the still water bending moment for the intact flooded condition. For ships with the class notation Container ship, the intact flooded condition is given in MSC/Circ.608/Rev.1, Ch.6.

3.2.3 Where the still water bending moment in flooded condition exceeds the allowable value, or the draught in flooded condition is greater than the scantling draught, the actual still water bending moment and/or draught in flooded condition is to prevail.

3.2.4 The hull structure shall be considered as intact for the hull capacity calculation.

[1)] Application and implementation of these requirements to be comply with Rules for Classification and Surveys (Pt.1, Vol. I) Sec. 4-I.E.1.2.2

D. Double Bottom

1. For all passenger vessels and all cargo vessels of 500 GT and more excluding tankers the arrangement shall comply with Chapter II-1 of SOLAS as amended.

2. A double bottom shall 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)

3. Where a double bottom is required to be fitted the inner bottom shall 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:

$$\mathrm{h} = \mathbf{B}/20$$

However, in no case is the value of h to be less than 760 mm, and need not be taken as more than 2000 mm.

(SOLAS II-1, 9.2)

4. Small wells constructed in the double bottom in connection with drainage arrangements of holds, etc., shall not extend downward more than necessary. In no case shall the vertical distance from the bottom of such a well to a plane coinciding with the keel line 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)

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)

6. Any part of a passenger ship or a cargo ship that is not fitted with a double bottom in accordance with 1, 4 or 5 is to be capable of withstanding bottom damages as specified in 8 . as amended, in that part of the ship.

(SOLAS II-1, 9.6)

7. In the case of unusual bottom arrangements in a passenger ship or a cargo ship, it shall 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)

8. Compliance with paragraphs 6 or 7 is to be achieved by demonstrating that si, 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 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 36.3.
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 36.3 Assumed extend of damage

	For 0,3 L from the forward perpendicular of the ship	Any other part of the ship
Longitudinal extent	1/3 · **L**$^{2/3}$ or 14,5 m, whichever is less	1/3 · **L**$^{2/3}$ or 14,5 m, whichever is less
Transverse extent	**B**/6 or 10 m, whichever is less	**B**/6 or 5,0 m, whichever is less
Vertical extent, measured from the keel line	**B**/20 or 2,0 m, whichever is less	**B**/20 or 2,0 m, whichever is less

(SOLAS II-1, 9.8)

9. In case of large lower holds in passenger ships, the Administration may require an increased double bottom height of not more than **B**/10 or 3,0 m, whichever is less, measured from the keel line. Alternatively bottom damages may be calculated for these areas, in accordance with 8, but assuming an increased vertical extent.

(SOLAS II-1, 9.9)

E. Watertight Bulkheads and Decks

1. For watertight bulkheads Section 11 and for decks Section 7 is to be observed.

2. The scantlings of watertight bulkheads and decks, forming the boundaries of watertight compartments assumed flooded in the damage stability analysis, shall be based on pressure heights corresponding to 1,0 m above the deepest final waterline of the damage cases contributing to the attained subdivision index A.

3. Openings

3.1 Openings in watertight bulkheads and internal decks in cargo ships

3.1.1 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 watertightness 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)

3.1.2 Doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors (see Rules for Machinery Installations (Pt.1, Vol.III) Sec.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 shall be provided with an individual hand-operated mechanism. It shall be possible to open and close the door by hand at the door itself from both sides.

(SOLAS II-1, 13-1.2)

3.1.3 Access doors and access hatch covers normally closed at sea, intended to ensure the watertight integrity of internal openings, shall be provided with the 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)

3.1.4 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 shall not 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 shall be fitted with a device which prevents unauthorized opening.

(SOLAS II-1, 13-1.4)

3.1.5 Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of internal openings shall 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)

4. For openings in watertight bulkheads below the bulkhead deck in passenger ships refer to Chapter II-1 of SOLAS as amended.

F. External Openings

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)

Such openings shall, except for cargo hatch covers, shall be fitted with indicators on the bridge.

(SOLAS II-1, 15-1.2)

2. Openings in the shell plating below the deck limiting the vertical extent of damage shall be fitted with a device that prevents unauthorized opening, if they are accessible during the voyage.

(SOLAS II-1, 15-1.3)

3. Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of external openings shall 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 so marked.

(SOLAS II-1, 15-1.4)

4. For openings in the shell plating of passenger ships see Section 29, F.

G. Openings in the shell plating below the bulkhead deck of passenger ships and the freeboard deck of cargo ships

1. The number of openings in the shell plating shall be reduced to the minimum compatible with the design and proper working of the ship.

(SOLAS II-1, 15.1)

2. The arrangement and efficiency of the means for closing any opening in the shell plating shall 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)

3. Subject to the requirements of the ICLL in force, no side scuttle 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)

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 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)

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)

6. No sidescuttlers are to be fitted in any spaces which are appropriated exclusively to the carriage of cargo or coal.

I(SOLAS II-1, 15.5.1)

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)

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)

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)

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)

11. Subject to the requirements of the International Convention on Load Line in force, each separate discharge led through the shell plating from spaces below 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)

12. The requirements of ICLL in force are to be applied to discharges led through the shell plating from spaces above the freeboard deck of cargo ships.

(SOLAS II-1, 15.8.2.2)

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)

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)

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 BKI.

(SOLAS II-1, 15.8.5)

16. Gangway, cargo and fuelling ports fitted below 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)

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)

18. If the inboard opening is situated below 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)

H. Cross-Flooding Arrangements

1. Where the damage stability calculation requires the installation of cross-flooding arrangements in order to avoid high asymmetrical flooding, these arrangements shall work automatically as far as possible. Non-automatic controls for cross flooding fittings are to be capable of being operated from the bridge or another central location. The position of each closing device has to be indicated on the bridge and at the central operating location (see also Rules for Machinery Installations (Pt.1, Vol.III) Sec.11.P and Rules for Electrical Installations (Pt.1, Vol.IV) Sec.7.H). The sectional areas of the cross-flooding fittings are to be determined[2)] in such a way that the time for equalization does not exceed 10 minutes. Particular attention is to be paid to the effects of the cross-flooding arrangements upon the stability in intermediate stages of flooding.

2. Suitable information concerning the use of the closing devices installed in cross-flooding arrangements shall be supplied to the master of the ship.

3. 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 shall be taken into account.

[2)] Following the Res. MSC.245(83)

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Section 37 Special Requirements for In-Water Surveys

A. General

Ships intended to be assigned the Class Notation **IW** (In-Water Survey) shall comply with the requirements of this Section enabling them to undergo in-water surveys.

B. Special Arrangements for In-Water Surveys

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 anti fouling shall have a minimum film thickness of 250 μm, are to be compatible with the cathodic protection and are to be appropriate for mechanical underwater cleaning. The cathodic protection system has to be designed for at least one docking period.

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.

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 less than 900 × 600 mm.

4. All inlet and outlet openings below the deep water-line are to be capable of being sealed for carrying out repairs and maintenance work.

5. 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.

6. It are to be possible to present proof of tightness of the stern tube, in case of oil lubrication, by static pressure loading.

7. 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.

8. For other equipment, such as bow thrusters the requirements will be specially considered taking into account their design.

9. In case of existing ships below 100 m in length the requirements specified in paragraphs 3, 5 and 7 may be dispensed with.

C. Documents for Approval, Trials

1. In addition to the approval documents listed in Section 1, G drawings and, where necessary instruction manuals, documenting the arrangements specified in B. are to be submitted in form of electronic format.

2. Prior to commissioning of the vessel the equipment is to be surveyed and subjected to trials in accordance with the Surveyor's discretion.

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,
- instructions for handling of closures of sea chest strainers, bow thrusters and other outlet/inlet openings,
- additional instructions, where required, depending on structural characteristics,
- coating specification, cathodic protection, see Section 38, H.2.

4. 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.

Section 38 Corrosion Protection

A. General

1. Field of Application

1.1 This section deals with the corrosion protection measures specified by BKI 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).

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 BKI.

1.3 Requirements with respect to the contractors executing the work and the quality control are subject to the conditions laid down in Section 1, N.1.1 and 1.2.

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. BKI is to be consulted when clarifying such issues.

Note:

In addition, BKI also offers advisory services for general questions concerning corrosion and corrosion protection.

1.5 Supplementary to this Section, Guidance for the Corrosion Protection and Coating Systems (Pt.1, Vol.G) contain further comments and recommendations for the selection of suitable corrosion protection systems, as well as their professional planning and execution.

B. Shop Primers

1. General

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.

1.2 Customarily, coatings with a thickness of 15 μm to 20 μm are applied.

1.3 The coating shall be of good resistance to withstand the mechanical stresses incurred during the subsequent working of the steel material in the shipbuilding process.

1.4 Flame-cutting and welding speed are not to be unduly impaired. It must 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 Rules for Welding (Pt.1, Vol.VI) Sec.6.

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.

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.

2. Approvals

Only those over weldable shop primers may be used for which the Society has issued a confirmation of acceptability based on a porosity test in accordance with the Rules for Welding (Pt.1, Vol.VI) Sec.6.

C. Hollow Spaces

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

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.

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

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.

2. Steps are to be taken to prevent the formation of stray currents, and suitable electric drainage is to be provided.

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 Tank

Guidance for the Corrosion Protection and Coating Systems (Pt.1, Vol. G) Ch.3 are applicable.

G. Corrosion Protection of Cargo Holds

1. General

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 shall be given in consultation with the owner to the intended cargo and conditions expected in service.

For existing bulk carriers, where Owners may elect to coat or recoat cargo holds as noted above, consideration may be given to the extent of the close-up and thickness measurement surveys. Prior to the coating of cargo holds of existing vessels, scantlings are to be ascertained in the presence of a Surveyor.

1.2 The coating used shall be approved by the manufacturer for application in cargo holds.

1.3 The coating manufacturer's instructions with regard to surface preparation as well as application conditions and processing shall be adhered to.

1.4 The minimum thickness of the coating shall be 250 μm in the complete area defined under 1.1.

2. Documentation

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 shall be contained in the coating plan.

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.

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 shall be agreed to between the parties involved. The papers pertaining to the documentation shall 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

1. General

1.1 Vessels intended to be assigned the Class Notation **IW** (In-Water Survey) shall provide a suitable corrosion protection system for the underwater hull, consisting of coating and cathodic protection.

1.2 Coatings based on epoxy, polyurethane and polyvinyl chloride are considered suitable.

1.3 The coating manufacturer's instructions with regard to surface preparation as well as application conditions and processing shall be observed.

1.4 The coating system, without antifouling, shall have a minimum dry film thickness of 250 μm on the complete surface, shall be compatible to cathodic protection in accordance with recognized standards, and shall be suitable for being cleaned underwater by mechanical means.

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 mA/m^2 is to be ensured.

1.6 In the case of impressed current systems, over protection due to inadequately low potential is to be avoided. A screen (dielectric shield) is to be provided in the immediate vicinity of the impressed-current anodes.

1.7 Cathodic protection by means of sacrificial anodes is to be designed for one dry-docking period.

1.8 For further instruction refer to Guidance for the Corrosion Protection and Coating Systems (Pt.1, Vol.G) Ch.1.Sec.8.

1.9 In the case of other materials, such as aluminium for instance, special conditions are to be agreed with BKI.

2. Documentation

2.1 The coating plan and the design data for the cathodic protection are to be submitted for examination.

2.2 In the case of impressed current systems, the following details shall also be submitted:

- arrangement of the ICCP system
- location and constructional integration (e.g. by a cofferdam) of the anodes in the vessel's skin,
- 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

2.3 The work processes involved in setting up the coating system as well as the coating materials to be used shall be laid down in the coating plan.

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.

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 shall 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.

2.6 In the case of impressed current systems, the function ability of the cathodic corrosion protection is to be tested during sea trials. The values obtained for the protection current and voltage shall be recorded.

J. Corrosion Protection of Cargo Oil Tanks of Crude Oil Tankers

Guidance for the Corrosion Protection and Coating Systems (Pt.1, Vol.G) Ch.2 are applicable.

Section 39 Requirements for Use of Extremely Thick Steel Plates in Container Ships

A. General

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

IACS UR S33 Rev.3[1)]

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

1. Scope

1.1 This section is to be complied with for container ships incorporating extremely thick steel plates having steel grade and thickness in accordance with 3. and 4. respectively.

1.2 This section identifies when measures for the prevention of brittle fracture of extremely thick steel plates are required for longitudinal structural members.

1.3 This section defines the following methods to apply to the extremely thick plates of container ships for preventing the crack initiation and propagation:

— Non-Destructive Testing (NDT) during construction detailed in B.

— Periodic NDT after delivery detailed in C.

— Brittle crack arrest design detailed in D.

(IACS UR S33.1.1.3)

2. Application

2.1 The application of the measures specified in B, C and D is to be in accordance with E.

2.2 These requirement gives the basic concepts for application of extremely thick steel plates to longitudinal structural members in the upper deck region.

(IACS UR S33.1.1.4)

2.3 For the application of this section, the upper deck region means the upper deck plating, hatch side coaming plating, hatch coaming top plating and their attached longitudinals.

(IACS UR S33.1.1.5)

[1)] Changes introduced in Rev.3 are to be uniformly implemented by BKI for ships contracted for construction on or after 1 July 2021

2.4 Furthermore and particularly if no additional requirements are stated in these rules is to be in accordance with Rules for Materials (Pt.1, Vol.V) and Rules for Welding (Pt.1, Vol.VI).

3. Steel Grade

3.1 This section is to be applied when any of YP36, YP40 and YP47 steel plates are used for the longitudinal structural members in the upper deck region.

(IACS UR S33.1.2.1)

Note:

YP36 YP40 and YP47 refers to the minimum specified yield strength of steel 355, 390 and 460 N/mm^2, respectively. The grade of YP36 and YP40 steel plates are KI-E36 and KI-E40 as defined in Rules for Materials (Pt.1, Vol.V) Sec.4.L.

(IACS UR S33.1.2 Note)

3.2 In case YP47 steel plates are used for longitudinal structural members in the upper deck region, the steel plates are to be of KI-E47 grade as specified in Rules for Materials (Pt.1, Vol.V) Sec.4.L.

(IACS UR S33.1.2.2)

4. Thickness

4.1 For steel plates with thickness of over 50 mm and not greater than 100 mm, the measures for prevention of brittle crack initiation and propagation specified in B, C and D are to be taken.

4.2 For steel plates with thickness exceeding 100 mm, appropriate measures for prevention of brittle crack initiation and propagation are to be taken in accordance with BKI's procedures.

4.3 Welding procedures (WPS) shall be qualified through welding procedure qualification test (WPQT) according to Rules for Welding (Pt.1, Vol.VI) Sec.12.

5. Hull structures (for the purpose of design)

5.1 Material factor k

The material factors of KI-E36 and KI-E40 steels are defined in Rules for Materials (Pt.1, Vol.V) Sec.4.B. The material factor k of YP47 steel for the assessment of hull girder strength is to be taken as 0,62.

(IACS UR S33.1.4.1)

5.2 Fatigue assessment

The Fatigue assessment on the longitudinal structural members is to be performed in accordance with Section 20.

(IACS UR S33.1.4.2)

5.3 Details of construction design

Special consideration is to be paid to the construction details where extremely thick steel plates are applied to structural members such as connections between outfitting and hull structures. Connections details are to be in accordance with BKI's requirements.

(IACS UR S33.1.4)

B. Non-Destructive Testing during construction (Measures No.1 of Table 39.2)

Where non-destructive testing (NDT) during construction is required in E, the NDT is to be in accordance with 1 and 2. Enhanced NDT as specified in D.3.2.e) is to be carried out in accordance with an appropriate standard.

(IACS UR S33.2)

1. General

1.1 Ultrasonic testing (UT) in accordance with Rules for Welding (Pt. 1, Vol.VI) Sec.10 requirement is to be carried out on all block-to-block butt joints of all upper flange longitudinal structural members in the cargo hold region. Upper flange longitudinal structural members include the topmost strakes of the inner hull/bulkhead, the sheer strake, main deck, coaming plate, coaming top plate, and all attached longitudinal stiffeners. These members are defined in Fig. 39.1.

(IACS UR S33.2.1)

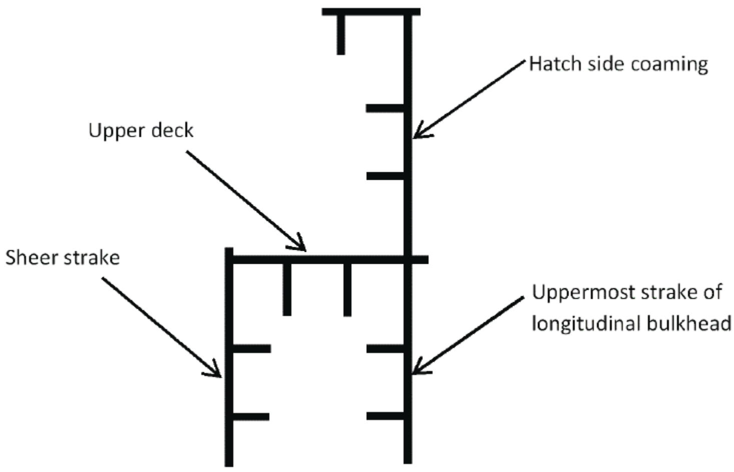

Fig. 39.1 Upper Flange Longitudinal Structural Members

2. Acceptance criteria of UT

2.1 Acceptance criteria of UT are to be in accordance with Rules for Welding (Pt. 1, Vol. VI) Sec.10, G.

2.2 The acceptance criteria may be adjusted under consideration of the appertaining brittle crack initiation prevention procedure and where this is more severe than that found in Rules for Welding (Pt. 1, Vol. VI) Sec.10, G, the UT procedure is to be amended accordingly to a more severe sensitivity.

(IACS UR S33.2.2)

C. Periodic NDT after delivery (Measures No.2 of Table 39.2)

Where periodic NDT after delivery is required, the NDT is to be in accordance with following requirements.

1. General

The procedure of the NDT is to be in accordance with Guidance for Marine Industry (Pt.1 , Vol.AC) Sec.1 R-20 or Rules for Welding (Pt.1, Vol.VI) Sec.10 and Table 10.5.

2. Timing of UT

Where UT is carried out, the frequency of survey is to be in accordance with Rules for Welding (Pt.1, Vol.VI) Sec.10.E.

3. Acceptance criteria of UT

Where UT is carried out, acceptance criteria of UT are to be in accordance with Rules for Welding (Pt. 1, Vol. VI) Sec.10, G.

(IACS UR S33.3)

D. Brittle crack arrest design (Measures No. 3, 4 and 5 of Table 39.2)

1. General

1.1 The brittle crack arrest steel method may be used when the measures No. 3, 4 and 5 of Table 39.2 are applied and the steel grade material of the upper deck is not higher than KI-E40. Otherwise other means for preventing the crack initiation and propagation shall be agreed with BKI.

(IACS UR S33.4.1)

1.2 Measures for prevention of brittle crack propagation are to be taken within the cargo hold region. A brittle crack arrest design means a design using these measures.

(IACS UR S33.4.1.2)

1.3 The measures given in this subsection generally apply to the block-to-block joints but it should be noted that cracks can initiate and propagate away from such joints. Therefore, appropriate measures should also be considered for the case specified in 2.1.b.ii).

(IACS UR S33.4.1.3)

1.4 Brittle crack arrest steel are defined in Rules for Materials (Pt.1, Vol.V) Sec.4.L.

(IACS UR S33.4.1.4)

2. Functional requirements of brittle crack arrest design

2.1 The purpose of the brittle crack arrest design is to arrest propagation of a crack at a proper position and to prevent large scale fracture of the hull girder.

a. The locations of most concern for brittle crack initiation and propagation are the block-to-block butt weld joints either on hatch side coaming or on upper deck plating. Other locations in block fabrication where joints are aligned may also present higher opportunity for crack initiation and propagation along butt weld joints.

   ((IACS UR S33.4.2.1)

b. Both of the following cases are to be considered:
   - i) where the brittle crack runs straight along the butt joint, and
   - ii) where the brittle crack initiates in the butt joint but deviates away from the weld and into the plate, or where the brittle crack initiates from any other weld (see the figure below for definition of other welds) and propagates into the plate.

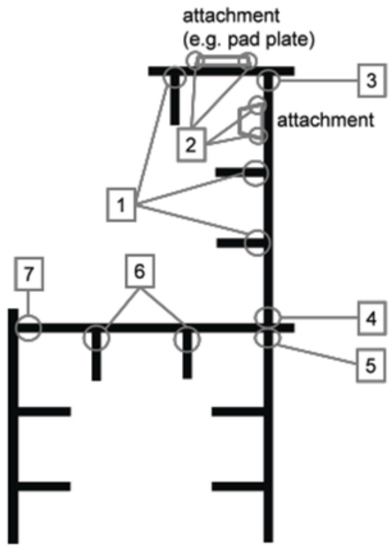

Fig. 39.2 Other Weld Areas

***“Other weld” includes the following (refer to Fig. 39.2):

1) Fillet welds between hatch side coaming plating, including top plating, and longitudinal;

2) Fillet welds between hatch side coaming plating, including top plating and longitudinal, and attachments. (e.g., Fillet welds where hatch side top plating and hatch cover pad plating.);

3) Fillet welds between hatch side coaming top plating and hatch side coaming plating;

4) Fillet welds between hatch side coaming plating and upper deck plating;

5) Fillet welds between upper deck plating and inner hull/bulkheads;

6) Fillet welds between upper deck plating and longitudinal; and

7) Fillet welds between sheer strakes and upper deck plating.

(IACS UR S33.4.2.1)

3. Concept examples of brittle crack arrest design

The following are considered acceptable examples of measures that can be used on a brittle crack arrest-design to prevent brittle crack propagations. The detail design arrangements are to be submitted to BKI for approval. Other measures may be considered and accepted for review by BKI.

3.1 Brittle crack arrest design for 2.1.b.ii):

a) Brittle crack arresting steel is to be used for the upper deck plating along the cargo hold region in a way suitable to arrest a brittle crack initiating from the coaming and propagating into the structure below.

3.2 Brittle crack arrest design for 2.1.b.i):

b) Where the block to block butt welds of the hatch side coaming and those of the upper deck are shifted, this shift is to be greater than or equal to 300 mm.

c) Where crack arrest holes are provided in way of the block-to-block butt welds at the region where hatch side coaming weld meets the deck weld, the fatigue strength of the lower end of the butt weld is to be assessed. Additional countermeasures are to be taken for the possibility that a running brittle crack may deviate from the weld line into upper deck or hatch side coaming. These countermeasures are to include the application of brittle crack arrest steel in hatch side coaming plating

d) Where Arrest Insert Plates of brittle crack arrest steel or Weld Metal Inserts with high crack arrest toughness properties are provided in way of the block-to-block butt welds at the region where hatch side coaming weld meets the deck weld, additional countermeasures are to be taken for the possibility that a running brittle crack may deviate from the weld line into upper deck or hatch side coaming. These countermeasures are to include the application of brittle crack arrest steel in hatch side coamings plating.

e) The application of enhanced NDT particularly time of flight diffraction (TOFD) technique using stricter defect acceptance in lieu of standard UT technique specified in B. can be an alternative to b, c and d.

4. Selection of brittle crack arrest steels

4.1 The brittle crack arrest steels fitted in the upper deck region of container ships are to comply with Table 39.1 where suffixes **BCA1** and **BCA2** are defined in Rules for Materials (Pt.1 Vol. V) Sec.4.L.

4.2 The brittle crack arrest steel property is to be selected for each individual structural member with thickness above 50 mm according to Table 39.1.

Table 39.1 Brittle crack arrest steel requirement in function of structural members and thickness

Structural members plating (*)	Thickness (mm)	Brittle crack arrest steel requirement
Upper deck	50 < t < 100	Steel grade KI-E36 or 40 with suffix BCA1
Hatch coaming side	50 < t < 80	Steel grade KI-E40 or 47 with suffix BCA1
	80 < t < 100	Steel grade KI-E40 or 47 with suffix BCA2
(*) Excluding their attached longitudinals		

4.3 When brittle crack arrest steels as specified in Table 39.1 are used, the weld joints between the hatch coaming side and the upper deck are to be partial penetration weld details approved by BKI.

In the vicinity of ship block joints, alternative weld details may be used for the deck and hatch coaming side connection provided additional means for preventing the crack propagation are implemented and agreed by BKI in this connection area.

(IACS UR S33.4.4)

E. Measures for Extremely Thick Steel Plates

The thickness and the yield strength shown in the following Table 39.2 apply to the hatch coaming top plating and side plating, and are the controlling parameters for the application of the countermeasures given in D.3.1. These controlling parameters are not applicable for the upper deck.

If the as built thickness of the hatch coaming top plating and side plating is below the values contained in the Table 39.2, countermeasures are not necessary regardless of the thickness and yield strength of the upper deck plating.

(IACS UR S33.Annex 1)

Table 39.2 Measures depending on thickness and yield strength of hatch coaming structures.

Yield Strength (N/mm^2)	Thickness [mm]	Option	Measures			
			1	2	3+4	5
360	50 < t ≤ 85	-	NA	N.A	N.A	N.A
	85 < t ≤ 100	-	X	N.A	N.A	N.A
400	50 < t ≤ 85	-	X	N.A	N.A	N.A
	85 < t ≤ 100	A	X	N.A	X	X
		B	X*	N.A**	N.A	X
470(FCAW)	50 < t ≤ 100	A	X	N.A	X	X
		B	X*	N.A**	N.A	X
470(EGW)	50 < t ≤ 100	-	X	N.A	X	X

Symbols:

(a) X means To be applied.

(b) N.A. means Need not to be applied.

(c) Selectable from option A and B.

Measures:

1 NDT other than visual inspection on all target block joints (during construction) See B.

2 Periodic NDT other than visual inspection on all target block joints (after delivery) See C.

3 Brittle crack arrest design against straight propagation of brittle crack along weldline to be taken (during construction) See D.3.2.b), c) or d).

4 Brittle crack arrest design against deviation of brittle crack from weldline (during construction) See D.3.1.a).

5 Brittle crack arrest design against propagation of cracks from other weld areas (see Fig. 39.2) such as fillets and attachment welds. (during construction) See D.3.1.a).

Notes:

* : See D.3.2.e).

** : may be required at the discretion of BKI

(IACS UR S33.Annex 1)

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Annex 1 Guidelines for ballast loading conditions of cargo vessels involving partially filled ballast tanks

A. General

1. This Annex is intended for guidance and interpretation of “Partially filled ballast tanks in ballast loading conditions”.

2. Case A and B are generally applicable for ballast loading conditions for any cargo vessel which might have one Ballast Water (BW) Tank (or one pair of BW Tanks) partially filled.

3. Case C is showing the conditions necessary for checking longitudinal strength for a conventional ore carrier with two pairs of large wing water ballast tanks partly filled during the ballast voyage.

4. Where applicable, similar considerations are to be given to other cargo vessels covered by Section 5 where ballast loading conditions involving partially filled ballast tanks may cause concerns for the longitudinal strength of the vessels.

5. This Annex does not apply to CSR Bulk Carriers and Oil Tankers or to container ships to which Rules for Container Ships (Pt.1, Vol.XVIII), Sec. 5, is applicable.

6. In the Figure, the conditions only intended for strength verification (not operational) are marked with a star (*).

B. Case A and B

1. Case A

Fig. A1.1 shows Case A, with a cargo vessel where partial filling of BW Tank no. 6 (P/S) is permitted and may take place at any time during the ballast voyage. Intermediate condition(s) should be specified as shown in the Figure, however filling/partial filling of BW Tank no. 6 (P/S) may be done at any step to keep acceptable trim and propeller immersion during the ballast voyage.

To obtain full operational flexibility regarding the filling level of BW Tank no. 6 (P/S), loading conditions A2 (full at departure)* and A8 (empty at arrival)* shall be added for strength verification. Additional conditions (full and empty BW Tank no. 6 (P/S)) related to the intermediate conditions A3-A6 are not necessary as A2* and A8* will be the most critical one.

2. Case B

Fig. A1.2 shows Case B, with a cargo vessel where partial filling of BW Tank no. 6 (P/S) to a given level (f6-int%) will be done after a specified % consumables is reached, see conditions B2 and B3. Before this % consumables (shown as 50% in this Figure) is reached, BW Tank no. 6 (P/S) shall be kept empty. When reaching a given level of consumables (shown as 20% in Fig. A1.2), BW Tank no. 6 (P/S) shall be kept full, see conditions B5 and B6. Two additional intermediate conditions (B4* and B7*) shall be added for longitudinal strength verification.

In order to categorize a vessel according to Case B, clear operational guidance for partial filling of ballast tanks, in association with the consumption level as shown in Fig. A1.2, is to be given in the loading manual. If such operational guidance is not given, Case A is to be applied.

3. Case A has no limitation of consumables, whereas Case B has limitation of consumables.

Table 40.1 Figure A1.1

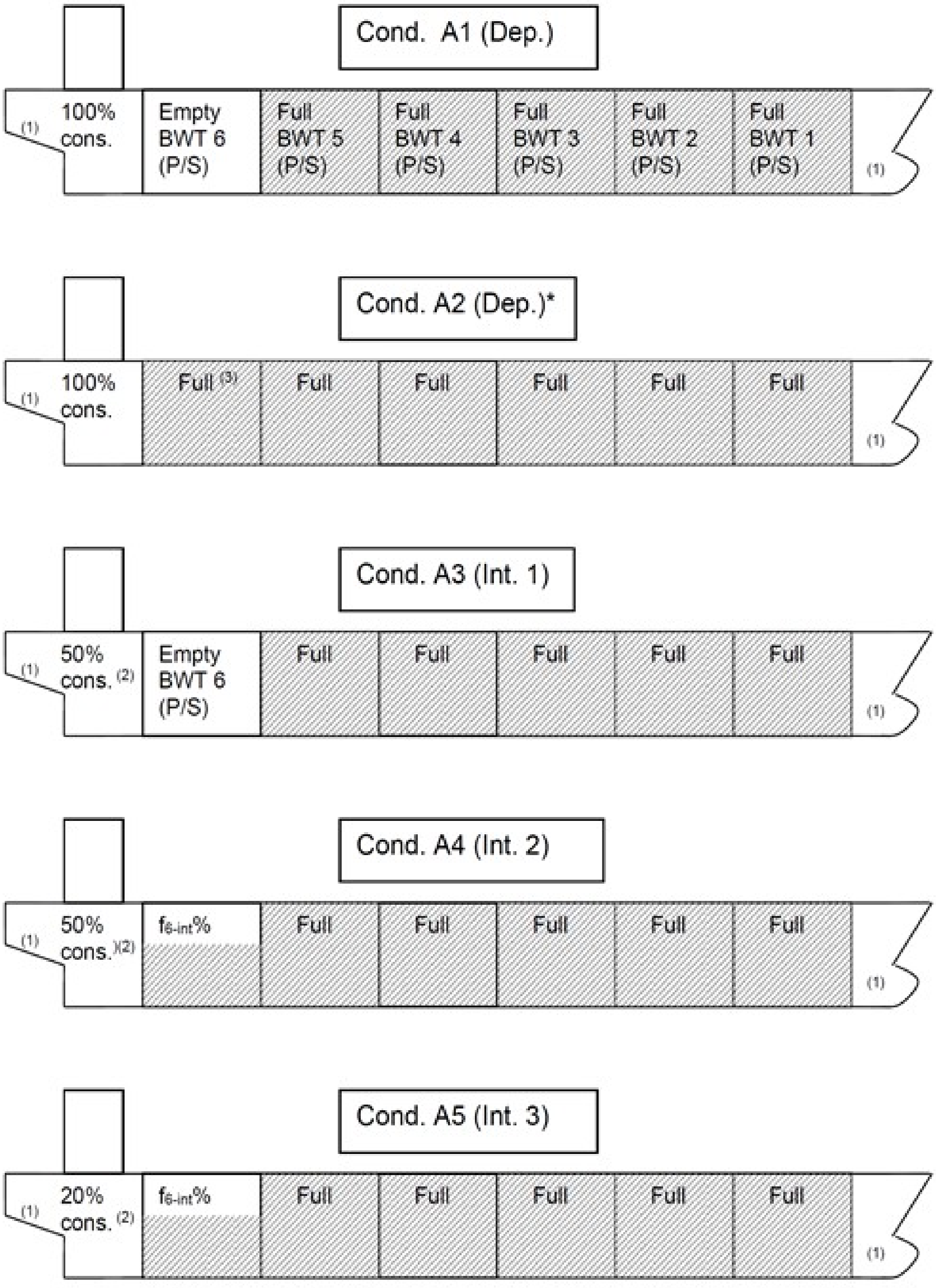
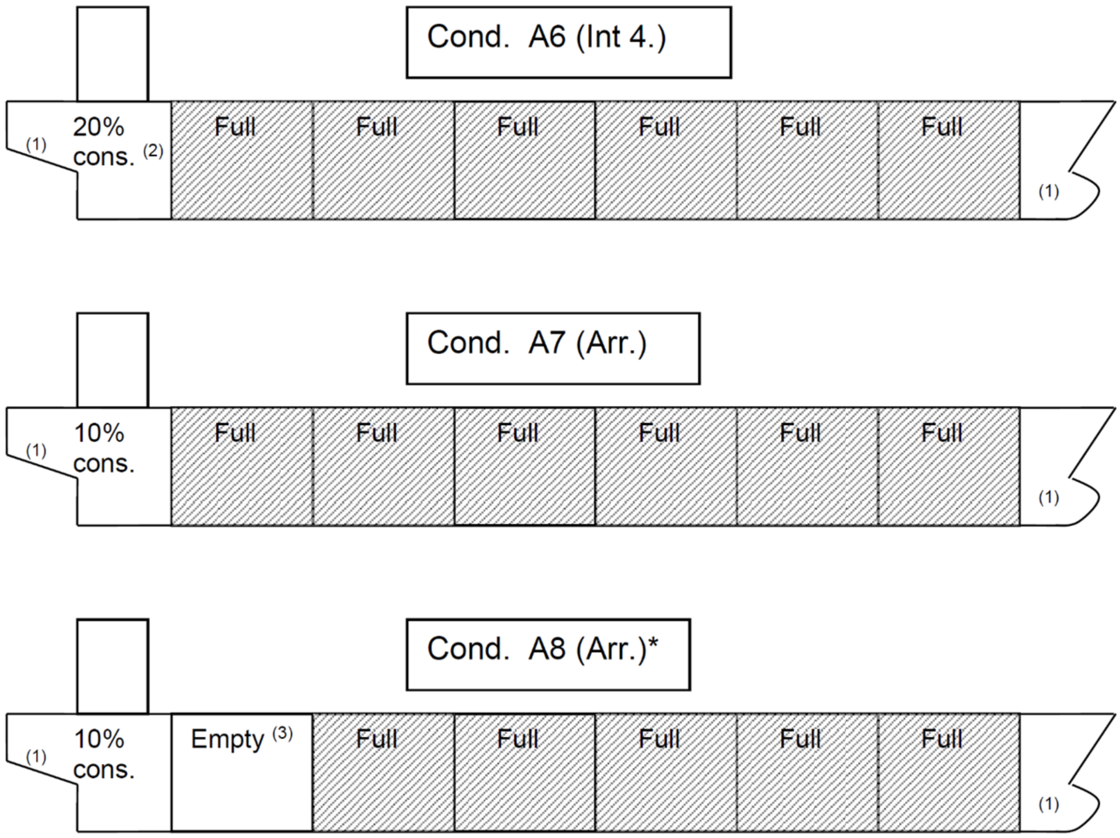


Fig. A1.1 **Case A, Partial filling of ballast tank no. 6 (P/S) is permitted at any stage during voyage. The intermediate condition is specified, however other partial filling of BW Tank no. 6 (P/S) may be applied to keep acceptable trim and propeller immersion during the ballast voyage. Conditions only intended for strength verification (not operational) are marked***



Note:

1) *For peak tanks intended to be partially filled, all combinations of full or partially filled at intended level for those tanks are to be investigated.*

2) *The intermediate condition(s) to be specified incl. % consumables.*

3) *For bulk carriers carrying ore and with large wing water ballast tanks full/empty may be replaced with maximum/minimum filling levels according to trim limitations given in Section 5, A.4.4.1.1.*

Fig. A1.1 Case A, Partial filling of ballast tank no. 6 (P/S) is permitted at any stage during voyage. The intermediate condition is specified, however other partial filling of BW Tank no. 6 (P/S) may be applied to keep acceptable trim and propeller immersion during the ballast voyage. Conditions only intended for strength verification (not operational) are marked* *(continued)*

Table 40.2 Figure A1.2

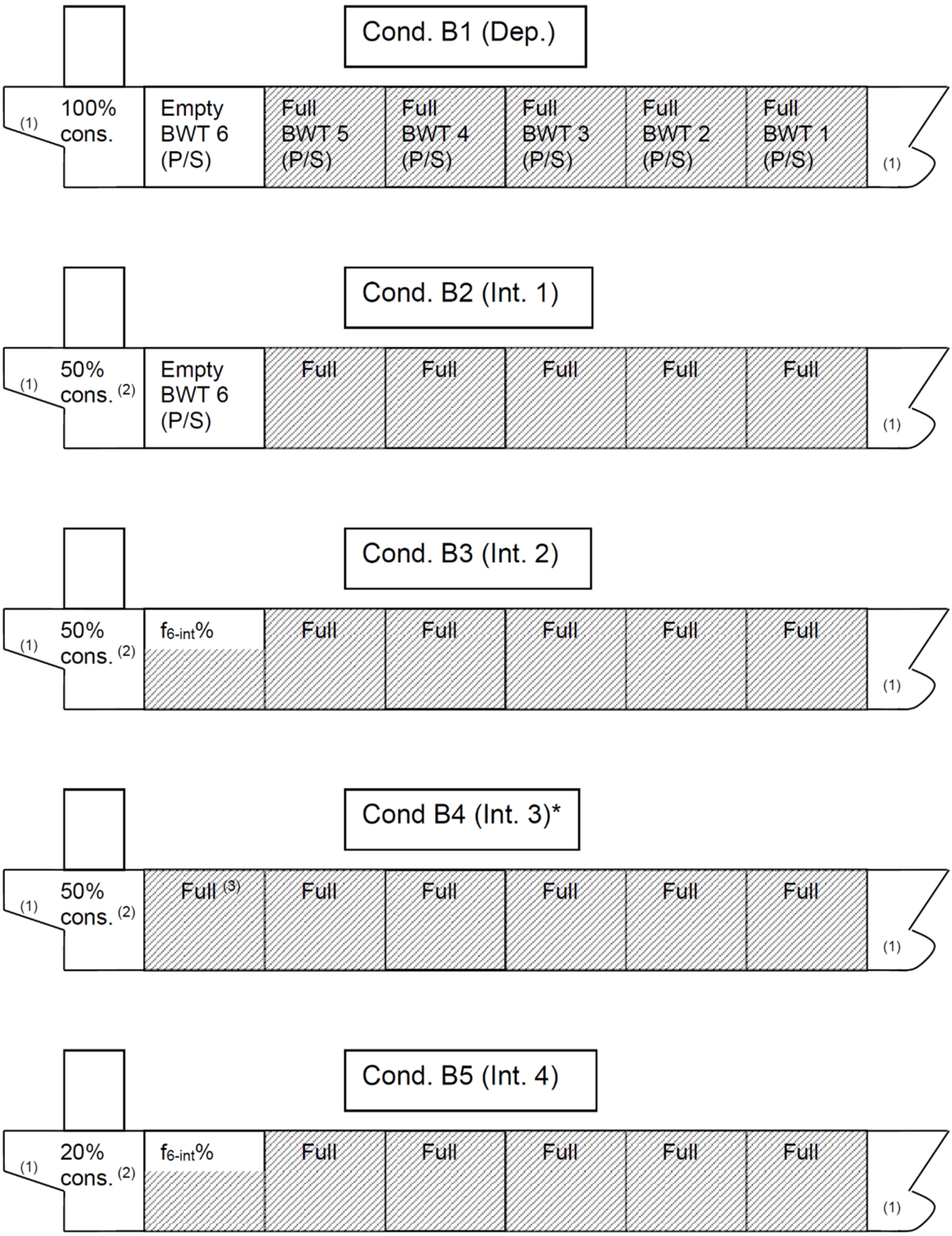
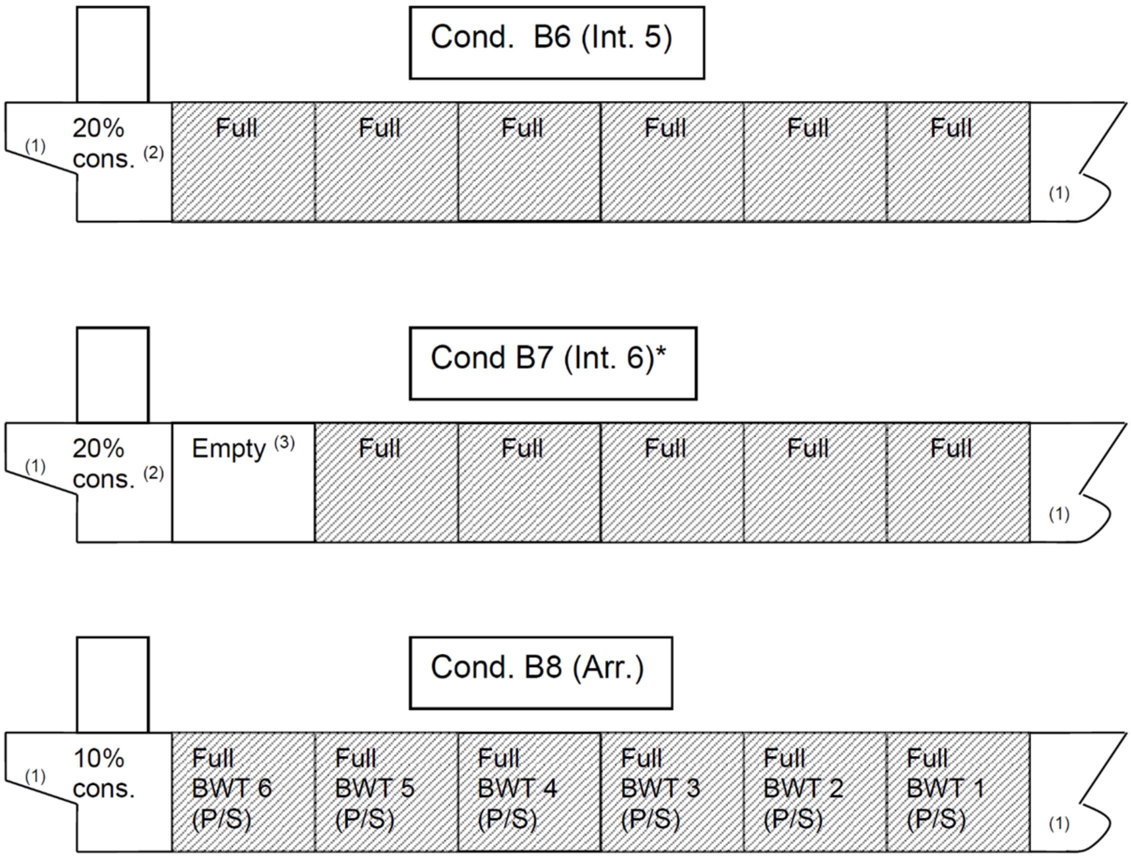


Fig. A1.2 Case B, Partial filling of BW Tank no. 6 (P/S) only allowed during intermediate conditions, in this example between 50-20% consumables. Conditions only intended for strength verification (not operational) are marked:*



Notes:

1) *For peak tanks intended to be partially filled, all combinations of full or partially filled at intended level for those tanks are to be investigated.*

2) *The intermediate condition(s) to be specified incl. % consumables.*

3) *For bulk carriers carrying ore and with large wing water ballast tanks full/empty may be replaced with maximum/minimum filling levels according to trim limitations given in Section 5, A.4.4.1.1.*

Fig. A1.2 Case B, Partial filling of BW Tank no. 6 (P/S) only allowed during intermediate conditions, in this example between 50-20% consumables. Conditions only intended for strength verification (not operational) are marked:* *(continued)*

C. Case C – Conventional (with usual arrangement of WBT) ore carrier with two pairs of partially filled ballast water tanks

Fig. A1.3(a) show the operational loading conditions, departure condition (C1), four intermediate conditions (C2-C5) and arrival condition (C6), for a conventional (with usual arrangement of WBT) ore carrier with partial filling of both BW tank no.1 (P/S) and 7 (P/S) during voyage.

Table A1.2 Filling level in partially filled BW tanks nos.1 (P/S) and 7 (P/S) for the operational conditions during ballast voyage

Loading cond.	Consumables	Filling level, WBT 1(P/S)	Filling level, WBT 7(P/S)
C1 - Departure	100%	f1 dep%	f7 dep%
C2 Intermediate 1	50% (i)	f1 dep %	f7dep%
C3 Intermediate 2	50% (i)	f1 int%	f7 int%
C4 Intermediate 3	20% (i)	f1 int%	f7 int%
C5 Intermediate 4	20% (i)	f1 arr%	f7 arr%
C6 - Arrival	10%	f1 arr%	f7 arr%
Note: *(i) % consumables to be specified, indicated to 50% and 20%*			

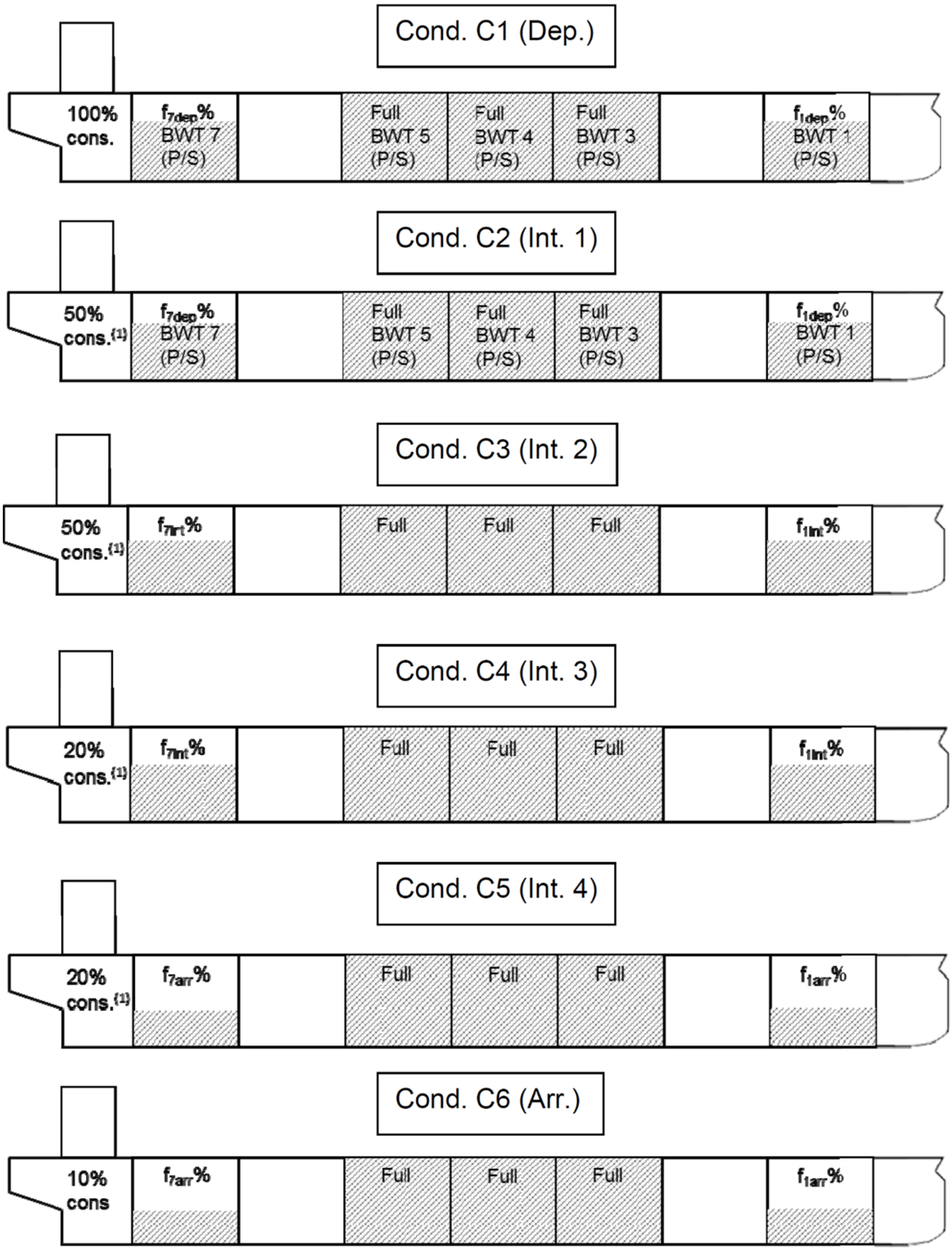
Fig. A1.3(b) and Fig. A1.3(c) show the additional twelve loading conditions (C1-1~C1-12) which shall be added for longitudinal strength verification of the departure condition (C1).

Fig. A1.3(d) and Fig. A1.3(i) show the additional 32 loading conditions (C2-1~C2-12, C3-1~C3-4, C4-1~C4-12 and C5-1~C5-4) which shall be added for longitudinal strength verification of the intermediate conditions (C2~C5).

Fig. A1.3(j) and Fig. A1.3(k) show the additional twelve loading conditions (C6-1~C6-12) which shall be added for longitudinal strength verification of the arrival condition (C6).

For the additional loading conditions, the maximum and the minimum filling level of BW tank are according to trim and propeller immersion limitations given in Section 5, A.4.4.1.1.

Table A1.3 Figure A1.3(a)



Notes:

1) *The intermediate condition(s) to be specified incl. % consumables..*

2) *Fig. A3(b)-A3(k): Maximum and minimum filling level of BW tank according to trim and propeller immersion limitations given in Section 5, A.4.4.1.1.*

Fig. A1.3(a) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during ballast voyage, operational conditions C1-C6.

Table A1.4 Figure A1.3(b)

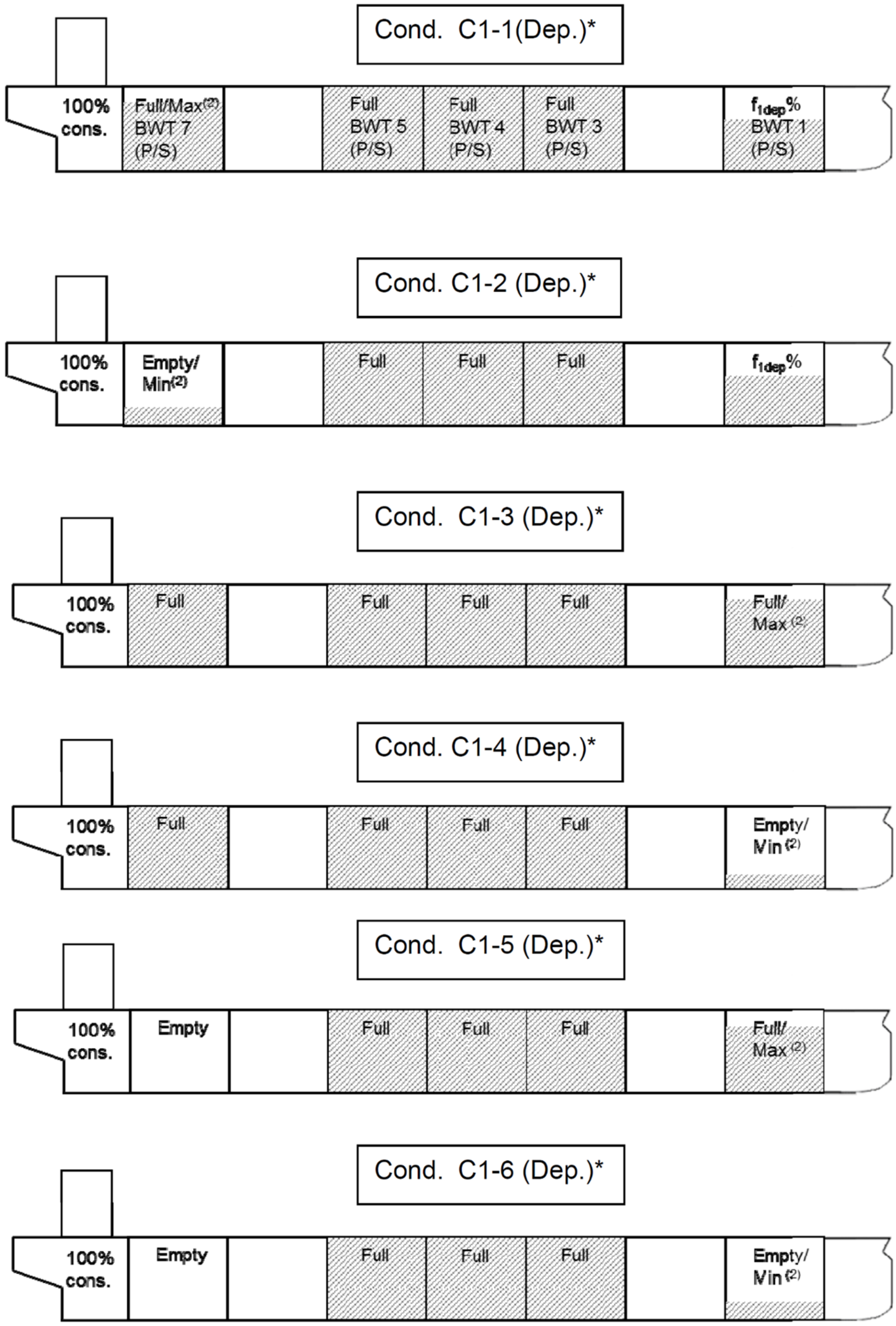


Fig. A1.3(b) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Departure conditions C1-1～C1-6, only intended for strength verification (not operational) are marked:*

Table A1.5 Figure A1.3(c)

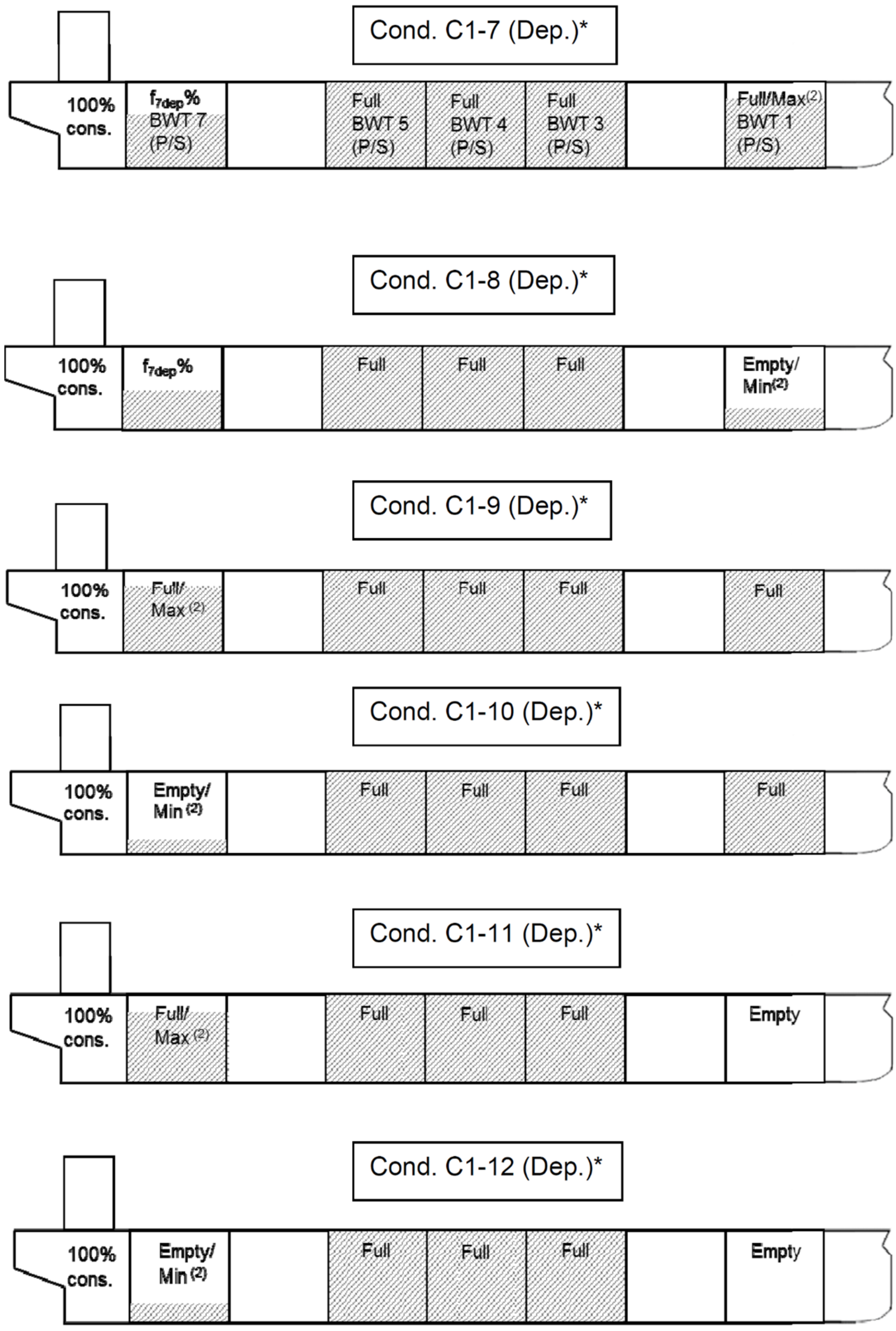


Fig. A1.3(c) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Departure conditions C1-7～C1-12, only intended for strength verification (not operational) are marked:

Table A1.6 Figure A1.3(d)

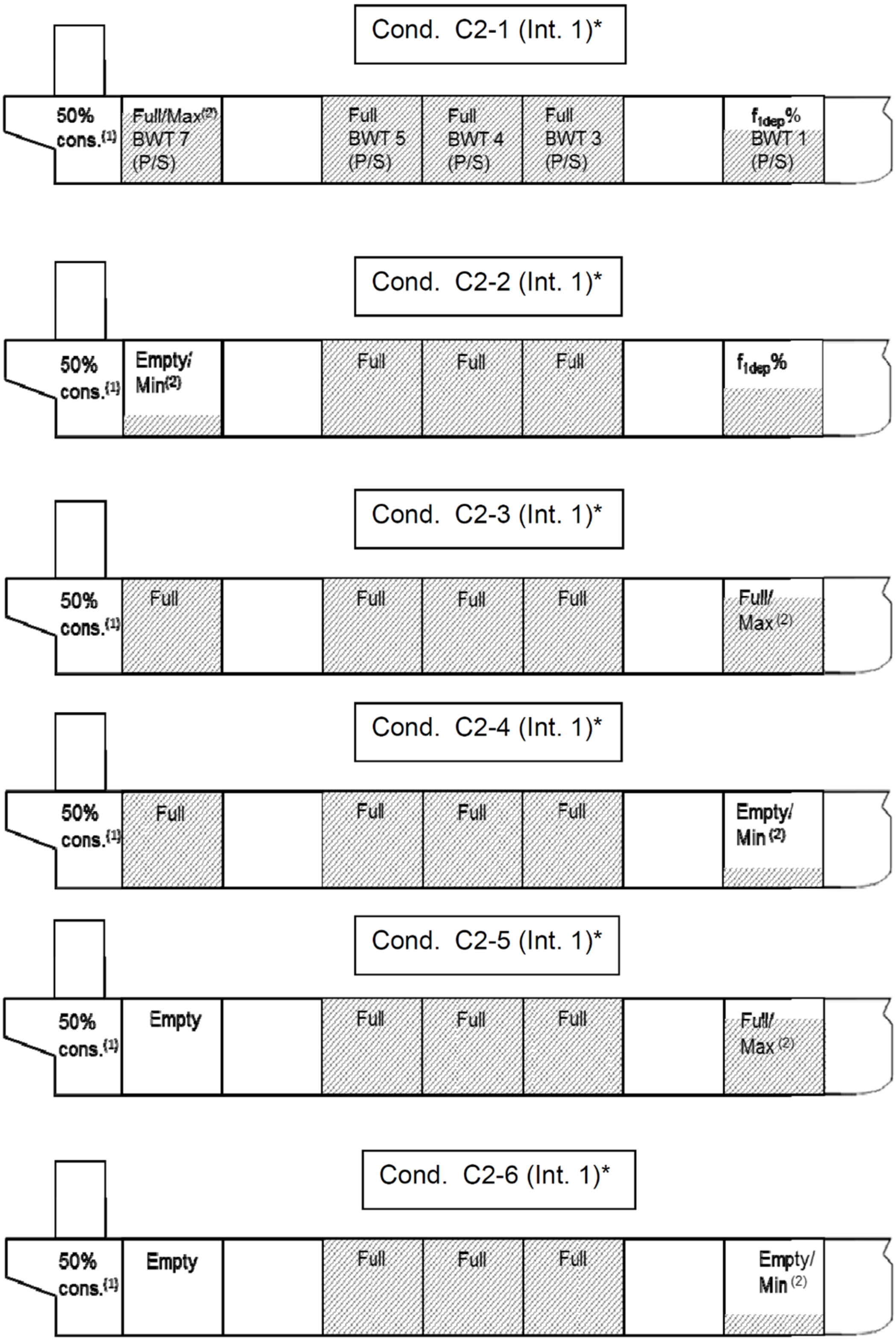


Fig. A1.3(d) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C2-1～C2-6, only intended for strength verification (not operational) are marked:*

Table A1.7 Figure A1.3(e)

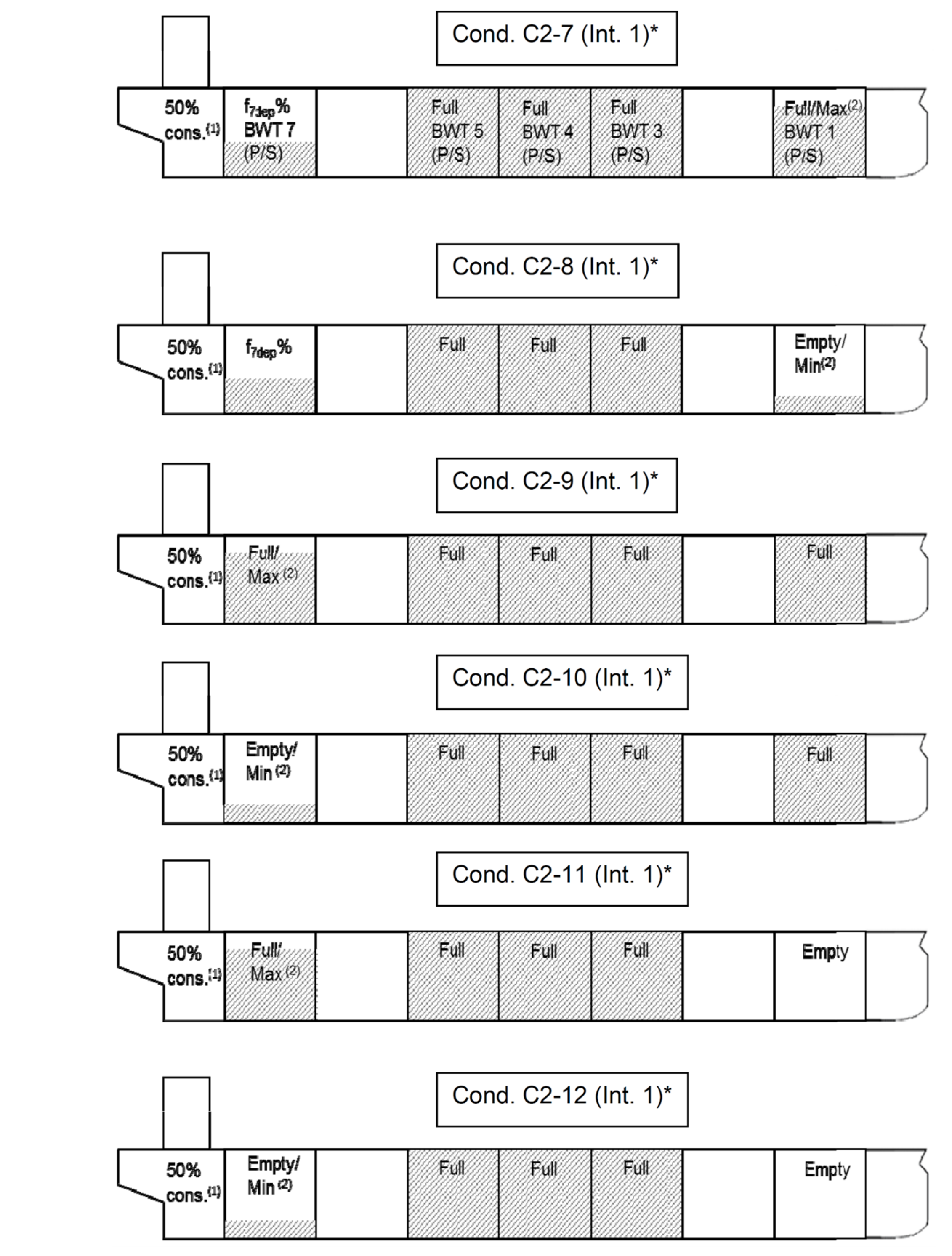


Fig. A1.3(e) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C2-7∼C2-12, only intended for strength verification (not operational) are marked:*

Table A1.8 Figure A1.3(f)

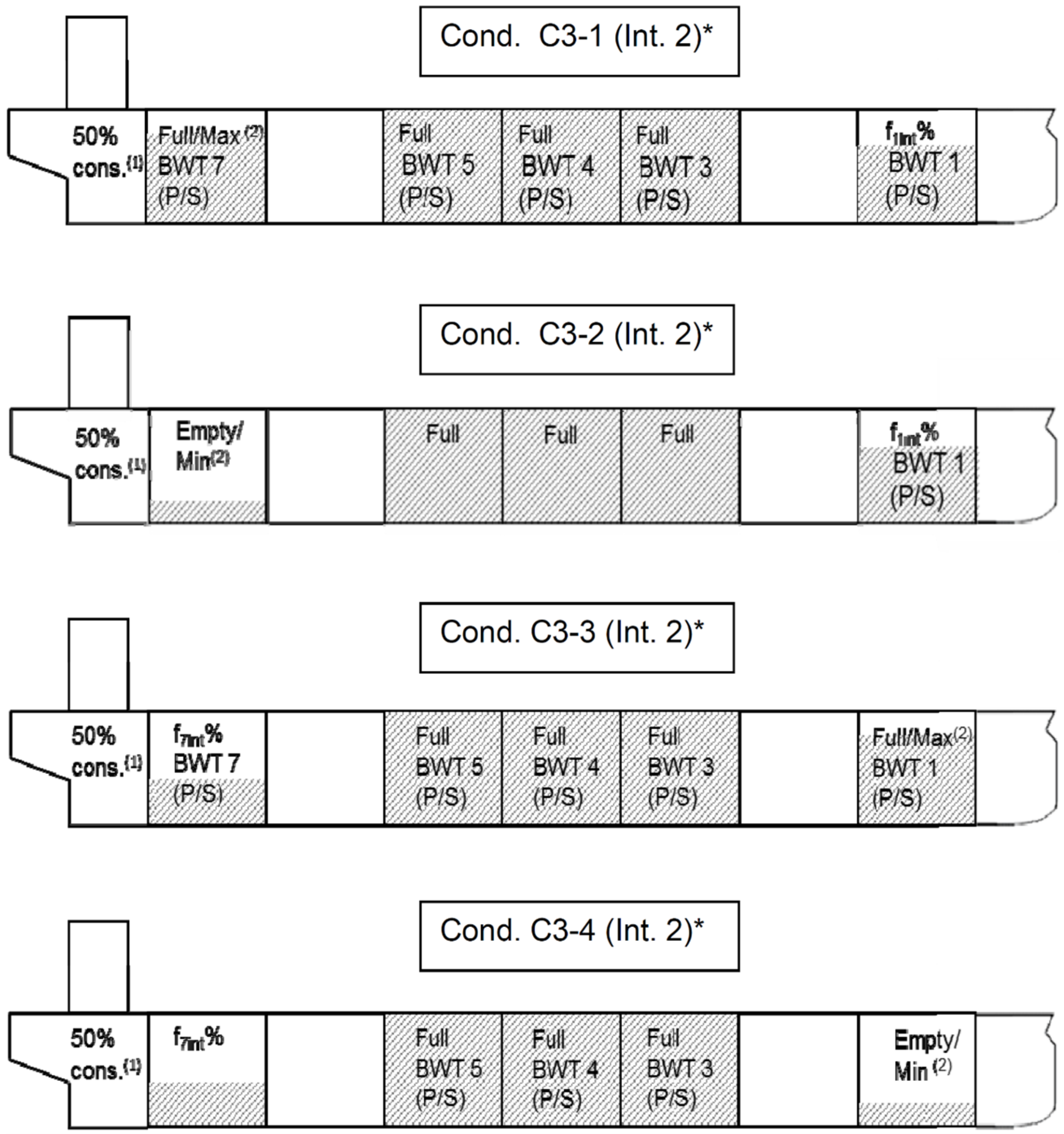


Fig. A1.3(f) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C3-1～C3-4, only intended for strength verification (not operational) are marked:*

Table A1.9 Figure A1.3(g)

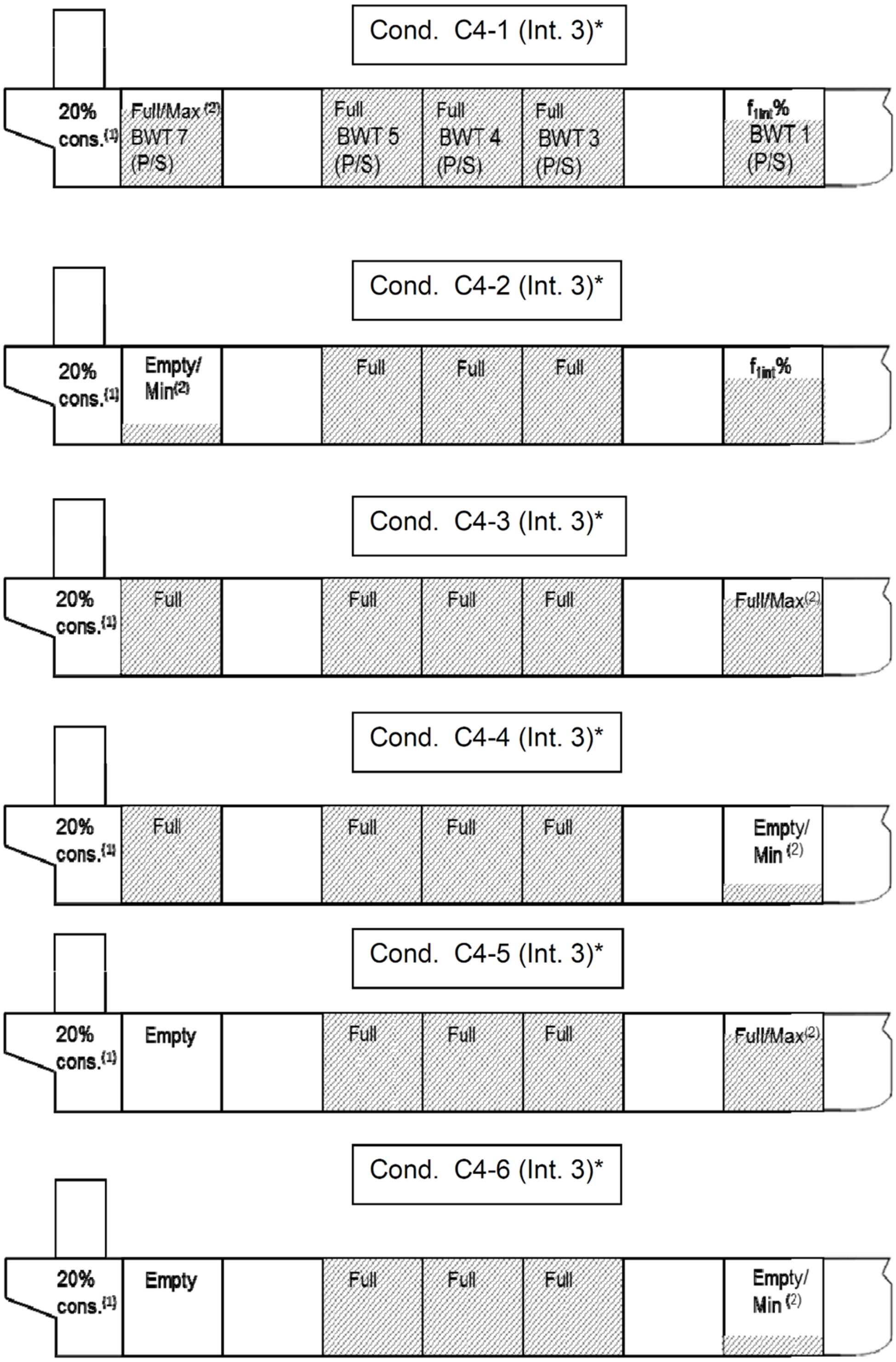


Fig. A1.3(g) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C4-1∼C4-6, only intended for strength verification (not operational) are marked:*

Table A1.10 Figure A1.3(h)

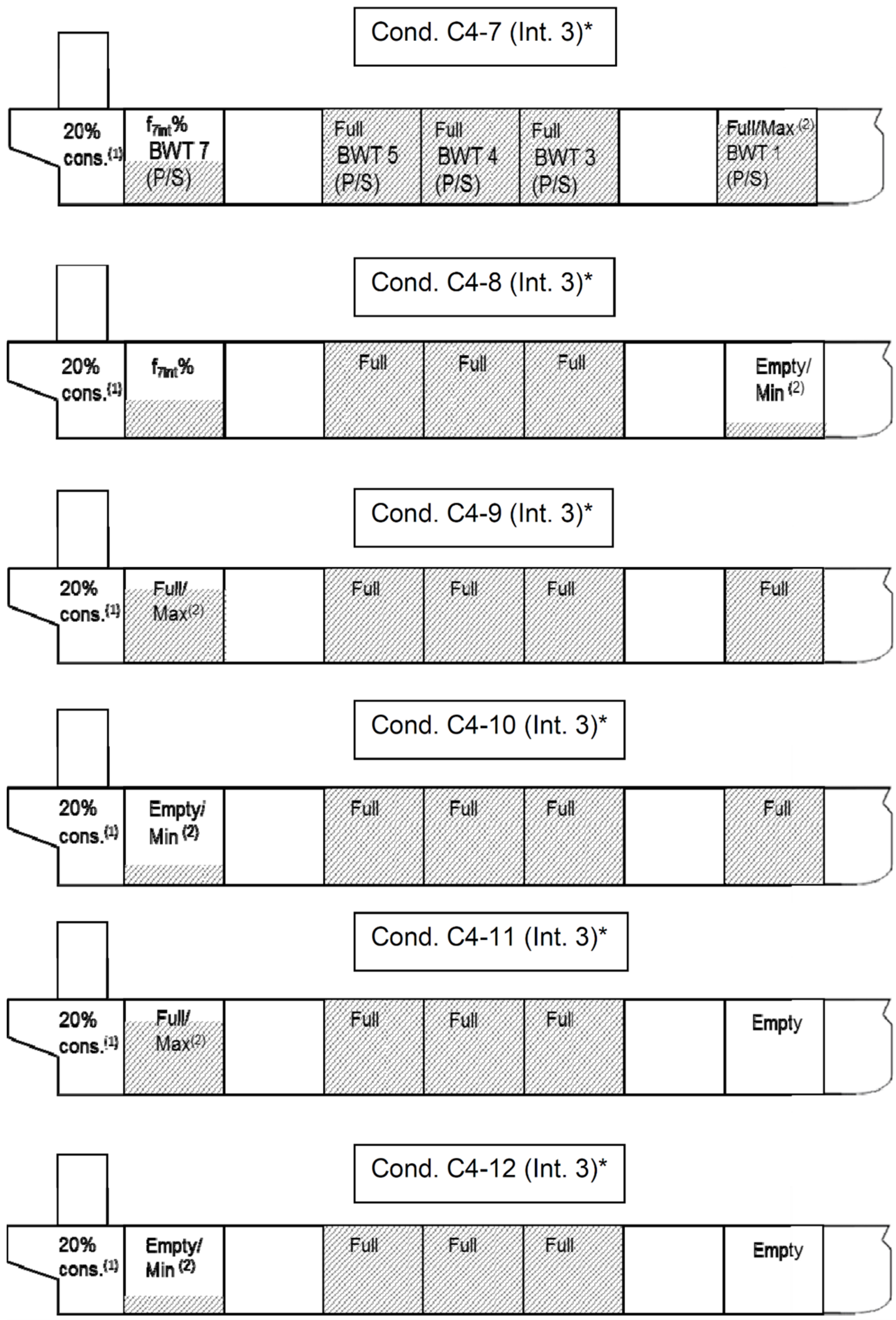


Fig. A1.3(h) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C4-7～C4-12, only intended for strength verification (not operational) are marked:*

Table A1.11 Figure A1.3(i)

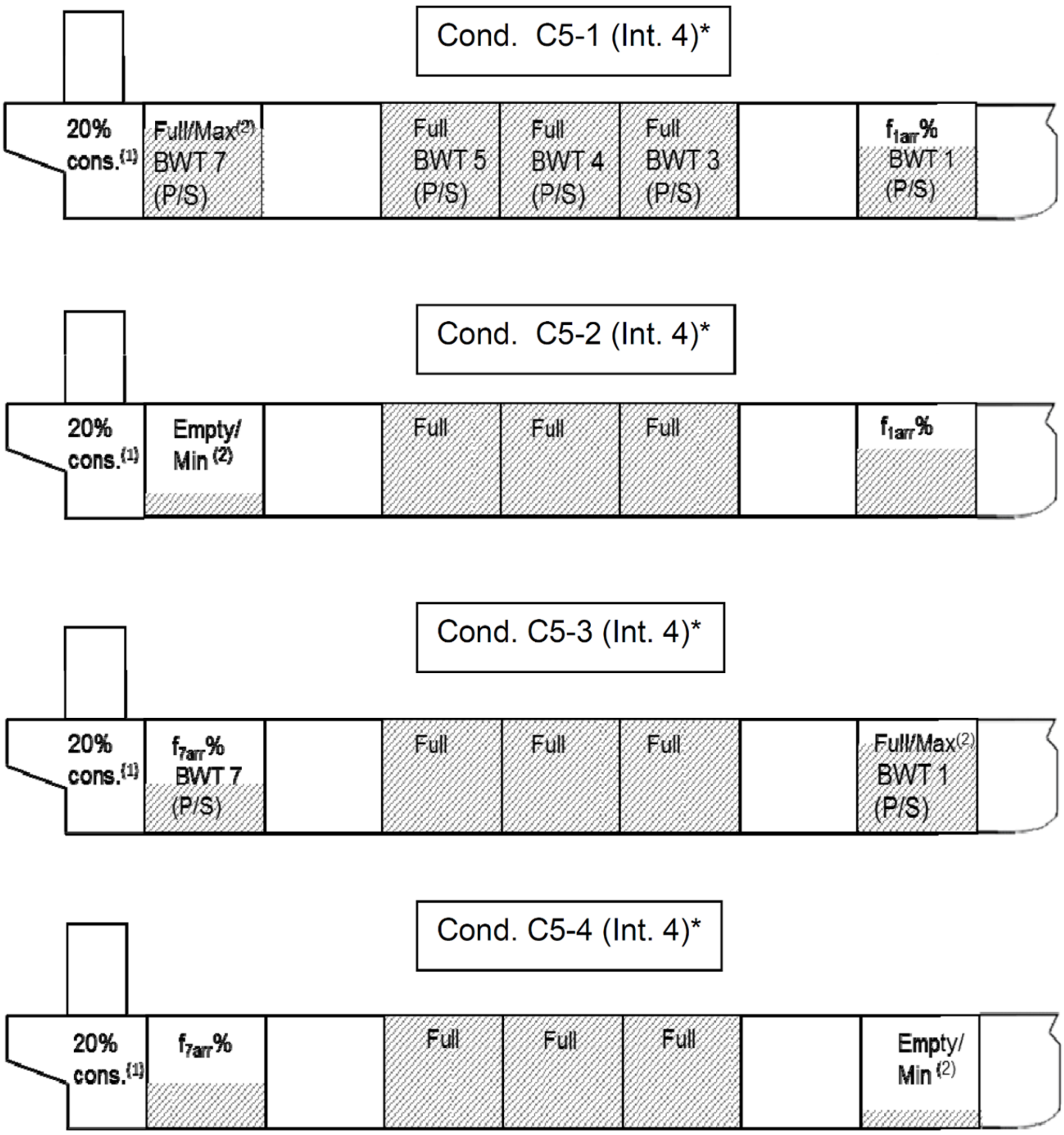


Fig. A1.3(i) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C5-1∼C5-4, only intended for strength verification (not operational) are marked:*

Table A1.12 Figure A1.3(j)

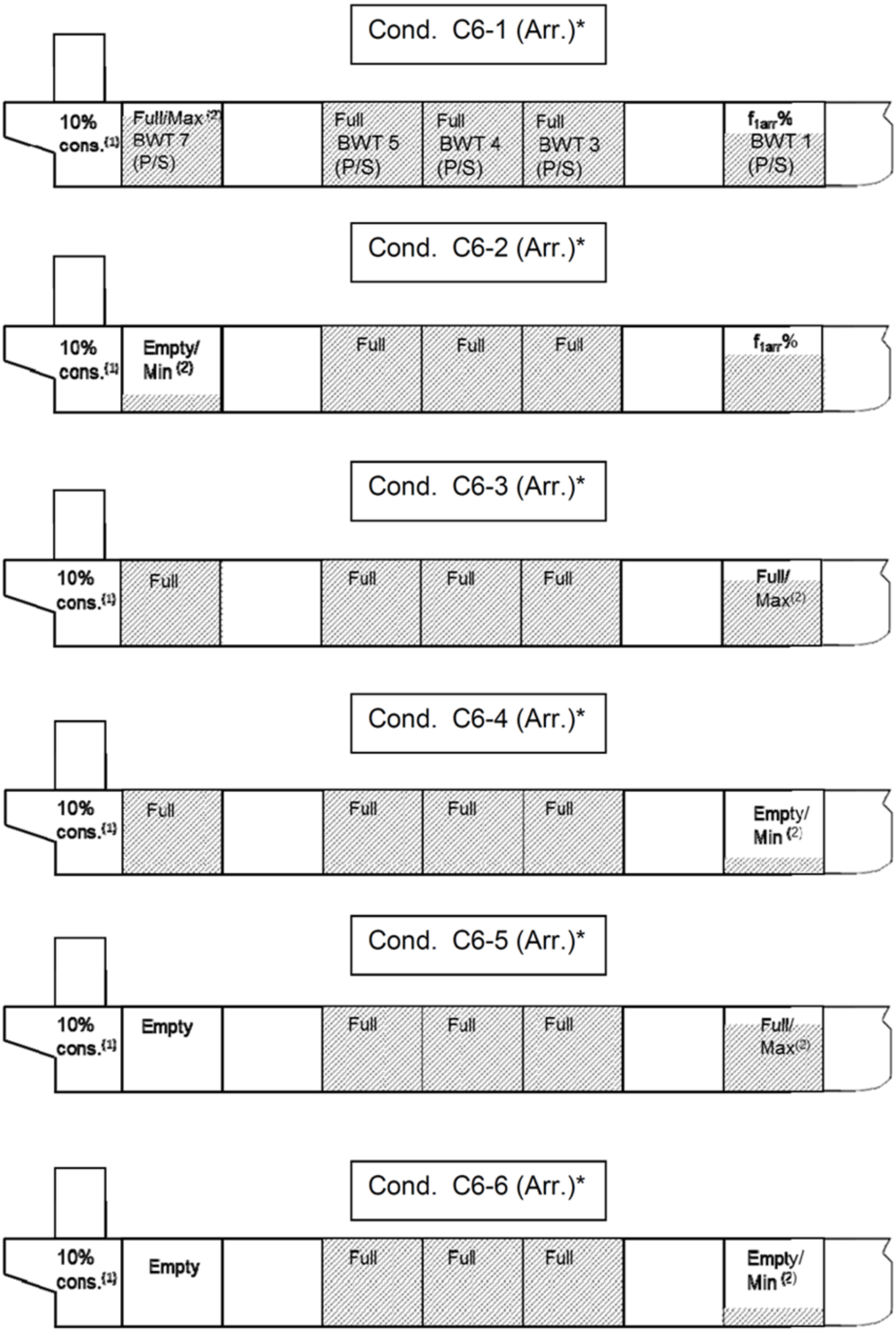


Fig. A1.3(j) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Arrival conditions C6-1～C6-6, only intended for strength verification (not operational) are marked:*

Table A1.13 Figure A1.3(k)

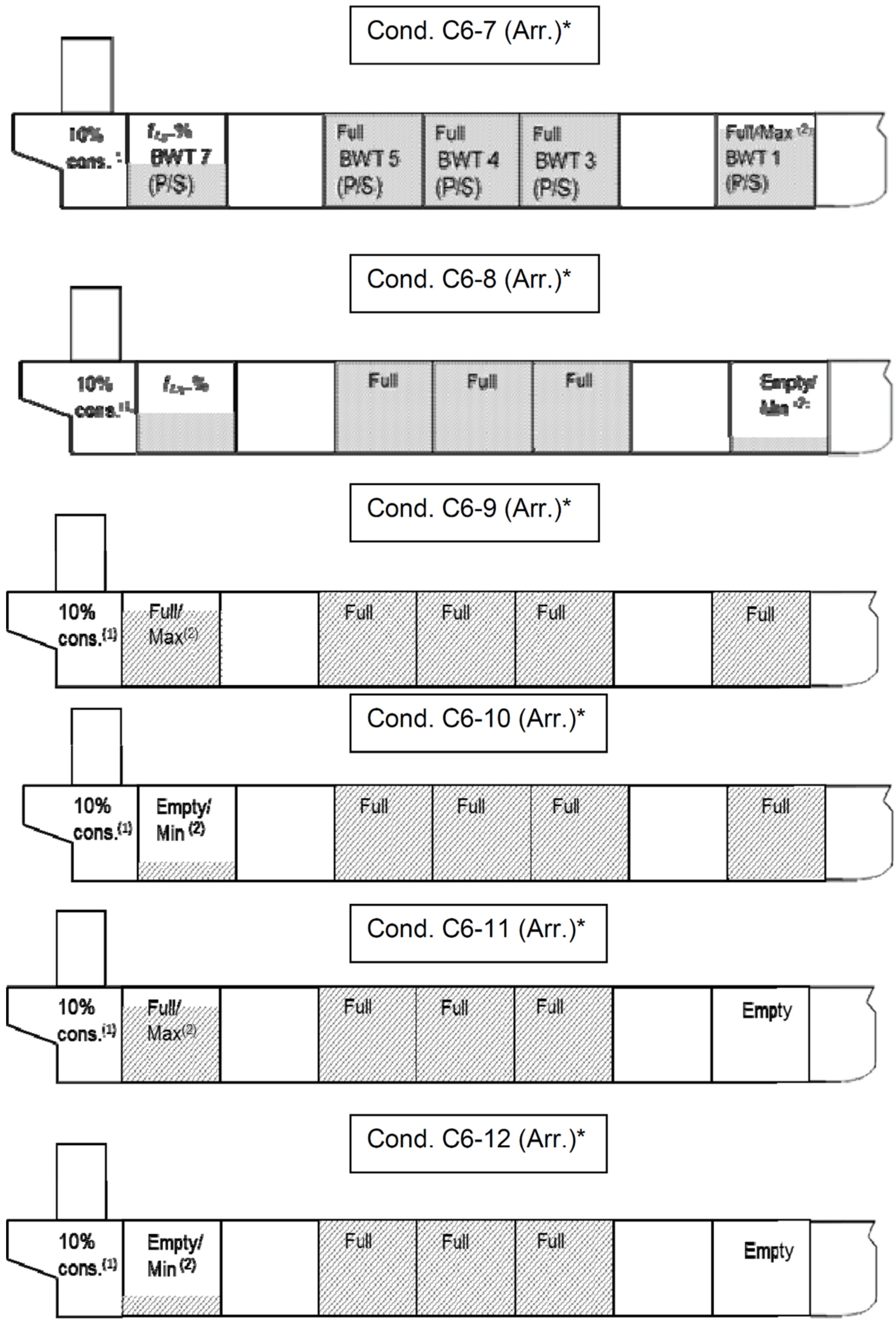


Fig. A1.3(k) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 5 (P/S) during voyage. Arrival conditions C6-7～C6-12, only intended for strength verification (not operational) are marked:*

Annex 2 Special Requirements for Pusher - Barge

A. General

1. Application

1.1 This Annex contains additional requirements for barges and tugs operating as a pusher unit (pusher), intended to be classed as an integrated tug-barge combination.

1.2 For items not specified in this Annex, the relevant requirements of Section 27 and 31 are to be applied.

1.3 Alternative hull, connection construction and equipment will be accepted by BKI, provided that BKI is satisfied that such hull, connection construction and equipment are equivalent to this requirements.

2. Class notations

2.1 In an integrated tug-barge combination, a tug is integrated to a barge with a special connection system such that the tug is secured in the barge notch or on fenders by mechanical means, other than just wire ropes, chains, lines or other tackles.

2.2 The tug and the barge are to be classed as two separate ships but where applicable will be cross referenced in the BKI register.

2.2.1 Tug as pusher unit may be assigned with the following special notation:

— **Pusher (Type A)**: Special notation assigned to tugs operating as pusher unit with (integrated) permanent connection.

— **Pusher (Type B)**: Special notation assigned to tugs operating as pusher unit with (articulated) removable connection.

2.2.2 Barge to operate as linked push barges may be assigned with the following special notation:

— **Linked Pusher Barge (Type A)**: Special notations assigned to barges intended to pusher-barge combination, which are connected in (integrated) permanent connection type to pushers that are operated by pusher tug. Therefore, the combination is integrated each other.

— **Linked Pusher Barge (Type B)**: Special notations assigned to Barges intended to pusher-barge combination, which are connected in (articulated) removable connection type to pushers that are operated by pusher tug. The connection should permit the pusher to move in relation to the barge.

2.3 Details explanation related to BKI class notation, see Guidance for Class Notations (Pt.0, Vol.B).

3. Approval Documents

3.1 In addition to the required documents by Section 27 and Section 31, the following documents are to be submitted:

- General arrangements of combined unit
- Loading manual
- Hydraulic system and drawings relating to the connection are to be submitted
- Hull structural details in way of the connection of tug and barge for each vessel
- Structural analysis of the connection
- Connection details and loads
- Towing and anchor equipment details
- Guard rail detail

3.2 Operational procedure for connection system is to be provided onboard, and its copy is to be submitted to BKI.

4. Definitions

Permanent connection (integrated)

Permanent connection is a combination method where a barge and pusher are connected to behave as one unit during a voyage without relative motion between the two.

Removable connection (articulated)

Removable connection is a combination method where a barge and pusher are connected to allow relative motion with one or more degree(s) of freedom during a voyage. Pusher-barge connected by this method is to engage in coastal services.

Length of connection $L_{con.}$

Length of connection Lcon. is distance in meters along the load line which is from inside face of side plate or forward side of fore part structure to after side of rudder post or the centre of the rudder stock under the permanent connection condition.

If the connection is based on hydraulic operation, the mechanical locking devices are to be fitted to hold locking condition even if the hydraulic system is failed in locking condition.

B. Longitudinal strength

1. Longitudinal strength calculation

1.1 Longitudinal strength calculation of pusher-barge with permanent connection is calculated accordance with Section 5 using length of connection $L_{con.}$.

1.2 Longitudinal strength calculation of pusher-barge with removable connection is calculated accordance with Section 5 using length of individual ship L.

2. Still water bending moment and shear force

2.1 Still water bending moment and shear force of permanent connection are calculated for connected unit of barge and pusher.

2.2 Still water bending moment and shear force of removable connection are calculated for individual ship. The effect of the degrees of freedom of the connection on the still water hull girder loads in the combination may be taken into account (e.g. free pitch of the tug with respect to the barge implies vertical bending moment equal to zero in the connection).

3. Loading manual

The requirements of Section 5, A.4. are to be complied with according to length of connection $\mathbf{L}_{con.}$.

C. Hull scantlings

1. Scantlings of pusher are to comply with the Section 27 using length of pusher only. In the case of pusher-barge with permanent connection, scantlings of the pusher’s hull structure (deck, shell, frame, superstructures, deckhouses, etc.) which will be exposed to wave loading when the pusher is acting as part of the combined unit (pusher + barge) should be designed using Lcon.. In this case, the scantlings are to be not less than the scantlings complying with the pusher’s length only.

2. Scantlings of barges are to comply with the Section 31. In calculating the scantlings of each member, the length of connection $\mathbf{L}_{con.}$ is to be used for permanent connection barge and length of barge **L** for removable connection barge.

3. Collision bulkhead of barge is to be located between 0,05$\mathbf{L}_{con.}$ and 0,08$\mathbf{L}_{con.}$. However, when the length of connection is less than 90 m, collision bulkhead may be located between 0,05$\mathbf{L}_{con.}$ and 0,13$\mathbf{L}_{con.}$.

4. Number and disposition of barge transverse watertight bulkheads

In addition to the criteria in Section 31, C, the barge is to be fitted at least with an aftermost transverse watertight bulkhead located forward of the connection area and extended from side to side.

The cargo spaces are to be separated from the other spaces not used for cargo by watertight bulkheads

D. Equipment

The equipment is to be in accordance with the requirements in both Section 27 for Tug and Section 31 for the Barge, considering the barge as a ship of the size of the integrated pusher-barge combination.

E. Type of pusher-barges

Pusher-barges are classified into two types and are to comply with Table A2.1

Table A2.1 Type and Application of Pusher-Barge

<table>
<tr><th>Items</th><th>Type A</th><th colspan="2">Type B</th></tr>
<tr><td rowspan="3">Definition</td><td>Permanent connection</td><td colspan="2">Disconnection (A verification as to whether disconnection can be made within the harbour by one person within 5 minutes. And after disconnection in the open sea, the pusher shall be able to tow the barge.)</td></tr>
<tr><td>Hard connection</td><td>Hard connection</td><td>Soft connection</td></tr>
<tr><td>No relative motion between the pusher and the barge</td><td>No relative motion between the pusher and the barge</td><td>Relative motion between the pusher and the barge with one or more degree(s) of freedom</td></tr>
<tr><td>Stability</td><td>Satisfactory under connected condition</td><td colspan="2">Satisfactory under connected condition (also as an unconnected pusher)</td></tr>
<tr><td>Freeboard</td><td>Greatest freeboard out of;
– pusher
– barge
– combination</td><td colspan="2">Pusher and barge each as an individual ship</td></tr>
</table>

Table A2.1 Type and Application of Pusher-Barge *(continued)*

Items	Type A	Type B	
Longitudinal Strength	Connected condition	Connected condition	Pusher and barge each as an individual ship
Scantling	Connected condition	Connected condition	Pusher and barge each as an individual ship
Safety Equipment	Connected condition (conventional certificates corresponding to connected condition to be issued for ocean-going services)	Pusher and barge each as an individual ship (conventional certificates to be issued for individual ships for ocean-going services)	
Navigation limit area	Ocean-going	Ocean-going	Costal service (**L20**)

F. Connection structure of pusher-barge

1. For the stress assessment of all strength members related to the connection of pusher and barge, a direct calculation is to be carried out.

— Where deemed necessary by BKI, the wave hull girder loads and the forces transmitted through the connection are to be calculated from a direct calculation of the pusher-barge combination motion and acceleration in irregular waves, unless such data are available from similar ships.

— These loads are to be obtained as the most probable that the pusher-barge combination may experience during its operating life for a probability level of 10^{-8}. For this calculation, the wave statistics relevant to the area of navigation and weather conditions are to be taken into account.

— When the difference between the pusher and the barge depths is considered to be not negligible by BKI, its effects are to be considered in evaluating the buoyancy force distributions and the corresponding hull girder loads on the pusher structures immediately aft of the connection section, for the different wave encountering conditions.

2. Permissible stresses in the connection are :

Normal stress (σ) : $\frac{225}{k}$ [N/mm^2]

Shearing stress (τ) : $\frac{120}{k}$ [N/mm^2]

$$k = \left(\frac{240}{R_{eH}}\right)^{0.75}$$

R_{eH} = minimum nominal upper yield point of the plating material [N/mm^2] according to Section 2, B

3. Data for direct calculation according to 1 and 2 are to be submitted to BKI for reference.