Rules for Classification and Construction

Part 1 Seagoing Ships

RULES FOR CONTAINER SHIPS

Volume XVIII

July 2024 Edition

Biro Klasifikasi Indonesia

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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 Container Ships (Pt.1, Vol.XVIII) July 2024 edition replaces the Rules for Container Ships (Pt.1, Vol.XVIII) 2018 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	RCN No.1, April 2023	1^{st} July 2023	
2	New Edition 2018	1^{st} July 2018	

Note:

- *Full previous edition and amendments including its amendment notice is available through the link above*
- *Generally, the effective date of Rules/RCN is given in the table above. However, several requirements within the amendment may be differently specified, see its amendment notice for detail*

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 2024, except stated otherwise as indicated in the Table below.

Paragraph	Title/Subject	Status/Remark
Section 1 General, Definitions		
A.	**General**	
1.2	-	Provided reference requirements for container ships design without hatch cover (Hatchcoverless)
2.5	-	Added new reference related to the interpretation of convention and code that mentioned in the rules
Section 2 Materials		
A.	**General**	Updated reference
B.	**Hull Structural Steel for Plates and Sections**	
Table 2.4	**Minimum material grades for ships with length exceeding 250 m**	Corrigenda and amendment requirements according to IACS UR S6 Rev.9 Corr.2 Nov 2021
3.4.2	-	Added new requirement related to material of structural members which are exposed to low temperatures according to IACS S6 Rev.9 July 2018
Table 2.9	**Material classes and grades for structures exposed to low temperatures**	Added new note regarding material class and grades for ships with breadth exceeding 70 m according to IACS UR S6
Table 2.10	**Material grade requirements for classes I, II and III at low temperatures**	Added new material grade requirements for Class I, II and III in low temperatures -11C until -25C according to IACS UR S6 Rev.9 July 2018
Section 3 Design Principles		
F.	**Proof of Buckling Strength**	
All	-	Superseded buckling strength requirements according to IACS UR S35
M.	**Testing of Watertight and Weathertight Compartments**	
All	-	Added new requirements related to testing of watertight and weathertight Compartments according to IACS UR S14
Section 11 Watertight Bulkheads		
B.	**Scantlings**	

Paragraph	Title/Subject	Status/Remark
2.1	-	Amendment coefficient related to buckling strength calculation according to IACS UR S35
Section 12 Tank Structures		
A.	**General**	
4.3	-	Updated reference related to testing tank requirements
5.	**Oil Fuel Tanks**	Added new requirements for design oil fuel tank according to SOLAS II-2
Section 13 Stem and Sternframe Structures		
C.	**Stern frame**	
4.	**Rudder horn of semi spade rudders with one elastic support**	Amendment of sub-section title
4.1	-	Added new requirements for calculation of rudder horn of semi spade rudder with one elastic support according to IACS UR S10 Rev.4 Apr 2015
5	**Rudder horn of semi-spade rudders with two conjugate elastic supports**	Added new requirements for calculation rudder horn of semi spade rudder with two conjugate elastic support according to IACS UR S10 Rev.4 Apr 2015
Section 14 Rudder and Manoeuvring Arrangement		
A.	**General**	
3.	**Definitions**	Added new definitions according to IACS UR S10 Rev.4 Apr 2015
5.3	-	Added new requirement for the arrangement of stuffing box in rudder trunk
6.6	-	Added new requirement for radii of rudder plating
6.7	-	Added new requirement for weld design in rudder side plating
Fig. 14.2	**Use of steel backing bar in way of full penetration welding of rudder side plating**	Added new figure according to IACS UR S10 Rev.7 Feb 2023
B.	**Rudder Force and Torque**	
2.2	-	Added new formula explanation
C.	**Scantlings of the Rudder Stock**	
2.	**Strengthening of rudder stock**	Added new criteria for spade rudder with trunk extending inside the rudder according IACS UR S10 Rev.7 Feb 2023
3.2.2	**Moment and forces**	Added new requirements for calculation maximum moment, MC, in top of the cone coupling of spade rudder according to IACS UR S10 Rev.7 Feb 2023

Paragraph	Title/Subject	Status/Remark
3.3.2	**Moment and forces**	Added new figure and requirement for calculation moment bending and forces of spade rudders with rudder trunks inside the rudder body according to IACS UR S10 Rev.7 Feb 2023
3.4.2	**Moment and forces**	Added new information for calculation rudder horn
3.5	**Semi-spade rudder with two elastic support**	Added new requirements for calculation moment bending and the shear force of semi-spade rudder with two elastic supports according to IACS UR S10 Rev.7 Feb 2023
4.3	-	Added new requirement of fillet shoulder radius of rudder trunk extending to skeg or shell according to IACS UR S10 Rev.7 Feb 2023
D.	**Rudder Couplings**	
4.2.3.1	**Push-up pressure**	Amendment formula for calculation push up pressure of rudder coupling according to IACS UR S10 Rev.7 Feb 2023
E.	**Rudder Body, Rudder Bearings**	
2.1	-	Amendment formula for calculation rudder plating according to IACS UR S10 Rev.7 Feb 2023
5.4	-	Amendment formula for calculation push-up pressure of the pintle according to IACS UR S10 Rev.7 Feb 2023
Fig. 14.13	**Pintle cone coupling indicating ℓ_a**	Added new figure of pintle cone coupling
Section 15 Strengthening for Navigation in Ice		
B.	**Requirements for the Notations ES1 – ES4**	
4.1.2	-	Amendment requirements and formula for calculation frames, ice stringer and web frames of ships strengthened navigation in ice
4.1.3	-	Added new requirements for longitudinal framing of ships strengthened navigation in ice
Section 16 Superstructures and Deckhouses		
A.	**General**	Updated reference
C.	**Superstructure End Bulkheads and Deckhouse Walls**	
1	-	Added new reference of breakwaters calculation and new formula explanation
E.	**Breakwater**	
2.1	-	Added a new definition of z in the calculation dimension of breakwater

Paragraph	Title/Subject	Status/Remark
Section 17 Cargo Hatchways		
A.	**General**	
1.4	-	Clarified application of this section with requirements of ICLL
1.5	-	Renumbering and updated reference
B.	**Hatch Covers**	
2.1	**Load case A: Vertical and horizontal weather design load**	Clarifified title of subsection
2.2	**Load case C: Container loads**	Clarifified title of subsection
2.2.1 - 2.2.3	-	Added new requirements for determination container loads according to IACS UR S21 Rev.6 Jan 2023
2.2.5	**Mixed stowage of 20' and 40' containers on hatch cover**	Added new requirements for mixed containers load on hatch cover
2.3	**Load case E: Loads due to elastic deformations of the ship's hull**	Clarifified title of subsection
3.1	-	Added new reference and method for consideration stress concentration
3.2	-	Added new requirements for hatch cover made of aluminium alloy
4.4	**FEM calculations**	Added requirements for fem calculation hatch cover using U-type stiffener IACS UR S21 Rev.6 Jan 2023
4.5	**Buckling strength of hatch cover structures**	Added new requirements for buckling strength of hatch cover structures according to IACS UR S21 Rev.6 Jan 2023
Fig. 17.7	**Determination of normal stress of the hatch cover plating**	Added new figure according to IACS UR S21 Rev.6 Jan 2023
5.4	**Hatch cover stiffeners**	Changed requirements for calculation of hatch cover stiffener according IACS UR S21 Rev.6 Jan 2023
5.5.1	-	Added new note related to support from the maker to provide proof that material is sufficient for intended design according to IACS UR S21 Rev.6 Jan 2023
6.	**Weathertightness of hatch covers**	Added new reference for testing of weather tightness of hatch covers
C.	**Hatch Coamings and Girders**	
1.1	-	Added new requirement secondary stiffener of hatch coaming according to IACS UR S21 Rev.6 Jan 2023
Fig. 17.10	**Example for a hatch side girder**	Added new figure according to S21A Rev.1 May 2015
2.1	**Plating**	Added new formula explanation

Paragraph	Title/Subject	Status/Remark
2.2.2	-	Added new requirements for calculation of effective breadth of the coaming plate according to IACS UR S21 Rev.6 Jan 2023
2.3	**Horizontal stiffeners**	Changed formula of coaming horizontal stiffener and added new formula explanation according to IACS UR S21 Rev.6 Jan 2023
D.	**Smaller Opening and Hatches**	
2.2.2	-	Added new application requirements strength and securing of small hatch on container ship according to IACS UR S26 Rev.5
Section 18 Equipment		
A.	**General**	
3.	**Design of the anchoring equipment**	Added new title
3.7	-	Added new requirement regarding design anchoring equipment in emergency situations according to UR A1 Rev.8
5.	**Structural requirements associated with towing and mooring equipments**	Added new requirements related to application of towing and mooring equipments
6.	-	Renumbering and added new references information
7.	**Definitions**	Renumbering and added new definitions related to terms used in the design of mooring lines and towlines according to IACS UR A2 (Rev.5 Sep 2020)
B.	**Equipment Numeral**	
1.	-	Changed formula for calculation equipment number related to funnels according to IACS UR A1 (Rev.7 Sep 2020)
Fig. 18.1a	**Side Projected Area**	Superseded figure related to funnel design according to IACS UR A1 (Rev.7 Sep 2020)
Fig. 18.1b	**Front projected area**	Added new figure related to funnel design according to IACS UR A1 (Rev.7 Sep 2020)
2.	-	Added new requirements for calculation number and minimum strength of mooring line according to IACS Rec. 10.2.1 Rev.5
C.	**Anchors**	
1.	**General**	Added requirements related to obligation to fitted of stream anchor according to IACS UR A1 (Rev.7 Sep 2020)

Paragraph	Title/Subject	Status/Remark
5.	**Stern anchor**	Added requirements for design stern anchor according to IACS Rec. 10 Rev.5
D.	**Chain Cables**	
5.	-	Added requirements for chain cables used for stream anchors
E.	**Chain Locker**	
1.	-	Added new requirements related to the design chain locker according to IACS Rec.10 Rev.5
2.1.1	-	Added new requirements design bulkhead between separate cable locker according to IACS L4 Rev.2 Nov 2005
2.1.3	-	Added new requirements related to the access for chain locker according to IACS UR L4 Rev.3 Mar 2011
2.1.4	-	Added new requirements of closing appliances spurling pipes through which anchor cables according to IACS UR L4 Corr.1 Aug 2011
F.	**Mooring Equipment**	
1.1	**Strength, Arrangement and selection**	Added reference information related to fittings intended to be used for both mooring and towing according to IACS UR A2 (Rev.5 Sep 2020)
4.2	**Mooring lines for ships with Z > 2000**	Superseded requirements for calculation of mooring lines with equipment number > 2000 according to IACS Rec. 10 Rev.4 Sep 2020
4.2.1	**Ship design minimum breaking load**	Superseded requirements for calculation ship design minimum breaking load according to IACS Rec. 10 Rev.4 Sep 2020
4.2.2	**Number of mooring lines**	Added new requirements for calculation number of mooring lines according to IACS Rec. 10 Rev.4 Sep 2020
G.	**Towing Equipment**	
1.1	**Strength, Arrangement and selection**	Added reference information related to the fittings intended to be used for both mooring and towing according to IACS UR A2 (Rev.5 Sep 2020)
1.1.1	**Notes**	Added reference for the definition of the nominal capacity condition according to IACS UR A2 (Rev.5 Sep 2020)
1.2	**Safe Towing Load (TOW)**	Amendment formula for safe towing load according to IACS UR A2 (Rev.5 Sep 2020)

Paragraph	Title/Subject	Status/Remark
2.	**Tow line**	Added new information regarding the adequacy of towing lines provided by the designer according to IACS Rec. 10 Rev.4 Sep 2020
H.	**Mooring and Towing Arrangements**	
1.	**Mooring and Towing arrangement Plan**	Added new title of subsection
2.	**Mooring winches**	Added new requirements for design mooring winches according to IACS Rec. 10 Rev.4 Sep 2020
3.	**Mooring and towing arrangement**	Added new requirements for design mooring and towing arrangement according to IACS Rec. 10 Rev.4 Sep 2020
J.	**Supporting hull structures of anchor windlass and chain stopper**	Added new requirements for design supporting hull structures of anchor windlass and chain stopper according to IACS UR A1 (Rev.7 Sep 2020)
Section 21 Hull Outfit		
A.	**General**	
1.	**References**	Updated reference information
Section 22 Structural Fire Protection		
B.	**Cargo Ships of 500 GT and over**	
7.1	-	Amendment requirements according to SOLAS II-2/9.7.1.1 and added reference interpretation of the requirements
7.9	-	Added new reference for the interpretation of the requirements according to IACS UI SC300
Section 23 Subdivisions and Stability		
A.	**General**	
2.	**Character of Classification**	deleted already covered in the respective subsection and renumbering subsection accordingly
B.	**Intact Stability**	
1.	**General**	Superseded requirements for calculation intact stability according BKI relevant rules
2.	**Alternative criteria for container ships greater than 100 m in length**	Added new reference information for alternative calculation intact stability for container ships > 100 m
3.3 - 3.5	-	Added new requirements for preparation on board intact stability documents according to SOLAS II-1, B-1
C.	**Damage Stability**	
All	-	Superseded damage stability requirements according to SOLAS II-1, Part B-1

Paragraph	Title/Subject	Status/Remark
Section 24 Special Requirements for In-Water Surveys		
C.	**Documents for Approval, Trials**	
1.	-	Added information related submited documents in electronic format
Section 27 Requirements for Use of Extremely Thick Steel Plates in Container Ships		
All	-	Superseded requirements according to IACS UR S33
Annex B Global Strength Analysis of Container Ships		
II.	**Global Strength Analysis**	
D.	**Design Loads**	
2.	**Mass model**	Added new requirements for determination mass model in the global strength calculation using FEM

Table of Contents

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Section 1 General, Definitions

A. General

1. Application

1.1 The Rules apply to seagoing steel ships classed **A100** with a length **L** of 90 m and above and an unlimited range of service whose intended to get the Notation **CONTAINER SHIP**.

1.2 For container ships designed without hatch covers (open-top container ships), additional requirements according to IMO MSC/Circ.608/Rev.1 must be complied with. Ships that comply with these requirements are eligible to be assigned with the additional notation "**Hatchcoverless**".

1.3 Ships deviating from the Construction Rules in their 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.

1.4 Passages printed in italics generally contain recommendations and notes which are not part of the Classification Rules. Requirements quoted in extracts of statutory regulations, which are mandatory besides Classification, may also be printed in italics.

2. References

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

2.2 International Conventions and Codes

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

IACS UR S2 Rev.2

IACS UR S21 Rev.6

ICLL containing all amendments up to 1st July 2010

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

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.

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

ICLL

International Convention on Load Lines, 1966 as amended.

MARPOL 73/78

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

SOLAS 74

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

2.4 For ships suitable for in-water surveys which will be assigned the Class Notation "**IW**", the requirements of Section 24, are to be observed.

2.5 Any requirements within these rules that is identified based on international conventions and/or codes, the interpretation of these requirements refers to Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) as applicable.

3. Definitions

3.1 General

Unless otherwise mentioned, the dimensions according to 3.2 and 3.3 are to be inserted [m] into the formulae stated in the following Sections.

3.2 Principal dimension

3.2.1 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)

3.2.2 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)

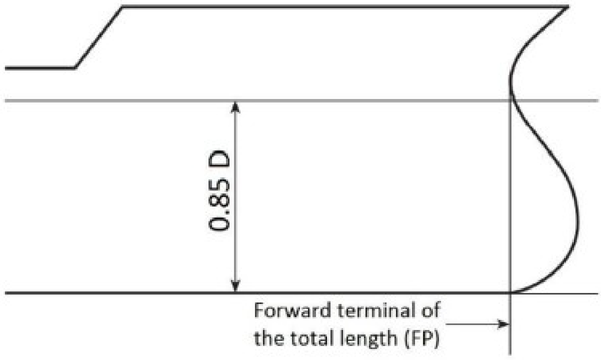

Figure 1.1: Length L_C in case of concave stem contour

3.2.3 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)

3.2.4 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.

3.2.5 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.

3.2.6 Breadth B

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

3.2.7 Depth H

The depth **H** is the vertical distance, at the middle of the length **L**, from the base line[1)] 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.

3.2.8 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))

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

3.2.9 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.

3.3 Frame spacing a

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

3.4 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 $\mathbf{B_{SC}}$.

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

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)

3.5 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.

3.6 Definition of decks

3.6.1 Bulkhead deck

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

3.6.2 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))

3.6.3 Strength deck

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

3.6.4 Weather deck

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

3.6.5 Lower decks

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

3.6.6 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.

3.6.7 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 S21 1.2.2)

4. 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. Accessibility

1. General

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

1.2 Spaces, which are to be accessible for the service of the ship, hold spaces and accommodation spaces are to be gastight against each other.

1.3 The design appraisal and testing of accesses to ships (accommodation ladders, gangways) are not part of Classification.

However, approval of substructures in way of accommodation ladders and gangways is part of Classification.

2. Provisions for safe access

2.1 The minimum clearance for transit areas should be at least 2 m high and 600 mm wide.

2.2 All relevant deck surfaces used for movement about the ship and all passageways and stairs should have non-slip surfaces.

2.3 Where necessary for safety, walkways on deck should be delineated by painted lines or otherwise marked by pictorial signs.

2.4 All protrusions in access ways, such as cleats, ribs and brackets that may give rise to a trip hazard should be highlighted in a contrasting colour.

3. Access to the steering gear compartment

The steering gear compartments is to be:

- easily accessible
- provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements are to include handrails and gratings or other nonslip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

(SOLAS II-1, 29.13)

4. Access to shaft tunnels

See Section 11, C.

C. Intact and Damage Stability

Ships will be assigned Class only after it has been demonstrated that their stability is adequate for the service intended, see Section 23.

D. *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.*

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

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

Vibration load to the crew:

- *measurement and analysis techniques according to ISO 6954, ed. 2000*
- *limit values according to ISO 6954, depending on ship type and location within the ship*
- *vibrations of machinery, installations and other equipment according to Rules for Machinery Installations, (Pt.1, Vol. III) Sec.1*

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.

E. 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).

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

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.

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.

F. 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.

G. 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

2.3 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.

H. 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 25.

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 3.

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.

The application of higher strength hull structural steel with a nominal yield stress of 460 N/mm2 is in general limited to structural members of the upper hull of container ships according to Rules for Materials (Pt.1, Vol.V).

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:

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

$R_{eH} \neq 315$ 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 In the drawings submitted for approval it is to be shown which structural members are made of higher strength hull structural steel. These drawings are to be placed on board in case any repairs are to be carried out.

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

3. Material selection for the hull

3.1 Material classes

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

3.2 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 2.7 General requirements are given in Table 2.2 while additional minimum requirements are given in the following:

Table 2.3: for ships with length exceeding 150 m and single strength deck.

Table 2.4: for ships with length exceeding 250 m.

Table 2.5: for ships with ice strengthening.

Table 2.6: for ships with cranes

The material grade requirements for hull members of each class depending on the thickness are defined in Table 2.7.

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	
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	- 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	Bilge strake [1)]	- Class III within 0,4**L** amidships - Class II outside 0,4**L** amidships - Class I outside 0,6**L** amidships
C6	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
C7	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 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 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 2.5: Minimum material grades for ships with ice strengthening

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

(IACS UR S6 Table 6)

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

Thickness t [mm]		**> 12,5**	**> 25**	**> 70**
	≤ 12,5	**≤ 25**	**≤ 70**	
Minimum material grade	A/AH	B/AH	D/DH	E/EH

The requirements for material grades are valid for design temperatures up to 0° C. For lower design temperatures the requirements for material grades defined in Guidelines for Loading Gear on Seagoing Ships and Offshore Installations (Pt.4, Vol. 3) are to be considered.

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

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

1) Actual thickness of the structural member.
2) For thicknesses t > 60 mm E/EH
3) For thicknesses t > 100 mm the steel grade is to be agreed with BKI.
4) For nominal yield stresses R_{eH} ≥ 390 N/mm[2)] EH.

(IACS UR S6 Table 7)

3.3 Material selection for local structural members

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

Table 2.8: 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 3.3.2.

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

(IACS UR S6.1)

3.3.2 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.

3.3.3 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.

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

3.4.1 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

3.4.2 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 3.4.5.

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 2.9) are not to be of lower grades than those corresponding to classes I, II and III, as given in Table 2.9, depending on the categories of structural members (Secondary, Primary and Special). For non-exposed structures (except as indicated in Note 6 of Table 2.9) and structures below the lowest ballast waterline, 3.2 and 3.3 applies.

(IACS UR S6.2)

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

(IACS UR S6.2)

3.4.4 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 3.3.

(IACS UR S6.2)

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

- **Mean** : Statistical mean over an observation period
- **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)

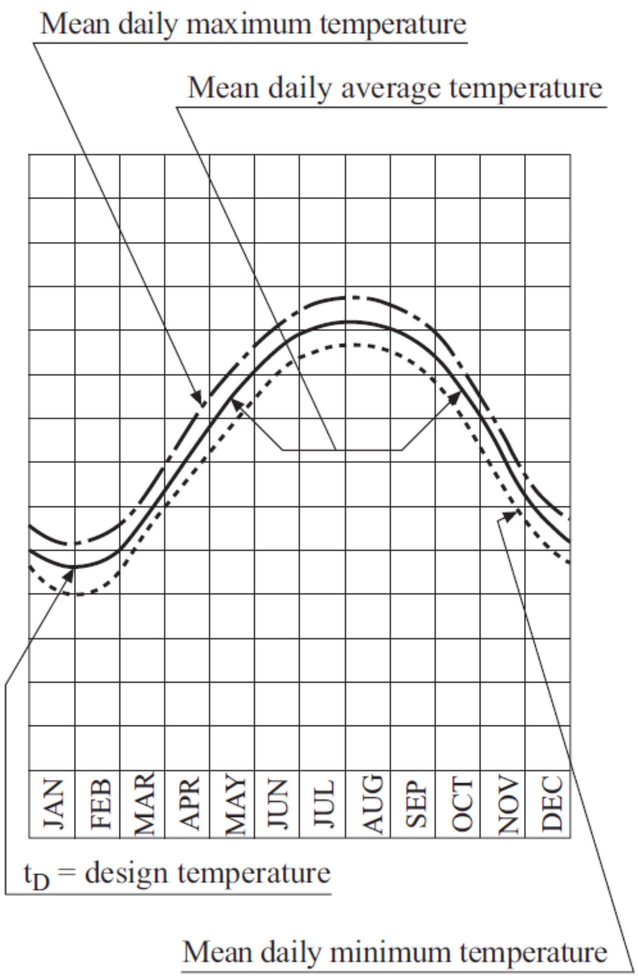

Figure 2.1: Commonly used definitions of temperatures

4. Structural members which are stressed in direction of their thickness

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

C. Forged Steel and Cast Steel

Forged steel and cast steel for stem, stern frame, rudder post as well as other structural components, which are subject of this Rule, are to comply with the 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.3. In this respect beside strength properties also toughness requirements and weldability shall be observed.

D. Aluminium Alloys

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

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

$R_{p0,2}$ = 0,2% proof stress of the aluminium alloy [N/mm^2]

R_m = tensile strength of the aluminium alloy [N/mm^2]

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

Method of conversion:

- section modulus : $W_{A\ell} = W_{St} \cdot k_{A\ell}$
- plate thickness : $t_{A\ell} = t_{St} \cdot \sqrt{k}$

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

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

E. Austenitic Steels

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

Table 2.9: 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)]	I	I
Primary: Strength deck plating [1)] Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings Longitudinal bulkhead 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.

(IACS UR S6 Table 8)

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

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
Class I										
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										
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										
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)

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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

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 · **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.

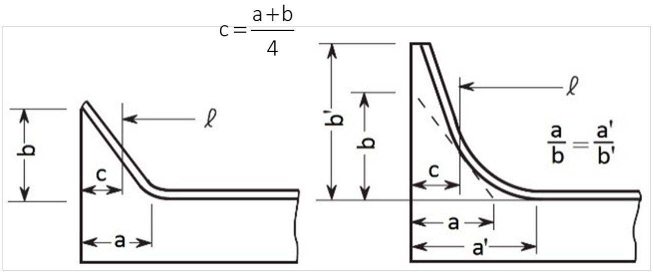


Figure 3.1: Unsupported span ℓ

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, see Section 12, A.7.

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:

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

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.

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.

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.

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

All structural members which are subjected to compressive and/or shear stresses are to be examined for sufficient resistance to buckling in according to Rules for Hull (Pt.1, Vol.II) Section 3, F related to the strength criteria for buckling and ultimate strength.

For this purpose the design stresses according to Section 5, D and the stresses due to local loads are to be considered. For structural members contributing to the longitudinal strength see also Section 5, C.7.

G. Rigidity of Transverses and Girders

The moment of inertia of deck transverses and girders, is not to be less than:

$$I = c \cdot W \cdot \ell \quad [\mathrm{cm}^4]$$

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.3.2.

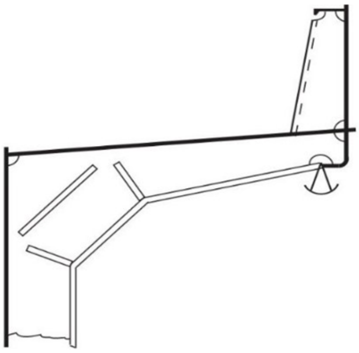


Figure 3.2: Support of face plates of cantilevers

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

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

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. 3.3

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

= $0,9 \cdot \frac{(b - t_f)^2}{R \cdot t_f} \leq 1,0$ 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. 3.3 (a).

n_3 = $\left(\frac{d}{t_f} - 8\right)^4$ if one stiffener is fitted according to Fig. 3.3 (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. 3.3 < 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 $\frac{d}{t_f} > 8$

= $\frac{d}{t_f} - 0,51 \cdot \sqrt[4]{\frac{d}{t_f}}$ for $8 \geq \frac{d}{t_f} > 1,35$

= $0,5 \cdot \frac{d}{t_f} + 0 \cdot 125$ for $1,35 \geq \frac{d}{t_f} \geq -0,25$

The welding seam has to be shaped according to Fig. 3.4.

Scantlings of stiffeners (guidance):

thickness : $t_b = \frac{\sigma_a}{\sigma_p} \cdot t_f \cdot 2 \sin\alpha$ [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.

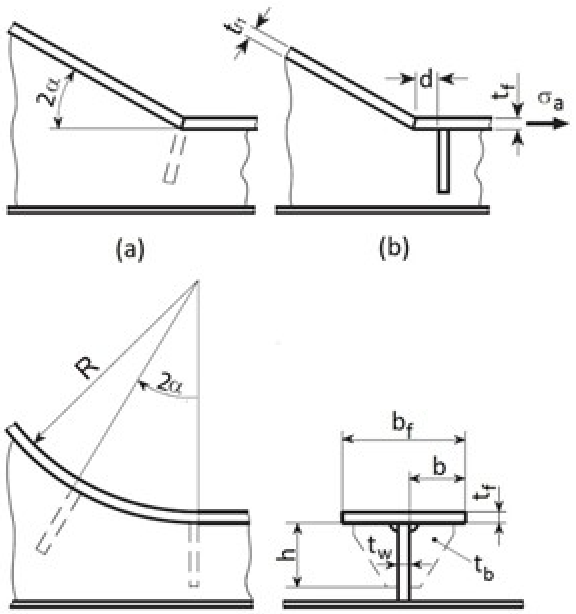


Figure 3.3: Typical stiffeners of rounded of knuckled face plates

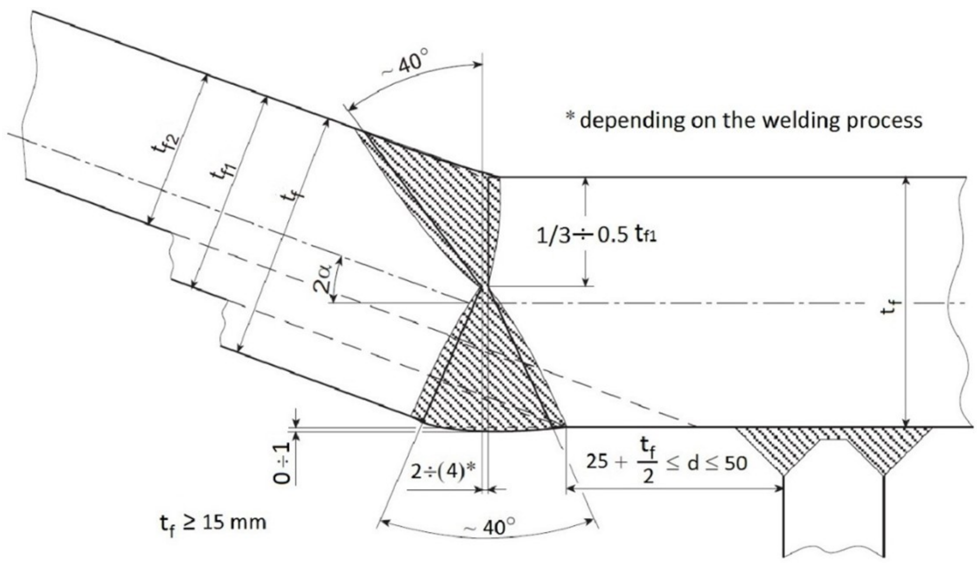


Figure 3.4: Welding and supporting of knuckles

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. 3.4.

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. 3.5 and Fig. 3.6

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. 3.7

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

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.

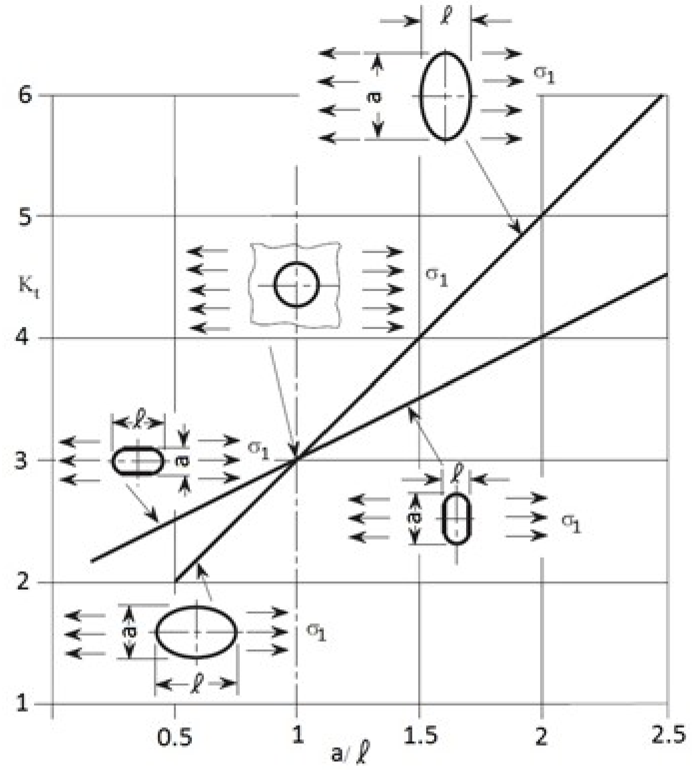


Figure 3.5: Notch factor K_t for rounded openings

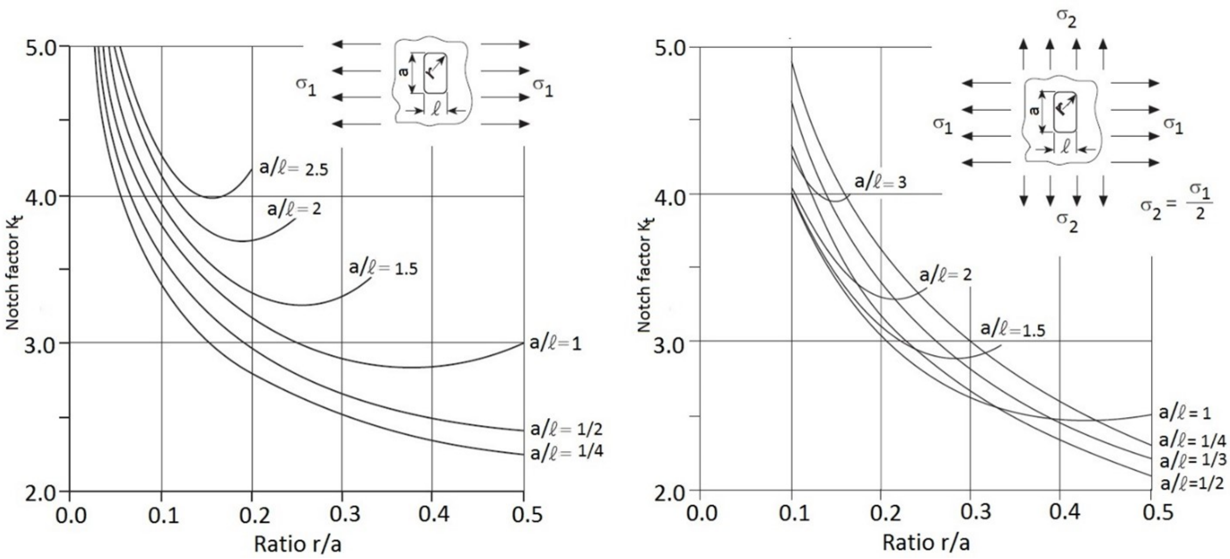


Figure 3.6: Notch factor K_t for rectangular openings with rounded corners at uniaxial stress condition (left) and at biaxial stress condition (right)

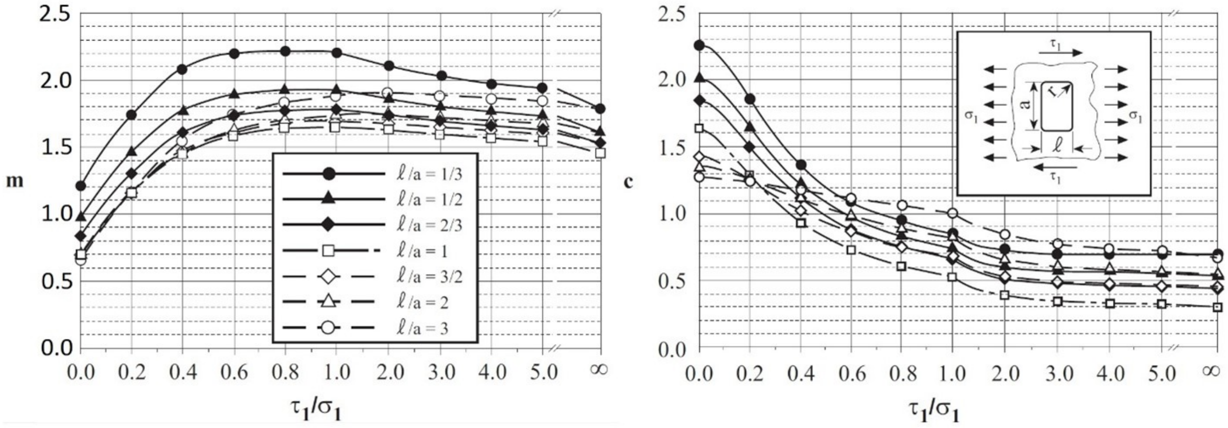


Figure 3.7: Parameters m and c to determine the notch factors of rectangular openings loaded by superimposed longitudinal and shear stresses

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'> 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 3.2. For corrosion protection see Section 25.

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

$t_k = \frac{0,1.t'}{\sqrt{k}}$ max.$2,5$ mm

however, not less than 1,0 mm.

Table 3.2: Minimum corrosion addition

Area	t_{Kmin} [mm]
In ballast tanks	2,0
Horizontal members in fuel oil tanks	2,0

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 [mm] for t'$\leq$10 mm

$t_K = \frac{0,1 \cdot t'}{\sqrt{k}} + 0,5 \leq 3,0$ [mm] for t' $\geq$10 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:

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

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. 3.8. $b_1 \geq b_2$
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.

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

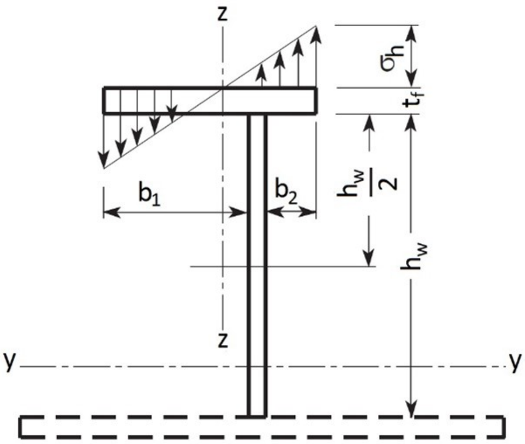


Figure 3.8: Asymmetrical profile

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 3.3

Table 3.3: 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.

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

v_0 = ship's speed according to Section 1, A.3.5

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

ρ = density of liquids $[t/m^3]$

= 1,0 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

= $2,1 \cdot (C_B + 0,7) \cdot c_0 \cdot c_L \cdot f$ $[kN/m^2]$

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, A.3.4, 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 ≤ **L** ≤ 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 ≤ **L** ≤ 500 m

c_L = length coefficient

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

= 1,0 for **L** ≥ 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

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: $L_{min} = 100m$ $L_{max} = 250m$	$1,0 + \frac{20}{C_B}\left(\frac{x}{L} - 0,7\right)^2$

[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

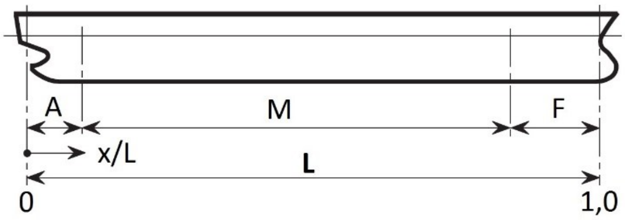


Figure 4.1: Longitudinal sections A, M, and F according to Table 4.1

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:

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

for wave directions with or against the ship's heading.

$$p_{s1} = 10 \cdot (T - z) + p_{01} \cdot c_F \left[1 + \frac{z}{T}\left(2 - \frac{z}{T}\right)\right] \cdot 2\,\frac{|y|}{B} \quad [kN/m^2]$$

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:

$$p_s = p_0 \cdot c_f \cdot \frac{20}{10 + z - T} \quad [kN/m^2]$$

for wave directions with or against the ship's heading.

$$p_{s1} = p_{01} \cdot c_f \cdot \frac{20}{5 + z - T} \cdot \frac{|y|}{B} \quad [kN/m^2]$$

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 :

$$p_e = c\left[0,2 \cdot \mathbf{v}_0 + 0,6\sqrt{\mathbf{L}}\right]^2 \quad [kN/m^2]$$

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.

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 **T** + $c_0/2$ is to be determined according to the following formulae:

$$p_e = c_a \cdot \mathbf{L} \quad [kN/m^2]$$

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:

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

For wave direction with or against the ship's heading.

$$p_{B1} = 10 \cdot \mathbf{T} + p_{01} \cdot 2\frac{|y|}{\mathbf{B}} \quad [kN/m^2]$$

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 forebody may be determined by the following formulae:

$$p_{SL} = 162 \cdot \sqrt{\mathbf{L}} \cdot c_1 \cdot c_{SL} \cdot c_A \cdot c_S \quad [kN/m^2] \quad \text{for } \mathbf{L} \leq 150\ m$$

$$= 1984\,(1,3 - 0,002 \cdot L)\, c_1 \cdot c_{SL} \cdot c_A \cdot c_S \quad [kN/m^2] \quad \text{for } \mathbf{L} > 150\ m$$

c_1	=	$3,6 - 6,5 \cdot \left[\frac{T_b}{L}\right]^{0,2}$ $\quad 0 \le c_1 \le 1,0$
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, T_b is to be considered for the sequence of exchange.

Note:

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

C_{SL} = distribution factor, see also Fig.4.2

$$C_{SL} = 0 \quad \text{for } \frac{x}{L} \le 0,5$$

$$= \frac{\frac{x}{L} - 0,5}{c_2} \quad \text{for } 0,5 < \frac{x}{L} \le 0,5 + c_2$$

$$= 1,0 \quad \text{for } 0,5 + c_2 < \frac{x}{L} \le 0,65 + c_2$$

$$= 0,5\left[1 + \frac{1 - \frac{x}{L}}{0,35 - c_2}\right] \quad \text{for } > 0,65 + c_2$$

$$c_2 = 0,33 \cdot C_B + \frac{L}{2500}$$

c_{2max} = 0,35

c_A = $10/A$ with $0,3 \le c_A \le 1,0$

= 1,0 for plate panels and stiffeners.

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

$$c_s = \frac{1 + c_{RW}}{2}$$

c_{RW} = see A.2.2

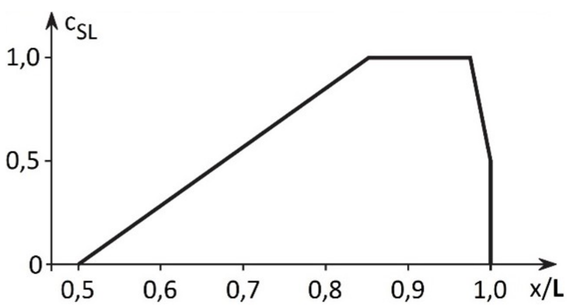


Figure 4.2: Distribution factor c_{SL}

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:

$$p_{DA} = p_D \cdot n \quad [kN/m^2] \qquad \text{for } \mathbf{L} > 150 \text{ m}$$

p_D = load according 1.1

n = $1 - \frac{z - \mathbf{H}}{10}$

= 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:

$$p_{DAmin} = 4,0 \quad [kN/m^2]$$

5.2 For exposed wheel house tops the load is not to be taken less than

$$p = 2,5 \quad [kN/m^2]$$

C. Load on Inner Decks

1. Load on inner bottom

1.1 The load on inner bottom is to be determined as follows:

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

p_c = static cargo load $[kN/m^2]$

a_v = acceleration factor as follows:

= F.m

F = coefficients, defined as:

= $0{,}11 \frac{\mathbf{v}_0}{\sqrt{\mathbf{L}}}$

m = coefficients, defined as:

= $m_0 - 5\,(m_0 - 1)\,\frac{x}{\mathbf{L}}$ for $0 \le \frac{x}{L} \le 0,2$

= 1,0 for $0,2 < \frac{x}{\mathbf{L}} \le 0,7$

= $1 + \frac{m_0 + 1}{0,3}\left[\frac{x}{\mathbf{L}} - 0,7\right]$ for $0,7 < \frac{x}{\mathbf{L}} \le 1,0$

m_0 = coefficients, defined as:

= $(1,5 + F)$

$\mathbf{v}_0$ = see A.2.2 $\mathbf{v}_0$ is not to be taken less than $\sqrt{\mathbf{L}}$ [kn]

1.2 The loads due to single forces P_E (e.g. in case of containers) are to be determined as follows:

$$P = P_E\,(1 + a_v) \quad [kN]$$

2. Loads on accommodation and machinery decks

2.1 The deck load in accommodation and service spaces is:

$$p = 3,5(1 + a_v) \quad [kN/m^2]$$

2.2 The deck load of machinery decks is:

$$p = 8,0(1 + a_v) \quad [kN/m^2]$$

2.3 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

= $\arctan\left(f_{bk} \cdot \frac{\mathbf{H}}{\mathbf{B}}\right)$ 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

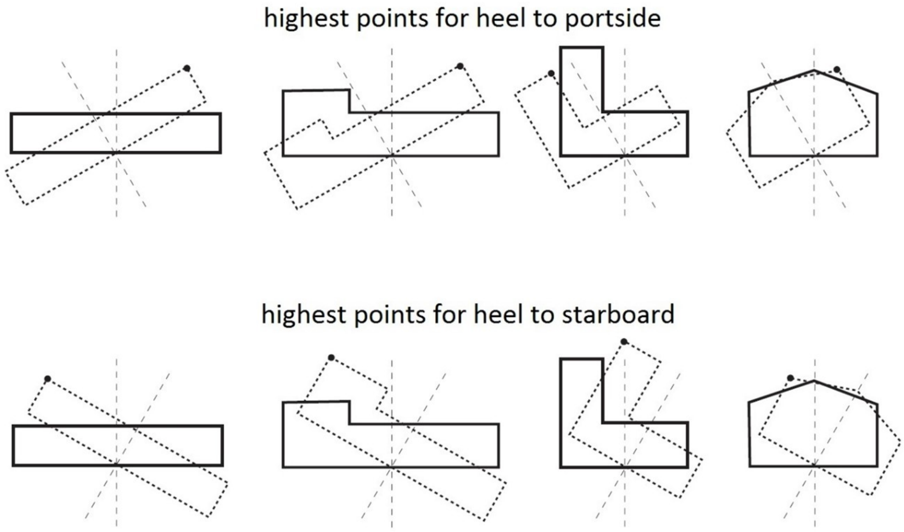


Figure 4.3: Highest points for different tank shapes

1.2 The maximum static load p_2 on tank structures is to be determined by the following formula:

$$p_2 = 9,81.h_2 \quad [\text{kN/m}^2]$$

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:

$$p_d = \left(4 - \frac{\mathbf{L}}{150}\right) \ell_t \cdot \rho \cdot n_x \cdot + 100.p_v \quad [\text{kN/m}^2]$$

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:

$$p_d = \left(5,5 - \frac{\mathbf{B}}{20}\right) b_t \cdot \rho \cdot n_y \cdot + 100 \cdot p_v \quad [\text{kN/m}^2]$$

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 = $\frac{13 \cdot \overline{GM}}{\mathbf{B}}$

$\overline{GM}$ = 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

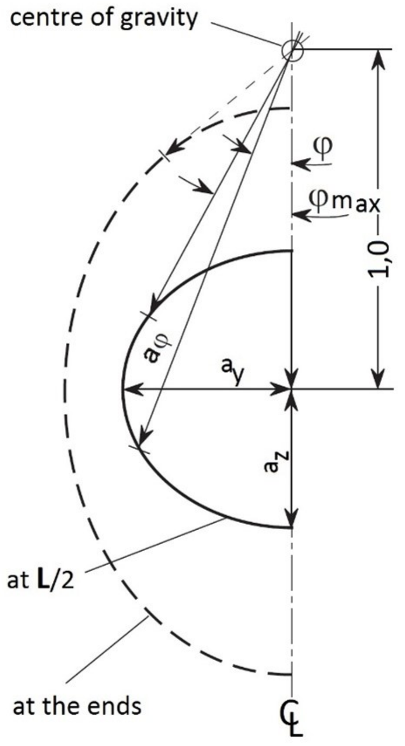


Figure 4.4: Acceleration ellipse

Section 5 Longitudinal Strength

A. General

1. Application

1.1 For container ships and ships dedicated primarily to carry their load in containers with a length of 90 m and greater and operated in unrestricted service, 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.

(IACS UR S11A.1.1))

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.

2. References

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 S11A

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.

3. Definitions

k	=	material factor according to Section 2, B
x	=	distance [m] between aft end of length **L** and the position considered
c_0	=	wave coefficient according to Section 4, A.2.2
$\mathbf{C_B}$	=	block coefficient as defined in Section 1, A.3.4
$\mathbf{C_W}$	=	waterplane coefficient at scantling draught, to be taken as:
	=	A_W / (**L** · **B**)
A_W	=	waterplane area [m^2], at scantling draught

v_0 = speed of the ship [kn] according to Section 1, A.3.5

I_y = moment of inertia of the midship section $[m^4]$ around the horizontal axis 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_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]

$$= \max \begin{bmatrix} Q_{SW,max} & + & Q_{WV,max} \\ |\ Q_{SW,min} & + & Q_{WV,min}\ | \end{bmatrix}$$

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.

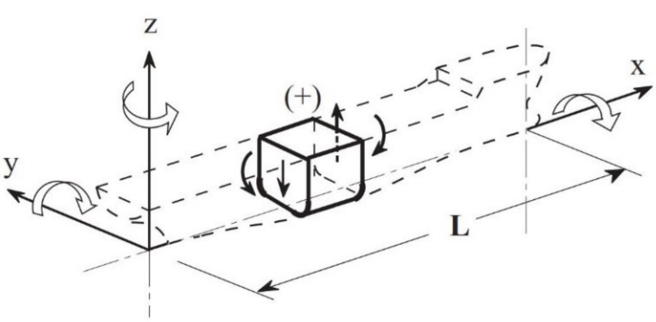


Figure 5.1: Sign rule

4. Assumptions for calculation, loading conditions

4.1 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 5.5.2, 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 S11A.2.2.2)

4.2 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.

5. Loading guidance information

5.1 General, definitions

5.1.1 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))

5.1.2 An approved loading manual is to be supplied for all container ships.

(IACS UR S1.2.1)

5.1.3 In addition, an approved loading instrument is to be supplied for all container ships.

(IACS UR S1.2.1)

5.2 Definitions:

A loading manual is a document which describes:

- the loading conditions on which the design of the ship has been based, including permissible limits of still water bending moment and shear force, and shear force correction values and, where applicable, permissible limits related to still water torsional moment and lateral loads
- the results of the calculations of still water bending moments, shear forces and still water torsional moments if unsymmetrical loading conditions with respect to the ships centreline,
- the allowable local 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 5.6. 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 5.4.1 and 5.6.

5.3 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 5.5 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)

5.4 Conditions of approval of loading instruments

5.4.1 The approval of the loading instrument is to include:

— verification of type approval, if required, see 5.2

— 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.

5.4.2 Subsection 5.6 contains information on approval procedures for loading instruments.

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

5.4.4 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.

5.4.5 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)

5.5 Design cargo and ballast loading conditions

5.5.1 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.

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 5.4.2 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.

.2 Partially filled ballast tanks in combination with cargo loading conditions

In such cargo loading conditions, the requirements in 5.5.1.1 apply to the peak tanks only.

(IACS UR S11.2.1.4)

.3 Sequential ballast water exchange

Requirements of 5.5.1.1 and 5.5.1.2 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)

5.5.2 In particular the following loading conditions should be included:

- homogeneous loading conditions at maximum draught,
- ballast conditions,
- special loading conditions, e.g:
  - container or light load conditions at less than the maximum draught,
  - deck cargo conditions, etc., where applicable
- docking condition afloat,

(IACS UR S1 Annex 1)

5.6 Approval procedures of loading instruments

For approval of the loading instrument see Guidelines for Certification of Loading Computer Systems (Pt.4, Vol.1).

5.7 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)

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. $\mathbf{L/B} \le 5$, $\mathbf{B/H} \ge 2{,}5$, $\mathbf{L} \ge 500$ m , $\mathbf{C_B} < 0{,}55$)
— ship speed of $\mathbf{v_0} \ge 1{,}6$ [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.

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 S11A.2.2.1)

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:

$$M_{SW,ini} = n_1 \cdot c_0 \cdot \mathbf{L}^2 \cdot \mathbf{B} \cdot (0,123 - 0,015 \cdot \mathbf{C_B}) \quad [kNm]$$

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:

$$M_{ST,max} = \pm 20 \cdot \mathbf{B} \cdot \sqrt{CC} \quad [kNm]$$

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:

$$M_{ST} = 0,568 \cdot M_{STmax}(|c_{TI}| + c_{T2}) \quad [kNm]$$

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 $0,5 \leq \frac{x}{\mathbf{L}} \leq 1,0$

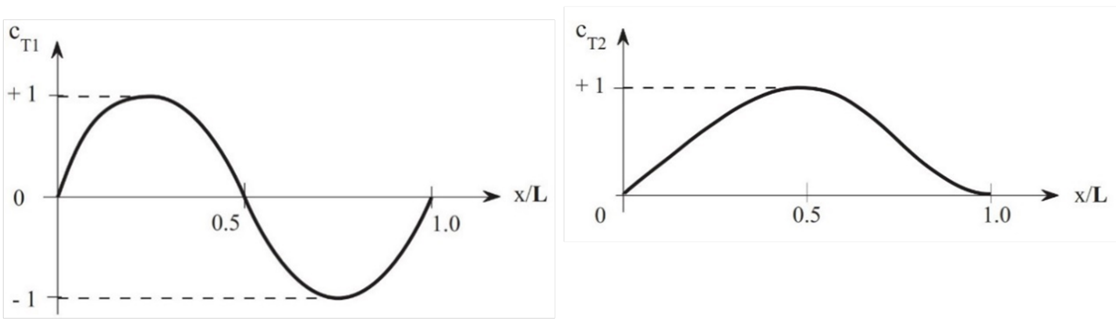


Figure 5.2: Distribution factors c_{T1} and c_{T2} for torsional moments

3. Wave induced loads

3.1 Wave parameter for vertical wave loads

The wave parameter is defined as follows:

$$c' = 1 - 1,50\left(1 - \sqrt{\frac{\mathbf{L}}{L_{ref}}}\right)^{2,2} \quad \text{for } L \le L_{ref}$$

$$c' = 1 - 0,45\left(\sqrt{\frac{\mathbf{L}}{L_{ref}}} - 1\right)^{1,7} \quad \text{for } L > L_{ref}$$

L_{ref} = Reference length [m], taken as :

= $315\ C_W^{-1,3}$ for the determination of vertical wave bending moments according to 3.2

= $330\ C_W^{-1,3}$ for the determination of vertical wave shear forces according to 3.3

(IACS UR S11A.2.2.1)

3.2 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:

$$M_{WV-Hog} = +1,5\, f_R \cdot \mathbf{L}^3 \cdot c' \cdot c_M \cdot c_W \left(\frac{\mathbf{B}}{\mathbf{L}}\right)^{0,8} f_{NL-Hog} \quad [kNm]$$

$$M_{WV-Sag} = -1,5\, f_R \cdot \mathbf{L}^3 \cdot c' \cdot c_M \cdot c_W \left(\frac{\mathbf{B}}{\mathbf{L}}\right)^{0,8} f_{NL-Sag} \quad [kNm]$$

f_R = factor related to the operational profile, to be taken as:

= 0,85 for strength assessment

= 0,80 for fatigue assessment

f_{NL-Hog} = non-linear correction for hogging, to be taken as:

= $0,3\frac{C_B}{C_W}\sqrt{T}$ for strength assessment not to be taken greater than 1,1

= 1,0 for fatigue assessment

f_{NL-Sag} = non-linear correction for sagging, to be taken as:

= $4,5\frac{1+0,2\, f_{Bow}}{C_W\sqrt{C_B}\, L^{0,3}}$ for strength assessment not to be taken greater than 1,0

= 1,0 for fatigue assessment

f_{Bow} = bow flare shape coefficient, to be taken as:

= $\frac{A_{DK} - A_{WL}}{0,2\,\mathbf{L}\, z_f}$

A_{DK} = projected area in horizontal plane of uppermost deck [m^2], including the forecastle deck, if any, extending from 0,8**L** forward (see Fig.5.3). Any other structures, e.g. plated bulwark, are to be excluded.

A_{WL} = waterplane area [m^2], at draught **T**, extending from 0,8**L** forward.

z_f = Vertical distance [m], from the waterline at draught **T** to the uppermost deck (or forecastle deck), measured at FP (see Fig.5.3). Any other structures, e.g. plated bulwark, are to be excluded.

c_M = distribution factors according to Table 5.1, see also Fig.5.4

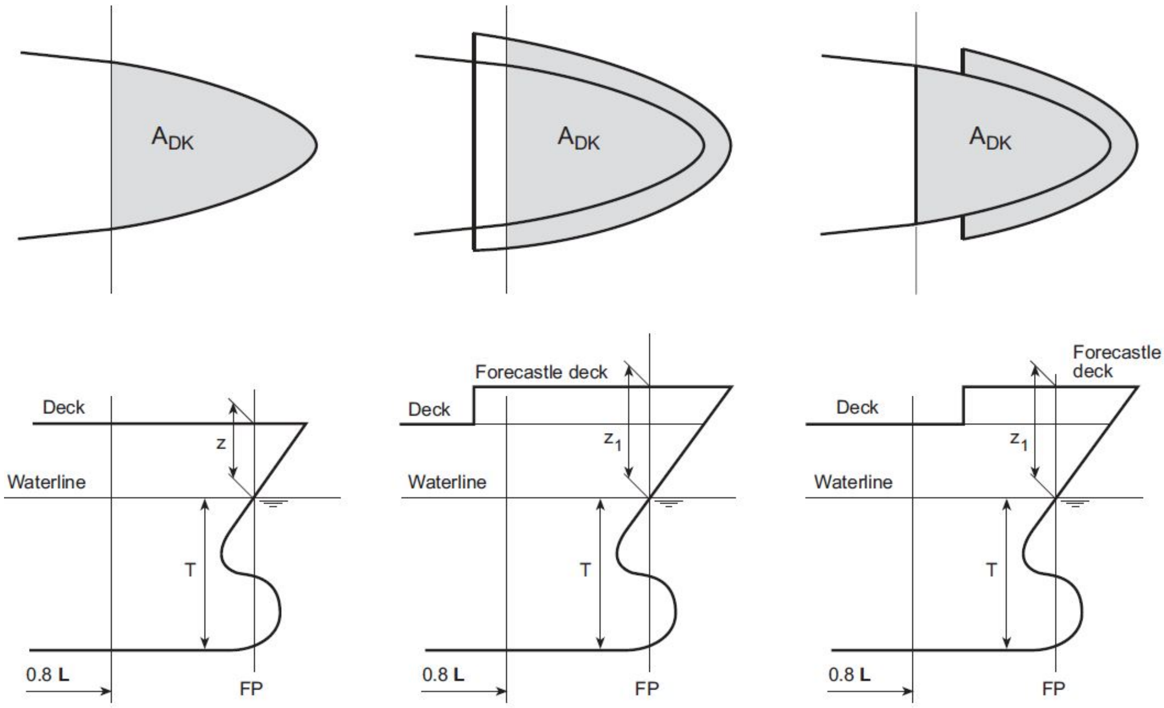


Figure 5.3: Projected area A_{DK} and vertical distance z_f

Table 5.1: Distribution factor c_M

hogging conditiom		sagging conditiom	
range	**value**	**range**	**value**
$0 \le \frac{x}{L} < 0{,}1$	$1{,}5\,\frac{x}{L}$	$0 \le \frac{x}{L} < 0{,}35$	$2{,}85\,\frac{x}{L}$
$0{,}1 \le \frac{x}{L} < 0{,}35$	$3{,}4\,\frac{x}{L} - 0{,}9$	$0{,}35 \le \frac{x}{L} < 0{,}6$	1,0
$0{,}35 \le \frac{x}{L} < 0{,}55$	1,0	$0{,}65 \le \frac{x}{L} \le 1{,}0$	$2{,}5\left(1 - \frac{x}{L}\right)$
$0{,}55 \le \frac{x}{L} < 0{,}8$	$2{,}65 - 3\frac{x}{L}$		
$0{,}8 \le \frac{x}{L} \le 1{,}0$	$1{,}25\left(1 - \frac{x}{L}\right)$		

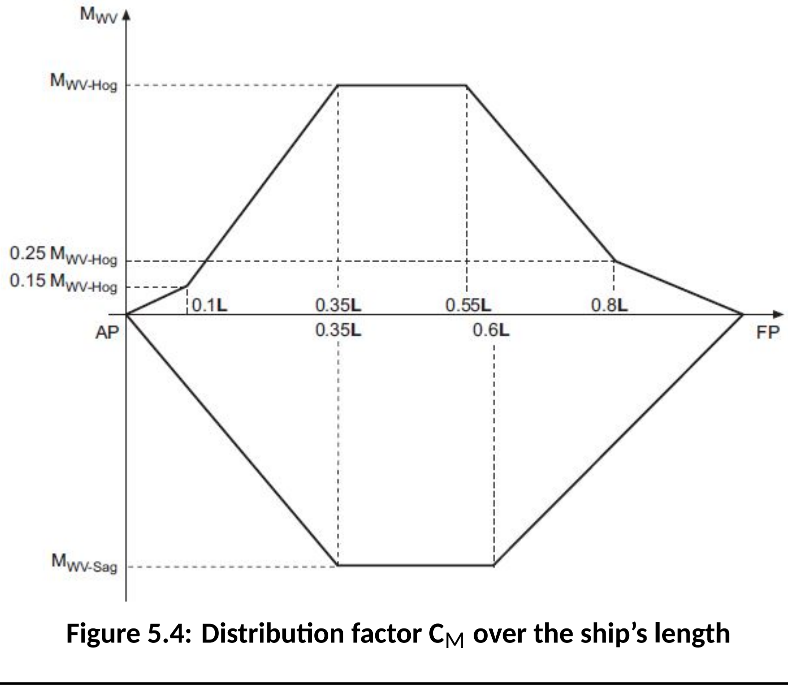


Figure 5.4: Distribution factor C_M over the ship's length

(IACS UR S11A.2.3.2)

3.3 Vertical wave shear forces

The vertical wave shear forces Q_{WV} [kN], over the ship's length are to be determined by the following formulae:

$$Q_{WHHog}^{Aft} = +5,2 \cdot f_R \cdot \mathbf{L}^2 \cdot c' \cdot C_W \left(\frac{\mathbf{B}}{\mathbf{L}}\right)^{0,8} (0,3 + 0,7 f_{NL-Hog}) \quad [kN]$$

$$Q_{WHHog}^{Fore} = -5,7 \cdot f_R \cdot \mathbf{L}^2 \cdot c' \cdot C_W \left(\frac{\mathbf{B}}{\mathbf{L}}\right)^{0,8} f_{NL-Hog} \quad [kN]$$

$$Q_{WHSag}^{Aft} = -5,2 \cdot f_R \cdot \mathbf{L}^2 \cdot c' \cdot C_W \left(\frac{\mathbf{B}}{\mathbf{L}}\right)^{0,8} (0,3 + 0,7 f_{NL-Sag}) \quad [kN]$$

$$Q_{WHSag}^{Fore} = +5,2 \cdot f_R \cdot \mathbf{L}^2 \cdot c' \cdot C_W \left(\frac{\mathbf{B}}{\mathbf{L}}\right)^{0,8} (0,25 + 0,75 f_{NL-Sag}) \quad [kN]$$

$$Q_{WHSag}^{Mid} = +4,0 \cdot f_R \cdot \mathbf{L}^2 \cdot c' \cdot C_W \left(\frac{\mathbf{B}}{\mathbf{L}}\right)^{0,8} \quad [kN]$$

Table 5.2: Shear force distribution over the ship's length

hogging condition		sagging condition	
range	**value**	**range**	**value**
$0 \le \frac{x}{\mathbf{L}} < 0,2$	$5 \frac{x}{\mathbf{L}} Q_{WVHog}^{Aft}$	$0 \le \frac{x}{\mathbf{L}} < 0,2$	$Q_{WVSag}^{Aft} \left(4\frac{x}{\mathbf{L}} + 0,2\right)$
$0,2 \le \frac{x}{\mathbf{L}} < 0,3$	Q_{WHHog}^{Aft}	$0,2 \le \frac{x}{\mathbf{L}} < 0,3$	Q_{WVSag}^{Aft}
$0,3 \le \frac{x}{\mathbf{L}} < 0,4$	$Q_{WVHog}^{Aft} \left(4 - 10\frac{x}{\mathbf{L}}\right)$ $Q_{WV}^{Mid} \left(10\frac{x}{\mathbf{L}} - 3\right)$	$0,3 \le \frac{x}{\mathbf{L}} < 0,4$	$Q_{WVSag}^{Aft} \left(4 - 10\frac{x}{\mathbf{L}}\right)$ $Q_{WV}^{Mid} \left(3 - 10\frac{x}{\mathbf{L}}\right)$
$0,4 \le \frac{x}{\mathbf{L}} < 0,5$	Q_{WV}^{Mid}	$0,4 \le \frac{x}{\mathbf{L}} < 0,5$	$-Q_{WV}^{Mid}$
$0,5 \le \frac{x}{\mathbf{L}} < 0,6$	$Q_{WVHog}^{Fore} \left(10\frac{x}{\mathbf{L}} - 5\right)$ $Q_{WV}^{Mid} \left(10\frac{x}{\mathbf{L}} - 6\right)$	$0,5 \le \frac{x}{\mathbf{L}} < 0,55$	Q_{WV}^{Mid}
$0,6 \le \frac{x}{\mathbf{L}} < 0,75$	Q_{WVHog}^{Fore}	$0,55 \le \frac{x}{\mathbf{L}} < 0,65$	$Q_{WVSag}^{Fore} \left(10\frac{x}{\mathbf{L}} - 5,5\right)$ $Q_{WV}^{Mid} \left(6,5 - 10\frac{x}{\mathbf{L}}\right)$
$0,75 \le \frac{x}{\mathbf{L}} \le 1,0$	$4Q_{WVHog}^{Fore} \left(1 - \frac{x}{\mathbf{L}}\right)$	$0,65 \le \frac{x}{\mathbf{L}} < 0,75$	Q_{WVSag}^{Fore}
		$0,75 \le \frac{x}{\mathbf{L}} \le 1,0$	$4Q_{WVSag}^{Fore} \left(1 - \frac{x}{\mathbf{L}}\right)$

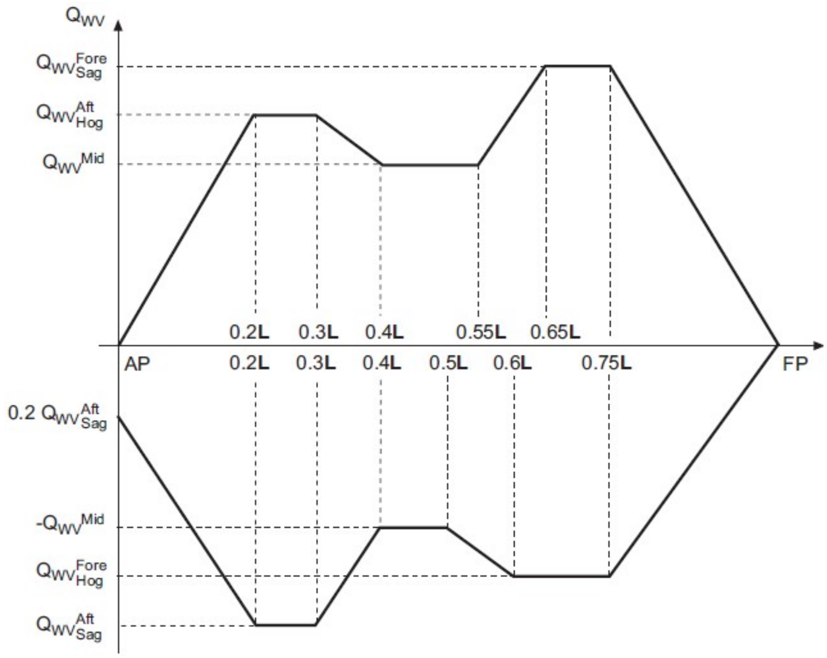


Figure 5.5: Shear force distribution over the ship's length

3.4 Horizontal bending moments

The horizontal bending moments M_{WH} over the ship's length are to be determined by the following formula:

$$M_{WH} = 0,32 \cdot \mathbf{L} \cdot Q_{WHmax} \cdot C_{MH} \quad [\text{kNm}]$$

C_{MH} = distribution factors according to Table 5.3, see also Fig. 5.6

Q_{WHmax} = see 3.5

Table 5.3: Distribution factor C_{MH}

Range	Value
$0 \leq \frac{x}{L} < 0,1$	$2,5 \cdot \frac{x}{L}$
$0,4 \leq \frac{x}{L} \leq 0,65$	1
$0,65 < \frac{x}{L} \leq 1$	$\frac{1 - \frac{x}{L}}{0,35}$

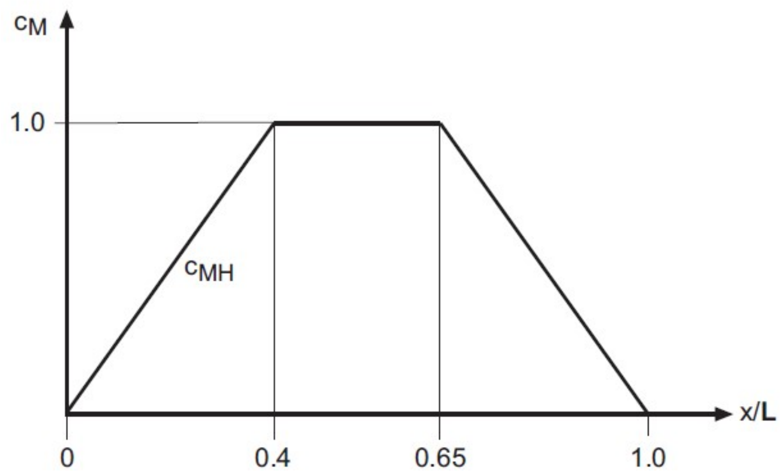


Figure 5.6: Distribution factor C_{MH} over the ship's length

3.5 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 5.4, see also Fig. 5.7

Table 5.4, see also Fig. 5.7

Table 5.4: Distribution factor c_{QH}

Range	c_{QH}
$0 \le \frac{x}{\mathbf{L}} < 0,1$	$0,4 + 6.\frac{x}{\mathbf{L}}$
$0,1 \le \frac{x}{\mathbf{L}} < 0,3$	1
$0,3 \le \frac{x}{\mathbf{L}} < 0,4$	$1,0 - 5.\left(\frac{x}{\mathbf{L}} - 0,3\right)$
$0,4 \le \frac{x}{\mathbf{L}} < 0,6$	0,5
$0,6 \le \frac{x}{\mathbf{L}} < 0,7$	$0,5 + 5.\left(\frac{x}{\mathbf{L}} - 0,6\right)$
$0,7 \le \frac{x}{\mathbf{L}} < 0,8$	1
$0,8 \le \frac{x}{\mathbf{L}} < 0,1$	$1,0 - 4,25.\left(\frac{x}{\mathbf{L}} - 0,8\right)$

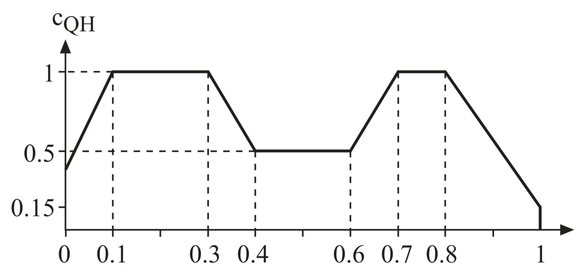


Figure 5.7: Distribution factor c_{QH}

3.6 Torsional moments

The maximum wave induced torsional moment is to be determined as follows:

$$M_{WTmax} = \pm\,\mathbf{L} \cdot \mathbf{B}^2 \cdot \mathbf{C_B} \cdot C_0 \cdot C_L \left[0,11 + \sqrt{a^2 + 0,012}\right] \quad [\text{kNm}]$$

$$a = \sqrt{\frac{\mathbf{T}}{\mathbf{L}}} \cdot \frac{C_N \cdot z_Q}{\mathbf{B}}$$

$$a_{min} = 0,1$$

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:

$$M_{WTmax} = \pm \mathbf{L} \cdot \mathbf{B}^2 \cdot \mathbf{C_B} \cdot c_0 \cdot c_L \cdot c_{WT} \quad [\text{kNm}]$$

c_{WT} = distribution factor, see also Fig. 5.8

= $(a \cdot |c_T| + 0,22 \cdot c_{T2})\,(0,9 + 0,08 \cdot a)$

c_{T1}, c_{T2} = see 2.2.2

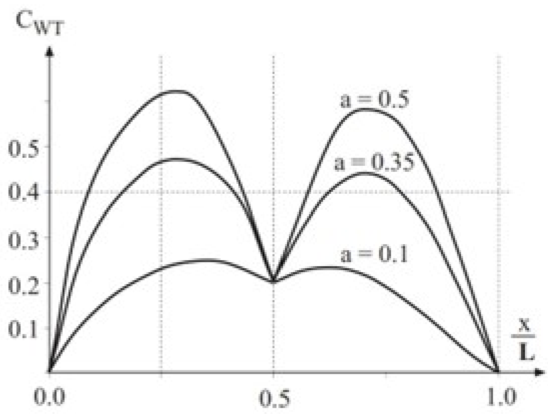


Figure 5.8: Distribution factor c_{WT}

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:

$$W = f_r \cdot \frac{|M_T|}{\sigma_p \cdot 10^3} \quad [m^3]$$

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} = $18,5 \dfrac{\sqrt{\mathbf{L}}}{k}$ for **L** < 90 m

= $\dfrac{175}{k}$ for **L** ≥ 90 m

c_s = $0,5 + \dfrac{5}{3} \cdot \dfrac{x}{\mathbf{L}}$ for $0 \le \dfrac{x}{\mathbf{L}} < 0,30$

= $1,0$ for $0,30 \le \dfrac{x}{\mathbf{L}} \le 0,70$

= $\dfrac{5}{3}\left[1,3 - \dfrac{x}{\mathbf{L}}\right]$ for $0,70 < \dfrac{x}{\mathbf{L}} \le 1,0$

For the calculation of the section moduli the relevant total bending moments M_T as defined in A.3 are to be considered.

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
- 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)

1.4 The scantlings of all continuous longitudinal members based on the minimum section modulus requirement are to be maintained within 0,4L 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 0,4L part, bearing in mind the desire not inhabit the vessel's loading flexibility.

(IACS UR S7.2)

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:

$$W_{min} = k \cdot c_0 \cdot \mathbf{L}^2 \cdot \mathbf{B}\,(\mathbf{C}_B + 0,7)\,10^{-6} \qquad [m^3]$$

c_0 according to Section 4, A.2.2 for unlimited service range.

(IACS UR S7.1)

3. Midship section moment of inertia

The net moment of inersia related to the horizontal axis refers to H.4.1.

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:

$$W_B = \frac{I_y}{e_B} \qquad [m^3]$$

$$W_D = \frac{I_y}{e_D} \qquad [m^3]$$

In general the section modulus of any point of the cross section has to be determined according to the following formula:

$$W = \frac{I_y}{e_z} \qquad [m^3]$$

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_z = vertical distance of the structural element considered from the horizontal neutral axis [m] (positive sign for above the neutral axis (e'_D), negative sign for below (e_D))

Continuous structural elements above e_D (e.g. longitudinal hatch coamings, 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.

$$e'_D = z \cdot \left(0,9 + 0,2 \cdot \frac{y}{\mathbf{B}}\right) \qquad [m]$$

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 $e'_D > e_D$

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. 5.9)

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. 5.9).

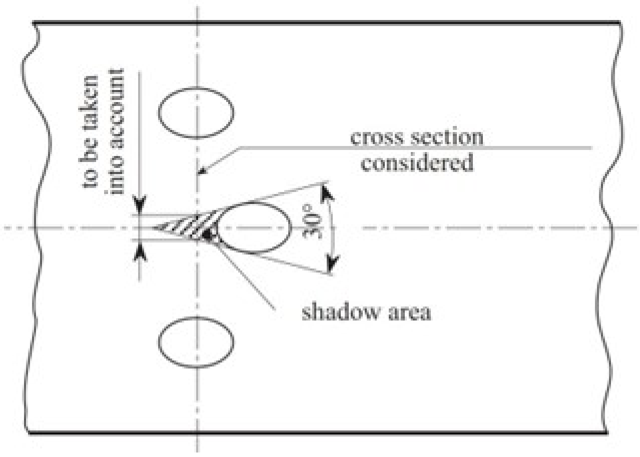


Figure 5.9: Shadow area

(IACS UR S5)

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

For the determination of section moduli the effectiveness of the longitudinal hatchway girders between the hatchways is to be determined by direct calculation.

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. Buckling assessment

In case of structural members contributing to the longitudinal strength and subjected to compressive stresses resulting from the total vertical bending moment M_T and/or subjected to shear forces resulting from the total vertical shear force Q_T are to be examined for sufficient resistance to buckling according to Section 3, F. For this purpose the following load combinations are to be investigated:

— M_T and 0,7 Q_T

— 0,7 · 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 net scantlings as defined under H.2.1.

8.2 Ultimate vertical bending moment

$$\left|\gamma_{SW}\,M_{SW} + \frac{\gamma_{WV}\cdot M_{WV}}{c_s}\right| \le \left|\frac{M_U}{\gamma_M \gamma_{DB}}\right|$$

The partial safety factors have to be set as follows:

γ_{SW} = Partial safety factor for the still water bending moment, to be taken as: γ_{SW} = 1,0

γ_{WV} = Partial safety factor for the vertical wave bending moment, to be taken as: γ_{WV} = 1,2

γ_M = Partial safety factor for the hull girder ultimate bending capacity, covering material, geometric and strength prediction uncertainties, to be taken as: γ_M = 1,05

γ_{DB} = Partial safety factor for the hull girder ultimate bending moment capacity, covering the effect of double bottom bending, to be taken as:

— For hogging condition: γ_{DB} = 1,15

— For sagging condition: γ_{DB} = 1,0

For cross sections where the double bottom breadth of the inner bottom is less than that at amidships or where the double bottom structure differs from that at amidships (e.g. engine room sections), the factor γ_{DB} for hogging condition may be reduced based upon agreement with BKI.

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

(IACS UR S11A.5.2 and IACS UR S11A.5.4)

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. 5.10.

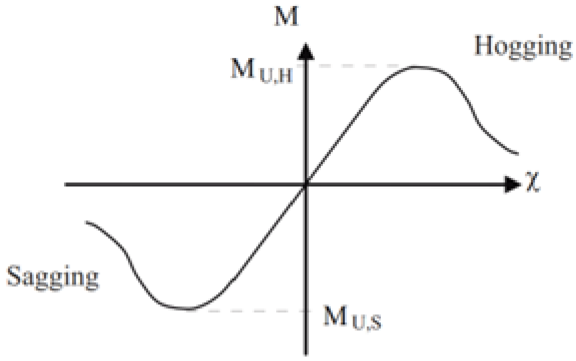


Figure 5.10: Moment-curvature curve

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, $\chi_j = \chi_{j\text{-}1} + \Delta_j$, 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 8.2.1). 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)).

z_i = z co-ordinate of ith structural element [m] relative to basis, see also Fig. 5.12

Step 5 For the value of curvature, χ_j = $\chi_{j\text{-}1} + \Delta\chi$, 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 ith 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. 5.11, where the subscript k refers to the modes 0, 1, 2, 3 or 4, as applicable.

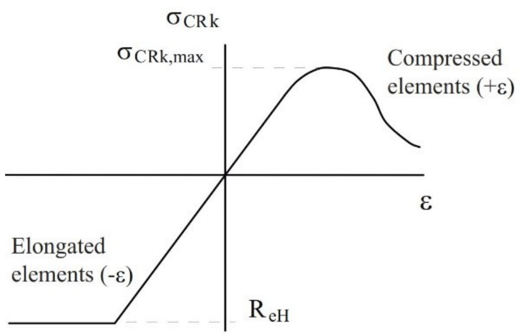


Figure 5.11: Typical average stress - average strain curve

.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:

$$\sigma_{CR0} = \Phi \cdot R_{eH} \quad [\text{N/m}^2]$$

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. 5.12.

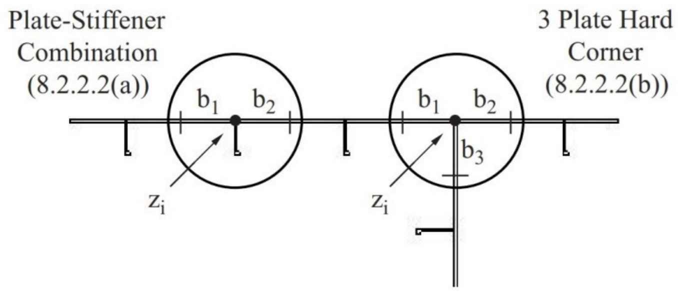


Figure 5.12: Structural elements

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 $0 \leq \varepsilon \leq 1$

= 1 for $\varepsilon > 1$

κ_{BC} = reduction factor

= 1 for $\lambda_K \leq 0,2$

= $\dfrac{1}{k_D + \sqrt{k_D^2 - \lambda_k^2}}$ for $\lambda_K > 0,2$

$$\lambda_K = \sqrt{\frac{\varepsilon_E \cdot a_2 \cdot A_x}{\varphi^2 \cdot I_x}} \cdot 10^{-4}$$

$$k_D = \left(1 + 0,21\,(\lambda_K - 0,2) + \lambda_K^2\right)/2$$

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 Rules for Hull (Pt.1, Vol.II) Section 3, F.5.1.6 or F.5.2.3.5, in general based on Load Case 1 of Rules for Hull (Pt.1, Vol.II) Table 3.12, where the reference degree of slenderness is to be defined as:

$$\lambda = \sqrt{\frac{\varepsilon_E}{0,9\left(\frac{t}{b}\right)^2 K}}$$

b_1, b_2 = breadths of single plate fields on sides 1 and 2 of stiffener [mm], see also Fig. 5.12

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 $\sigma_{CR2} - \varepsilon$

The positive strain portion of the average stress – average strain curve $\sigma_{CR2} - \varepsilon$ 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 Rules for Hull (Pt.1, Vol.II) Section 3, F.5.2.2.1

iii) Web/flange local buckling $\sigma_{CR3} - \varepsilon$

The positive strain portion of the average stress – average strain curve $\sigma_{CR3} - \varepsilon$ 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 Rules for Hull (Pt.1, Vol.II) Section 3, F.5.1.6 or F.5.2.3.5 (generally based on Load Case 3 of Rules for Hull (Pt.1, Vol.II) 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 ($\sigma_{CR4} - \varepsilon$).

i) Plate buckling $\sigma_{CR4} - \varepsilon$

$$\sigma_{CR4} = \Phi\, R_{eH} \frac{\sum_{i=1}^{n} b_{mj} \cdot t_i}{\sum_{i=1}^{n} b_i \cdot t_i} \quad [\mathrm{N/m^2}]$$

$b_{m,i}$ = effective breadths of single plate fields [mm] according to Rules for Hull (Pt.1, Vol.II) Section 3, F.5.1.6 or F.5.2.3.5, as applicable, in general based on applicable Load Cases in Rules for Hull (Pt.1, Vol.II) Table 3.12 and 3.13, where the reference degree of slenderness is to be defined as

$$\lambda = \sqrt{\frac{\varepsilon_E}{0,9\left(\frac{t}{b}\right)^2 K}}$$

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

$$\left| Q_{SW} + \frac{\gamma_{WV} . Q_{WV}}{C_s} \right| \leq \left| \frac{Q_U}{\gamma_R} \right|$$

c_S = stress factor according to 1.1

Q_U = ultimate vertical shear force of the ship's transverse section [kN]

$$= \frac{1}{1000 \cdot \sqrt{3}} \cdot \sum_{i=1}^{q} \kappa_{\tau i} \cdot b_i \cdot t_i \cdot R_{eH,i}$$

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 Rules for Hull (Pt.1, Vol.II) 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]

(IACS UR S11A.5.3 and IACS UR S11A Annex 3)

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 approved calculation prosedures (see B.1.1 and also Annex B).

If no complete hull analysis is carried out, the most unfavourable values of the stress combinations according to Table 5.5 are to be taken for σ_L and τ_L respectively. The formulae in Table 5.5 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

= $0,75 + \frac{x}{L}\left(1 - \frac{x}{L}\right)$ for fatigue strength calculations according to Section 20

f_Q = probability factor according to Table 5.2

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:

$$\sigma_L \leq \sigma_p$$

$$\tau_L \leq \frac{110}{k} \quad [N/mm^2]$$

$$\sigma_v = \sqrt{\sigma_L^2 + 3 \cdot \tau_L^2} \leq \frac{190}{k} \quad [N/mm^2]$$

Table 5.5: 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.3 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.3.4 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

$C_{Tor}, I_\omega, \omega_i, \lambda, e, a, \ell_c, C_c, x_A$ 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.3.6

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

= $\sqrt{\frac{I_T}{2,6 \cdot I_\omega}}$ [l/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]

= $0,5 \cdot L \cdot C_c$ for $\frac{L}{B} < 6$

= $\left(1,22 - 0,12 \cdot \frac{L}{B}\right) \cdot L \cdot C_c$ for $\frac{L}{B} \le 8,5$

= $0,2 \cdot L \cdot C_c$ for $\frac{L}{B} > 8,5$

However, $\ell_c \le L - X_A$

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 5.6 and Table 5.7

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} :

$$\tau_{SW} = \frac{Q_{SW} \cdot S_y(z)}{I_y \cdot t}(0,5 - \alpha) \qquad [\text{N/mm}^2]$$

dynamical from Q_{WV} :

$$\tau_{WV} = \frac{Q_{WV} \cdot S_y(z)}{I_y \cdot t}(0,5 - \alpha) \qquad [\text{N/mm}^2]$$

$S_y(z)$ = 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 = $0,16 + 0,08\,\frac{A_S}{A_L}$ for the longitudinal bulkheads

= $0,34 + 0,08\,\frac{A_S}{A_L}$ 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:

$$\tau_{ST} = 0,65 \cdot C_{Tor} \cdot M_{STmax} \cdot \frac{S_{\omega i}}{I_\omega \cdot t_i} \qquad [\text{N/mm}^2]$$

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}:

$$\tau_{WT} = C_{Tor} \cdot M_{WTmax} \cdot \frac{S_{\omega i}}{I_{\omega} \cdot t_i} \quad [N/mm^2]$$

The shear stresses τ_{ST} and τ_{WT} are related to the distributions of the torsional moments M_{ST} and M_{WT}.

For other distributions the shear stresses have to be determined by direct calculations.

3.4 Shear stress due to loads from transverse bulkheads stringers

Where stringers of transverse bulkheads are supported at longitudinal bulkheads or at the side shell, the supporting forces of these stringers are to be considered when determining the shear stress in the longitudinal bulkheads or side shell respectively. Likewise, where vertical girders of transverse bulkheads are supported at deck or inner bottom, the supporting forces of these vertical girders are to be considered when determining the shear stresses in the deck or inner bottom respectively.

The shear stress introduced by the stringer into the longitudinal bulkhead or side shell may be determined by the following formula:

$$\tau_{St} = \frac{P_{St}}{2 \cdot b_{St} \cdot t} \quad [N/mm^2]$$

P_{St} = supporting force [kN] of stringer or vertical girder

b_{St} = breadth [m] of stringer or depth of vertical girder including end bracket (if any) at the supporting point

M_{WTmax} = thickness of tank boundaries according to Section 12, B.2

The additional shear stress τSt is to be added to the shear stress τL due to longitudinal bending in the following area:

- 0.5 m on both sides of the stringer in the ship's longitudinal direction
- 0.25 x bSt above and below the stringer

Thereby the following requirement is to be satisfied:

$$\tau_{St} + \tau_L \leq \frac{110}{k} \quad [N/mm^2]$$

τ_L = shear stress due to longitudinal bending according to D.1

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.3.2 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.3.3

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.

2.2 Supporting forces at the bottom grillage

The supporting forces of the bottom grillage at the transverse bulkheads may be determined by direct calculation

3. Static torsional moments

3.1 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.

3.2 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.

3.3 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.3.6.

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 increase of the stress level due to torsion of the ship's hull is taken into account by the factor f_r, The factor is to be determined for the structural member at which the maximum normal stress due to static torsion occurs by the following formula:

$$f_r = \frac{\sigma_{L1}}{\sigma_{SW} + 0,75 \cdot \sigma_{WV}}$$

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 5.6.

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):

$t_1 = \sqrt{L}$ [mm] or $t_1 = 0,5\, t_0$ [mm]

$t_2 = 0{,}85$ [mm] or $t_2 = 12 \cdot a$ [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.

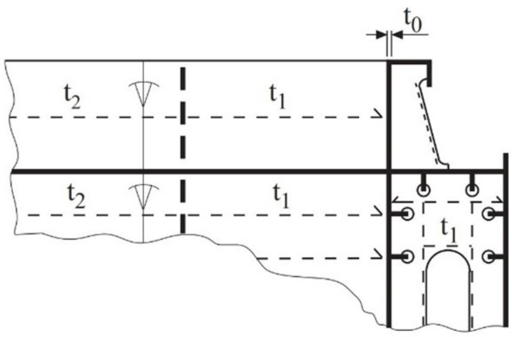
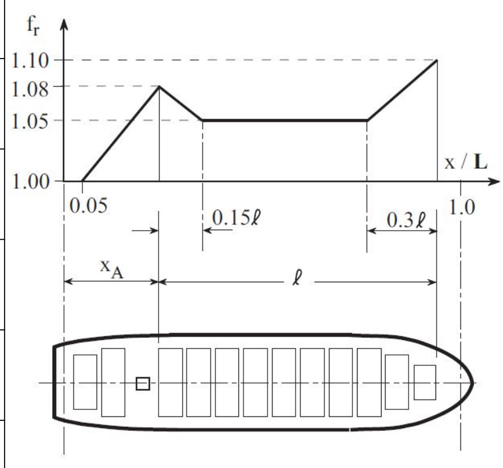


Figure 5.13: Plate thickness of the transverse box girder

Table 5.6: Correction factor f_r

Range	**Value**	**Distribution over the ship‘s length**
$\frac{x}{L} \leq 0,05$	1,00	
$0,05 < \frac{x}{L} \leq \frac{x_A}{L}$	$1,00 + 0,08 \cdot \frac{x - 0,05 \cdot L}{x_A - 0,05. \cdot L}$	
$\frac{x_A}{L} < \frac{x}{L} \leq \frac{x_A + 0,15 \cdot \ell}{L}$	$1,08 + 0,2 \cdot \frac{x_A - x}{\ell}$	
$\frac{x_A + 0,15 \cdot \ell}{L} < \frac{x}{L} \leq \frac{x_A + 0,70 \cdot \ell}{L}$	1,05	
$\frac{x_A + 0,70 \cdot \ell}{L} < \frac{x}{L} \leq \frac{x_A + \ell}{L}$	$1,10 + \frac{x - x_A - \ell}{6 \cdot \ell}$	
$\frac{x_A + \ell}{L} < \frac{x}{L}$	1,00	

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:

$$\Delta_u = 6 \cdot 10^{-5} \left(M_{STmax} + M_{WTmax}\right) \cdot \left(1 - \frac{L}{450}\right) \cdot \left[4 + 0,1 \left(\frac{L}{B}\right)^2\right] \cdot c_u + 20 \qquad [mm]$$

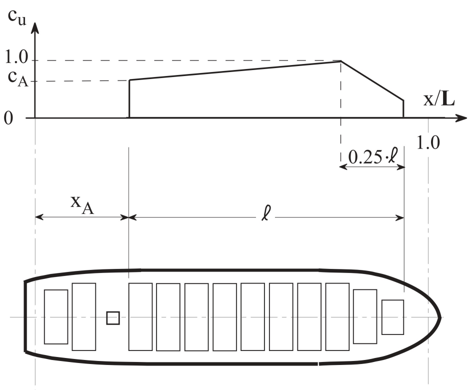
M_{STmax}, M_{WTmax} according to B.2.2.2 or B.3.6, respectively

c_u	=	distribution factor according to Table 5.7
c_A	=	value for cu at the aft part of the open region, see also Table 5.7

$$= \left(1,25 - \frac{\mathbf{L}}{400}\right) \cdot \left(1,6 - \frac{3 \cdot x_A}{\mathbf{L}}\right) \leq 1,0$$

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 5.7: 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	

G. Global Strength Analysis

1. General

1.1 The Global Strength Analysis by means of Finite Element (FE) Analysis with an entire model allows verification of complex structures under a more refined approach, which ensures identification of highly stressed structural members or details and facilitates further optimisation of structural design and material utilisation. Global strength analysis is required for ships with one or more of the following characteristics:

- Novel design
- Complex structural arrangement
- rule length **L** ≥ 290 m
- breadth **B** ≥ 47 m
- v_0 ≥ 25 kn
- Hatch coaming built of steel with yield strength of 460 N/mm^2

1.2 Detailed guidance for global strength analysis of container ships using a finite element model of the entire vessel is provided in the Annex B. The focus of a global FE analysis is on global stress and deformation under particular consideration of torsional response which is significant due to large hatch openings. Such an analysis is mandatory for all container ships of novel design, exceptional size, or complex structural arrangement.

1.3 The objective of the global strength analysis is to obtain a reliable description of the overall hull girder stiffness and to calculate and assess the global stresses and deformations of all primary hull members for specified load cases resulting from realistic loading conditions and the wave-induced forces and moments.

H. Longitudinal Strength Check

1. Longitudinal extent

The stiffness, yield strength, buckling strength and hull girder ultimate strength assessment are to be carried out in way of 0,2**L** to 0,75**L** with due consideration given to locations where there are significant changes in hull cross-section, e.g. changing of framing system and the fore and aft end of the forward bridge block in case of two-island designs.

In addition, strength assessments are to be carried out outside this area. As a minimum assessments are to be carried out at forward end of the foremost cargo hold and the aft end of the aft most cargo hold.

(IACS UR S11A.1.1.3)

2. Corrosion margin and net-thickness

2.1 Net scantling definitions

2.1.1 The strength is to be assessed using the net thickness approach on all scantlings.

2.1.2 The net thickness, tnet, for the plates, webs and flanges is obtained by subtracting the voluntary addition t_{vol_add} and the factored corrosion addition t_c from the as built thickness $t_{as-built}$, as follows:

$$t_{net} = t_{as-built} - t_{vol\_add} - \alpha t_c$$

where α is a corrosion addition factor whose values are defined in Table 5.8.

The voluntary addition, if being used, is to be clearly indicated on the drawings.

Table 5.8: Values of corrosion addition factor

Structural requirement	Property / analysis type	α
Strength assessment (see 3)	Section properties	0,5
Buckling strength (see C.7)	Section properties (stress determination)	0,5
	Buckling capacity	1,0
Hull girder ultimate strength (see 4)	Section properties	0,5
	Buckling / collapse capacity	0,5

2.2 Determination of corrosion addition

2.2.1 The corrosion addition for each of the two sides of a structural member, t_{c1} or t_{c2} is specified in Table 5.9. The total corrosion addition, t_c [mm] for both sides of the structural member is obtained by the following formula:

$$t_c = (t_{c1} + t_{c2}) + t_{res}$$

where t_{res} is the reserve thickness, which is to be taken as 0,5 mm.

Table 5.9: Corrosion addition for one side of a structural member

Compartment type	One side corrosion addition t_{c1} or t_{c2} [mm]
Exposed to sea water	1,0
Exposed to atmosphere	1,0
Ballast water tank	1,0
Void and dry spaces	0,5
Fresh water, fuel oil and	0,5
Accommodation spaces	0,0
Container holds	1,0
Compartment types not mentioned above	0,5

For an internal member within a given compartment, the total corrosion addition, t_c is obtained from the following formula:

$t_c = (2t_{c1}) + t_{res}$

The corrosion addition of a stiffener is to be determined according to the location of its connection to the attached plating.

2.2.2 The net section modulus, moment of inertia and shear area properties of a supporting member are to be calculated using the net thickness of the attached plate, web and flange, as defined in Fig. 5.14. The net cross-sectional area, the moment of inertia about the axis parallel to the attached plate and the associated neutral axis position are to be determined through applying a corrosion magnitude of 0,5 αt_c deducted from the surface of the profile cross-section.

3. Loads

3.1 Load Cases

Still water bending moments, M_{SW} [kNm], and still water shear forces, Q_{SW} [kN], are to be calculated at each section along the ship length for design loading conditions as specified in B.

For the strength assessment, the maximum hogging and sagging load cases given in Table 5.10 are to be checked. For each load case the still water condition at each section as defined in B.2 is to be combined with the wave condition as defined in B.3, refer also to Fig. 5.15.

Table 5.10: Combination of still water and wave bending moments and shear forces

Load case	**Bending Moment**		**Shear force**	
	M_{SW}	M_{WV}	Q_{SW}	Q_{WV}
Hogging	M_{SWmax}	M_{WH}	Q_{SWmax} for x < 0,5L	Q_{WVmax} for x < 0,5L
			Q_{SWmin} for x > 0,5L	Q_{WVmin} for x > 0,5L
Sagging	M_{SWmin}	M_{WV}	Q_{SWmin} for x < 0,5L	Q_{WVmin} for x < 0,5L
			Q_{SWmax} for x > 0,5L	Q_{WVmax} for x > 0,5L

M_{WH} : Wave bending moment in hogging at the cross section under consideration, to be taken as the positive value of M_{WV} as defined in Fig. 5.4.

M_{WVS} : Wave bending moment in sagging at the cross section under consideration, to be taken as the negative value of M_{WV} as defined in Fig. 5.4.

Q_{WVmax} : Maximum value of the wave shear force at the cross section under consideration, to be taken as the positive value of Q_{WV} as defined in Fig. 5.5

Q_{WVmin} : Maximum value of the wave shear force at the cross section under consideration, to be taken as the negative value of Q_{WV} as defined in Fig. 5.5

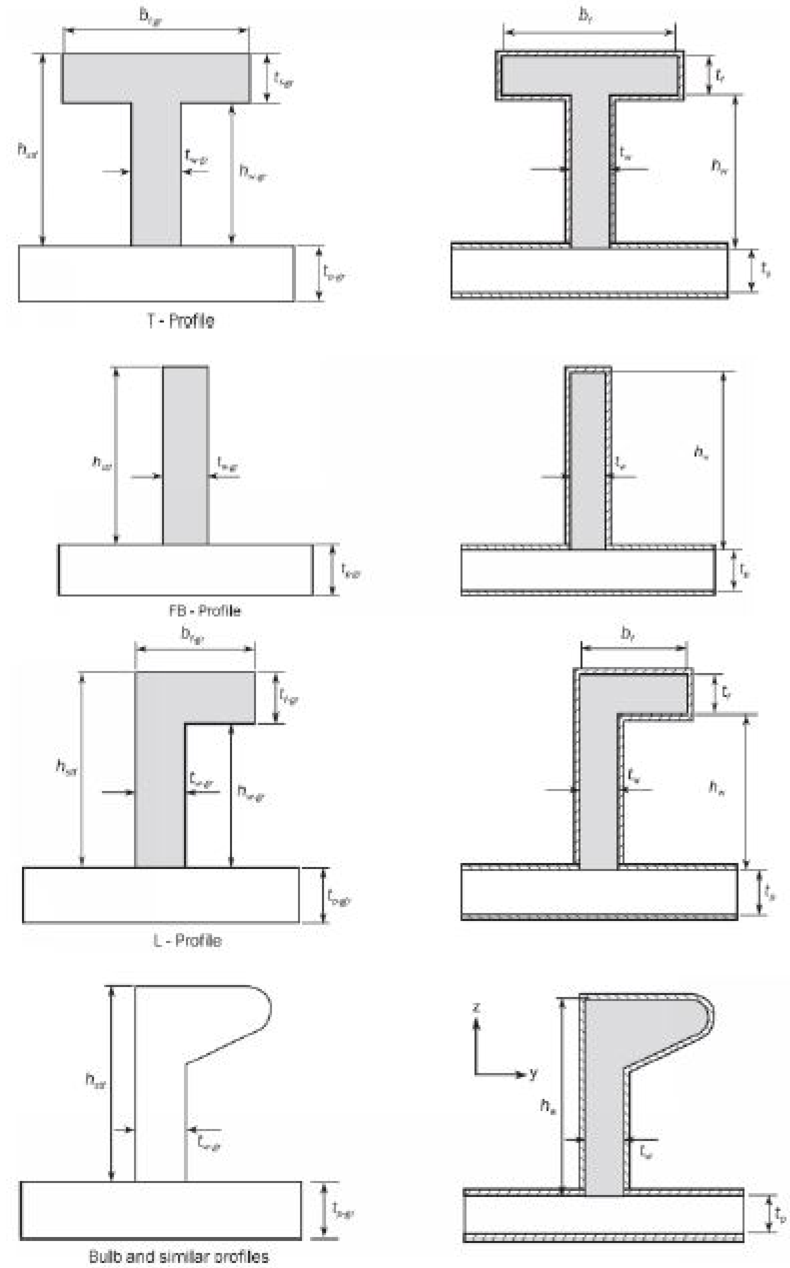


Figure 5.14: Net sectional properties of supporting members

(IACS UR S11A.1.3)

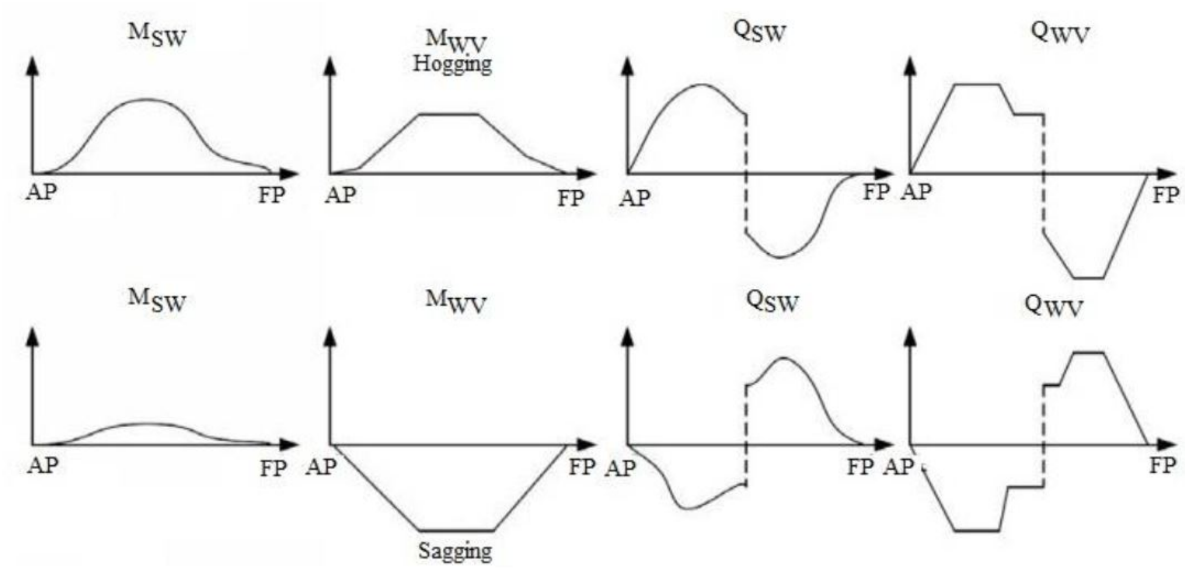


Figure 5.15: Load combination to determine the maximum hogging and sagging load cases as given in Table 5.10

(IACS UR S11A.2.4)

3.2 Hull girder stress

The hull girder stresses are to be determined at the load calculation point under consideration, for the "hogging" and "sagging" load cases defined in 3.1 as follows:

Bending stress:

$$\sigma_{HG} = \frac{\gamma_{SW} M_{SW} + \gamma_{WV} M_{WV}}{I_{net}} (e_Z)\, 10^{-3} \qquad [N/mm^2]$$

Shear stress:

$$\tau_{HG} = \frac{\gamma_{SW} Q_{SW} + \gamma_{WV} Q_{WV}}{t_{net/q_v}} 10^3 \qquad [N/mm^2]$$

where:

γ_{SW}, γ_{WV} : Partial safety factors, to be taken as:

γ_{SW} = 1,0

γ_{WV} = 1,0

(IACS UR S11A.2.5)

4. Strength Assessment

The stiffness, yield strength, buckling strength and hull girder ultimate strength assessment are to be carried out in way of 0,2**L** to 0,75**L** with due consideration given to locations where there are significant changes in hull cross section, e.g. changing of framing system and the fore and aft end of the forward bridge block in case of two-island designs. In addition, strength assessments are to be carried out outside this area. As a minimum assessments are to be carried out at forward end of the foremost cargo hold and the aft end of the aft most cargo hold.

(IACS UR S11A.1.1.3)

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 S11A.3.1)

4.1 Stiffness criterion

The two load cases “hogging” and “sagging” as listed in 3.1 are to be checked.

The net moment of inertia, is not to be less than:

$$I_{net} \geq 1{,}55\mathbf{L}\,|M_{SW} + M_{WV}|\,10^{-7} \quad [m^4]$$

(IACS UR S11A.3.2)

4.2 Yield strength assessment

4.2.1 The yield strength assessment is to check, for each of the load cases “hogging” and “sagging” as defined in 3.1, that the equivalent hull girder stress, σ_{eq} is less than the permissible stress σ_{perm} as follows:

$$\sigma_{eq} < \sigma_{perm} \quad [N/mm^2]$$

where:

$$\sigma_{eq} = \sqrt{\sigma_x^2 + 3 \cdot \tau^2}$$

$$\sigma_{perm} = \frac{R_{eH}}{\gamma_1 \gamma_2}$$

γ_1 = partial safety factor for material, to be taken as: $\gamma_1 = k\frac{R_{eH}}{235}$

γ_2 = partial safety factor for load combinations and permissible stress, to be taken as:

for bending strength assessment according to 4.2.2
γ_2 = 1,74 for x/L ≤ 0,7
γ_2 = 1,24 for 0,3 ≤ x/L ≤ 0,7
γ_2 = 1,74 for x/L ≥ 0,9
Intermediate values ⍰2 shall be obtained by linear interpolation.
for shear stress assessment according to 4.2.3
γ_2 = 1,13

For the ranges outside 0,4**L** the partial safety factor γ_2 for bending strength assessment can be decreased to γ_2 = 1,24, if the class notation **RSD (gFE)** in accordance with Annex B has been applied.

(IACS UR S11A.3.3.1)

4.2.2 The assessment of the bending stresses is to be carried out according to 4.2.1 at the following locations of the cross section:

- At bottom
- At deck
- At top of hatch coaming
- At any point where there is a change of steel yield strength

The following combination of hull girder stress as defined in 3.2 is to be considered:

$$\sigma_x = \sigma_{HG}$$

$$\tau = 0$$

(IACS UR S11A.3.3.2)

4.2.3 The assessment of shear stress is to be carried out according to 4.2.1 for all structural elements that contribute to the shear strength capability.

The following combination of hull girder stress as defined in 3.2 is to be considered:

$$\sigma_x = 0$$

$$\tau = \tau_{HG}$$

(IACS UR S11A.3.3.3)

5. Ultimate hull girder strength assessment

5.1 General

The hull girder ultimate strength is to be assessed for ships with length **L** equal or greater than 150 m.

The ultimate hull girder strength has to be assessed following the requirements in C.8.2.

(IACS UR S11A.5)

5.2 Assessments for ships with B > 32,26 m

For ships with B > 32,26 m the contribution of whipping to the vertical bending moment has to be considered by modification of the equation given under C.8.2 as follows:

$$\gamma_{SW} M_{SW} + M_{WV} \left(\gamma_{WV} + (\gamma_{WH} - \gamma_{WV})\, \gamma_{dU}\right) \leq \frac{M_U}{\gamma_M \gamma_{DB}}$$

where:

γ_{DB} = partial safety factor for the double bottom bending effect, to be taken as 1,1 in hogging and 1,0 in sagging condition. For reduction of γ_{DB} towards the ship end's refer to C.8.2

γ_{dU} = partial safety factor reducing the effectiveness of whipping during collapse (dynamic collapse effect), to be taken as 0,9, unless analysed for a specific ship

γ_{WH} = partial safety factor for the additional whipping contribution. In general, γ_{WH} is to be determined as follows:

$$= 1 + c_L \left[3,8 \cdot 10^{-7} (L + 1100)(v + 4,1)^2 \left(\tan \frac{\varphi}{180} \alpha - 0,19\right)\right] \geq 1,3$$

For ships with class notation **HRS**, γ_{WH} is to be determined as follows:

$$\gamma_{WH}^{HRS} = 1 + 0,7 \cdot (\gamma_{WH} - 1) \geq \gamma_{WV}$$

where:

α = bow flare angle, in degrees, between a vertical line and a tangential plane of side plating, measured at 0,05**L** aft of FP and between still water line at scantling draft and upper deck

$$= \arctan \frac{\alpha_1 + \alpha_2}{h_d}$$ with α_1, α_2, and h_d according to Fig. 5.16

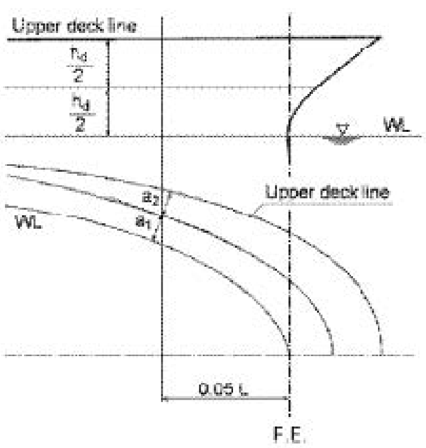


Figure 5.16: Determination of bow flare angle α

c_L = distribution factor to be taken as:
1,0 for $x/L \le 0{,}5$
$\sin(\pi\, x/L)$ for $x/L > 0{,}5$

v = contract speed [knots], at design draft and with 85% MCR and 15% sea margin

If the contract speed, v_d, is specified at another x% MCR and y% sea margin, it can be converted by the following formula:

$$v = 0{,}904 \cdot v_d \left(\frac{1 + y/100}{x/100}\right)^{1/3}$$

All other partial safety factors are to be taken according to C.8.2.

(IACS UR S11A.6.1)

Recommendation :

rule length L > 290 m

*breadth **B** > 47 m*

bow flare angle α > 55°

vessel contract speed v > 25 knots

an advanced assessment using methods based on direct hydrodynamic analysis including whipping and springing or model tests is recommended. This is also recommended for container ships with block coefficient C_B outside the range 0,6 to 0,7 or with vessel contract speed v of less than 20 knot.

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Section 6 Shell Plating

A. General, Definitions

1. General

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]

$= \dfrac{230}{k}$ [N/mm^2]

t_K = corrosion addition according to Section 3, K

B. Bottom Plating

1. Plate thickness based on load stress criteria

The thickness of the bottom plating is not to be less than the greater of the two following values:

$$t_{B1} = 18,3 \cdot n_f \cdot \mathbf{a} \cdot \sqrt{\frac{p_B}{\sigma_{p\ell}}} + t_k \quad \text{[mm]}$$

$$t_{B2} = 1,21 \cdot \mathbf{a} \sqrt{p_B \cdot k} + t_k \quad \text{[mm]}$$

$$\sigma_{P\ell} = \sqrt{\sigma_{perm}^2 - 3 \cdot \tau_L^2} - 0,89 \cdot \sigma_{LB} \quad \text{[N/mm}^2\text{]}$$

Note:
As a first approximation σ_{LB} and τ_L may be taken as follows:.

$$\sigma_{LB} = \frac{12,6\sqrt{\mathbf{L}}}{k} \quad \text{[N/mm}^2\text{]} \quad \text{for } \mathbf{L} < 90 \text{ m}$$

$$= \frac{120}{k} \quad \text{[N/mm}^2\text{]} \quad \text{for } \mathbf{L} \geq 90 \text{ m}$$

$$\tau_L = 0$$

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 $\sigma_{LB} \leq 0,6 \cdot R_{eH}$:

$$t_{crit} = c \cdot 2,23 \cdot \mathbf{a}\sqrt{\sigma_{LB}} + t_k \quad \text{[mm]}$$

for $\sigma_{LB} > 0,6 \cdot R_{eH}$:

$$t_{crit} = c \cdot 1,57 \cdot \mathbf{a}\frac{\sqrt{R_{eH}}}{1,474 - \frac{\sigma_{LB}}{R_{eH}}} + t_k \quad \text{[mm]}$$

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 Rules for Hull (Pt.1, Vol.II) Section 3, F.5.1.6)

σ_{LB} = largest compressive stress in the bottom due to longitudinal hull girder bending

F_{tran} = see Rules for Hull (Pt.1, Vol.II) Section 3, F.5.2.2.3)

= 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:

$$t_{min} = (1,5 - 0,01 \cdot \mathbf{L})\sqrt{\mathbf{L} \cdot k} \quad \text{[mm] for } \mathbf{L} < 50 \text{ m}$$

$$= \sqrt{\mathbf{L} \cdot k} \quad \text{[mm] for } \mathbf{L} \geq 50 \text{ m}$$

$$t_{max} = 16 \text{ mm in general}$$

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:

$$b = 800 + 5 \cdot \mathbf{L} \quad [\text{mm}]$$

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]

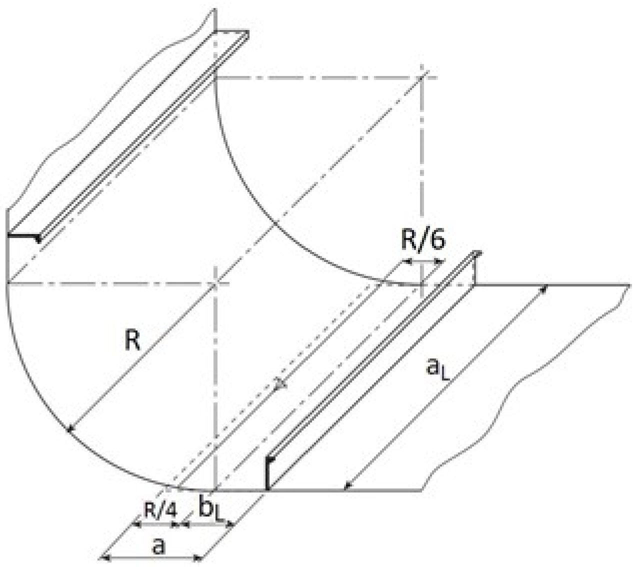

Figure 6.1: Bilge strake

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.

5. Flat plate keel and garboard strake

5.1 The width of the flat plate keel is not to be less than:

$$b = 800 + 5 \cdot \mathbf{L} \quad [mm]$$

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 Where 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 centreline. The sectional area of one longitudinal stiffener should not be less than 0,2**L** [cm^2].

C. Side Shell Plating

1. Plate thickness based on load stress criteria

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

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:

$$b = 800 + 5 \cdot \mathbf{L} \quad [mm]$$

$$b_{max} = 1800 \quad [mm]$$

3.2 The thickness of the sheer strake shall, in general, not be less than the greater of the following two values:

$$t = 0{,}5\,(t_D + t_S) \quad [mm]$$

$$= t_S \quad [mm]$$

t_D = required thickness of strength deck

t_S = required thickness of side shell

3.3 Welds on upper edge of sheer strake are subject to special approval.

Regarding welding between sheer strake and deck stringer see Section 7, B.2.

Holes for scuppers and other openings are to be carefully rounded, any notches shall be avoided.

4. Strengthenings for harbour and tug manoeuvres

4.1 In those zones of the side shell which may be exposed to concentrated loads due to harbour manoeuvres the plate thickness is not to be less than required by 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.

4.2 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.

4.3 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]

4.4 Tween decks, transverse bulkheads, stringer and transverse walls are to be investigated for sufficient buckling strength against loads acting in the ship's transverse direction. For scantlings of side transverses supporting side longitudinals see Section 9, B.5.4.

D. 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 90 ≤ **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:

$$t = 0,9 \cdot f_2 \cdot \mathbf{a}\sqrt{p_{SL} \cdot k} + t_K \quad [mm]$$

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:

$$W = 0,155 \cdot p_{SL} \cdot \mathbf{a} \cdot \ell^2 \cdot k \quad [cm^3]$$

3.2 The shear area of the stiffeners is not to be less than:

$$A = 0,028 \cdot p_{SL} \cdot \mathbf{a}(\ell - 0,5 \cdot \mathbf{a})\, k \quad [cm^2]$$

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 12, A.8). For vessels with a single propeller, plate fields and stiffeners should fulfill the following frequency criteria. To fulfill 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:*

= $\frac{P}{\Delta}$

P = *nominal main engine output [kW]*

= *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* $\frac{r}{d_p} \geq 1,0$

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]*

= $\frac{1}{60} \cdot n \cdot z$ [Hz]

n = *maximum propeller shaft revolution rate [1/min]*

z = *number of propeller blades*

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.

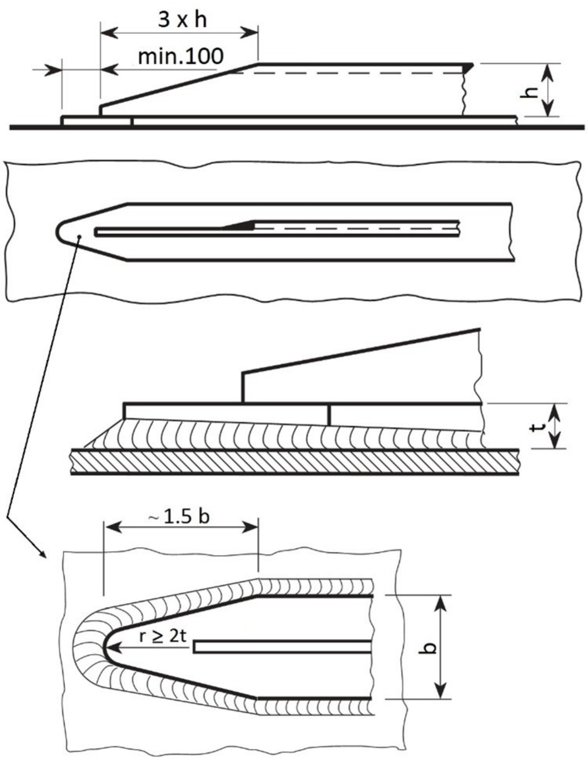

Figure 6.2: Soft transition zones at the ends of bilge keels

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. 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. Bulwarks

1. The thickness of bulwark plating is not to be less than :

$$t = 0,65\sqrt{\mathbf{L}} \quad \text{[mm]}$$

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 vertical bulwark height or height of guard rail is not to be less than 1,0 m.

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. 6.3, 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.

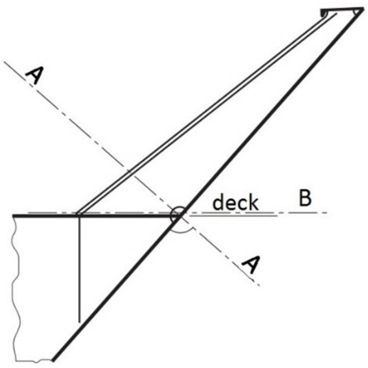

Figure 6.3: Bulwark stay

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.

6. For the connection of bulwarks with the sheer strake C.3.3 is to be observed.

7. Bulwarks are to be provided with freeing ports of sufficient size. See also Section 21, D.2 and **ICLL**.

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Section 7 Decks

A. General

1. Definitions

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.2

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

B. Strength Deck

1. General, Definition

1.1 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**,

1.2 For ships with a speed v_0 > 1,6 $\sqrt{\mathbf{L}}$ [kn], additional strengthening of the strength deck and the sheerstrake may be required

2. Connection between strength deck and sheer strake

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.

3. Openings in the strength deck

3.1 General

3.1.1 All openings in the strength deck are to have well rounded corners circular openings are to be edge-reinforced.

The sectional area 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.

3.1.2 The hatchway corners are to be surrounded by strengthened plates which are to extend over at least one frame spacing fore-and-aft and athwartships. Within 0,5**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.

3.2 Cargo hatchway corners

3.2.1 For cargo hatchways the 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. 7.1.
	=	$0{,}4 \cdot b_Q$	for hatchway corners at cross deck strips between hatchways adjacent to a closed deck area, see HC2 in Fig. 7.1.
	=	$\left(f_D + \frac{\ell}{750}\right) \cdot \sqrt{\frac{b_L^2 \cdot b_Q^2}{b_L^2 + b_Q^2}}$	for hatchway corners adjacent to a cross deck strip, see HC3 in Fig. 7.1.
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:

$$= \frac{|M_T(z_D - z_0)|}{I_y \cdot 175 \cdot 10^3 \cdot c_s} \cdot \frac{t_D}{t_i} \cdot \sqrt[4]{k_i}$$

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.3 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.3 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

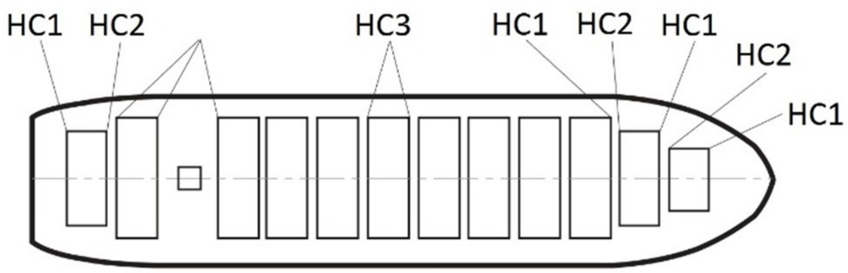

Figure 7.1: Positions of hatch corners

3.2.2 Where required by above calculation or on the basis of direct fatigue assessment hatchway corners are to be surrounded by strengthened plates, i.e. insert plates, which extend minimum distances a and b from hatch edges (see Fig. 7.2), where

a = 3 $(t_i - t) + 300$ [mm]

a_{min} = 350 mm

b = $r + 3 (t_i - t) + 125$ [mm]

3.2.3 Openings in way of hatchway corners are not to be located within the following minimum distances (see Fig. 7.2)

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 3.2.1

t = thickness [mm] of the deck plate

r = radius of the hatchway corner according to 3.2.1

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.

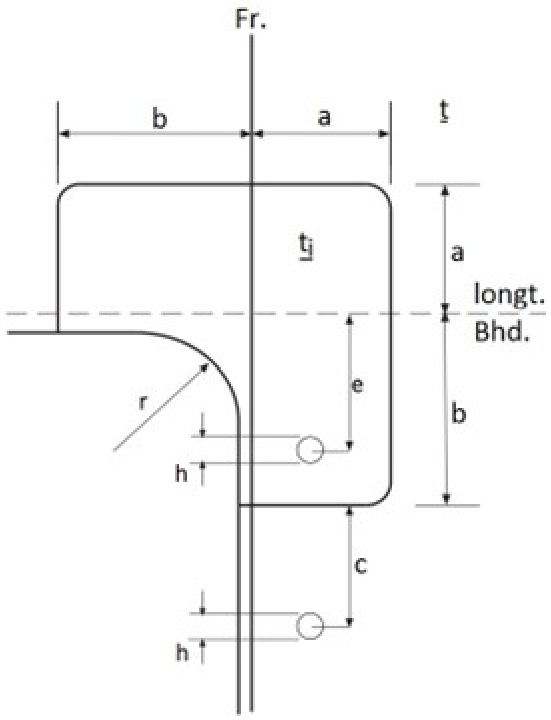

Figure 7.2: Strengthening of hatchway corners

3.3 Stresses due to lateral loads

$$\sigma_Q = \frac{M_Q}{W_1 \cdot 10^3} \quad [\mathrm{N/mm^2}]$$

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 [m^3] 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:

$$\sigma_Q = \frac{\left(\frac{T^3}{H} + 0,25 \cdot H \cdot p_0\right) \cdot \ell_L^2}{7,2.W_1 \cdot 10^3} \quad [N/mm^2]$$

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. Scantling

4.1 Ships with proven longitudinal strength

4.1.1 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.

4.1.2 Critical plate thickness, buckling strength

4.1.2.1 The critical plate thickness is to be determined according to Section 6, B.2 analogously.

4.1.2.2 Reductions from the critical plate thickness on account of restricted service are not admissible.

4.1.2.3 In regard to buckling strength the requirements of Section 6, B.2.2 apply analogously.

4.2 Minimum thickness

4.2.1 Within 0,4L amidships outside line of hatchways

4.2.1.1 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:

$$t_{min} = (4,5 + 0,05 \cdot L) \cdot \sqrt{k} \quad [mm]$$

or

t_E = according to 7.1,

L need not be taken greater than 200 m.

4.2.1.2 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.

4.2.2 Thickness at ship's ends and between hatchways

4.2.2.1 The thickness of strength deck plating for 0,1**L** from the ends and between hatchways is not to be less than:

$t_{E1} = 1,21 \cdot \mathbf{a}\sqrt{p_D \cdot k} + t_K$ [mm]

$t_{E2} = 1,1 \cdot \mathbf{a}\sqrt{p_L \cdot k} + t_K$ [mm]

$t_{Emin} = (5,5 + 0,02 \cdot \mathbf{L})\sqrt{k}$ [mm]

L need not be taken greater than 200 m.

4.2.2.2 Between the amidships thickness and the end thickness, the thicknesses are to be tapered gradually.

C. Other Decks

1. Decks for cargo loads

1.1 The plate thickness is not to be less than:

$t = 1,21 \cdot \mathbf{a}\sqrt{p_D \cdot k} + t_K$ [mm]

$t_{min} = (5,5 + 0,02 \cdot \mathbf{L})\sqrt{k}$ [mm] for the 2^{nd} deck

$= 6,0$ mm for other lower decks

L need not be taken greater than 200 m.

1.2 For the critical deck thickness see B.4.1.2.

2. 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:

$t = 1,11 \cdot \mathbf{a}\sqrt{p \cdot k} + t_K$ [mm]

$t_{min} = 5,0$ mm

2.1 At the corners of the engine room casings, strengthenings according to B.3.1.2 may also be required depending on the position and the dimensions of the casing.

Section 8 Bottom Structures

A. General

1. Reference

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

SOLAS II-1, 9.1- 9.4

ICLL Annex 1, Ch. IV, Reg. 43 (3)

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

1.2 For bottom strengthening forward see Section 6, E.

2. Definitions

a	=	spacing [m] of stiffeners
k	=	material factor according to Section 2, B
t_K	=	corrosion addition according to Section 3, K
p_0	=	basic external dynamic load for wave directions with or against the ship's heading according to Section 4, A.2.2
p_{01}	=	basic external dynamic load for wave directions transverse to the ship's heading according to Section 4, A.2.2
p_B	=	load on the ship's bottom according to Section 4, B.3
p_1	=	loads on filled tanks according to Section 4, D.1
P_L	=	load on inner bottom according to Section Section 4, C.1
σ_ℓ	=	bending stress [N/mm^2] in longitudinal girders
σ_L	=	design hull girder bending stress according to Section 5, D.1 (hogging or sagging, whichever condition is examined).
σ_q	=	bending stress [N/mm^2] in transverse girders
τ	=	shear stress [N/mm^2]

B. Single Bottom

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 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 C.6.2.1.

The floor plate height in the fore peak above top of keel or stem shoe is not to be less than:

$$h = 0{,}06 \cdot \mathbf{H} + 0{,}7 \quad [m]$$

The floor plates in the after peak are to extend over the stern tube (see also Section 13, C.1.4).

Particularly in case of flat bottoms additional longitudinal stiffeners are to be fitted above or forward of the propeller.

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:

$$t_w = 0{,}04 \cdot \mathbf{L} + 5 \quad [mm]$$

$$A_f = 0{,}2 \cdot \mathbf{L} + 6 \quad [cm^2]$$

Towards the ends, the thickness of the web plate and the sectional area of the face plate may be reduced by 10%.

C. Double Bottom

1. General

1.1 The arrangement of double bottom has to comply with Chapter II-1 of SOLAS as amended.

1.2 A double bottom is to be fitted extending from the collision bulkhead to the after-peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

(SOLAS II-1, 9.1)

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 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)

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.

B((ICLL Annex 1, Ch. IV, Reg. 43 (3))

1.7 For the material factor k see Section 2, B. For the corrosion addition t_K see Section 3, K.

1.8 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.

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:

$$h = 350 + 45 \cdot \ell \quad [mm]$$

$$h_{min} = 600 \text{ mm}$$

ℓ = unsupported span of floor plate [m]

ℓ = **B** In general

However, $\ell \geq 0{,}8$**B** in case of additional longitudinal bulkheads, the unsupported span can be shortened accordingly.

2.2.2 The thickness of the centre girder is not to be less than:

$$t_m = \frac{h}{h_a}\left(\frac{h}{120} + 3{,}0\right)\sqrt{k} \quad [mm]$$

h = depth of the center girder according to 2.2.1

h_a = depth of centre girder as built [mm]

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**. 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:

$$t_m = \frac{h^2}{120 \cdot h_a}\sqrt{k} \quad [mm]$$

h = depth of the centre girder [mm] according to 2.2.1

h_a = as built depth of side girders [mm], h_a need not be taken less than h to calculate t

For strengthenings under the engine seating, see D.2.1.

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 = according to Section 4, D.1.1

p_2 = according to Section 4, D.1.2

p_L = according to Section 4, C.1.1

4.2 For strengthening of inner bottom in machinery spaces, see D.2.3.

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 The thickness of structures is not to be less than the minimum thickness according to Section 12, A.7.

5.2.6 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.2.1, 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 Rules for Machinery Installations (Pt.1, Vol.III) Sec.11. Bilge wells are to be separated from the shell.

5.4 Sea chests

5.4.1 The plate thickness of sea chests is not to be less than:

$$t = 12 \cdot \mathbf{a}\sqrt{p \cdot k} + t_k \quad [mm]$$

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.

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

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 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.

6.2.4 For strengthening of floors in machinery spaces, see D.2.1.

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:

$$W = n \cdot c \cdot \mathbf{a} \cdot \ell^2 \cdot p \cdot k \quad [cm^3]$$

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_1 or p_2 according to Section 4, D.1

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:

$$P = 0{,}5 \cdot p \cdot \mathbf{a} \cdot \ell \quad [kN]$$

p = load according to 6.4.3

ℓ = unsupported span according to 6.4.3

7. Double bottom, longitudinal framing system

7.1 Bottom and inner bottom longitudinals

7.1.1 The section moduli are to be calculated according to Section 9, B.

7.1.2 Where bottom and inner bottom longitudinals are coupled by struts in the centre of their unsupported span ℓ their section moduli may be reduced to 60 % of the values required by Section 9, B. The scantlings of the struts are be determined in accordance with 6.6.

7.2 Plate floors

7.2.1 The floor spacing shall, in general, not exceed 5 times the mean longitudinal frame spacing.

7.2.2 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.

7.2.3 Regarding floors in way of the strengthening of the bottom forward, Section 6, E is to be observed.

7.2.4 The scantlings of floors are to be determined according to 6.2.

7.2.5 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.

7.3 Brackets

7.3.1 Where the ship's sides are framed transversely flanged brackets having a thickness of the floors are to be fitted between the plate floors at every transverse frame, extending to the outer longitudinals at the bottom and inner bottom.

7.3.2 One bracket is to be fitted at each side of the centre girder between the plate floors where the plate floors are spaced not more than 2,5 m apart. Where the floor spacing is greater, two brackets are should be fitted.

8. Direct calculation of bottom structures

Direct calculations of bottom structures are covered by the cargo hold analysis to be carried out according to Section 26.

D. Bottom Structure in Machinery Spaces in Way of the Main Propulsion Plant

1. General

1.1 Openings in way of the engine foundation are to be kept as small as possible with due regard, however, to accessibility. Where necessary, the edges of openings are to be strengthened by means of face bars or the plate panels are to be stiffened.

1.2 Local strengthenings are to be provided beside the following minimum requirements, according to the construction, the local conditions and the main engine maker requirements.

2. Double bottom

2.1 Plate floors

Plate floors are to be fitted at every frame. The floor thickness according to C.6.2.1 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.

2.2 Side girders

2.2.1 The thickness of side girders under an engine foundation top plate inserted into the inner bottom is to be equal to the thickness of side girders above the inner bottom according to 3.2.1.

2.2.2 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.

2.2.3 Side girders under foundation girders are to be extended into the adjacent spaces and to be connected to the bottom structure. This extension abaft and forward of the engine room bulkheads shall be two to four frame spacings if practicable.

2.2.4 No centre girder is required in way of the engine seating.

2.3 Inner bottom

Between the foundation girders, the thickness of the inner bottom plating required according to C.4.1 is to be increased by 2,0 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:

$$t = \frac{P}{750} + 14 \quad [mm] \quad \text{for} \quad P < 7500 \text{ kW}$$

$$t = \frac{P}{1875} + 20 \quad [mm] \quad \text{for} \quad P \geq 7500 \text{ kW}$$

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:

$$A_T = \frac{P}{75} + 70 \quad [cm^2]$$

Where twin engines are fitted, a continuous top plate is to be arranged in general if the engines are coupled to one propeller shaft.

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).

E. 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:

$$t = \sqrt{L \cdot k} + 5,0 \quad [mm]$$

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. 8.1 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

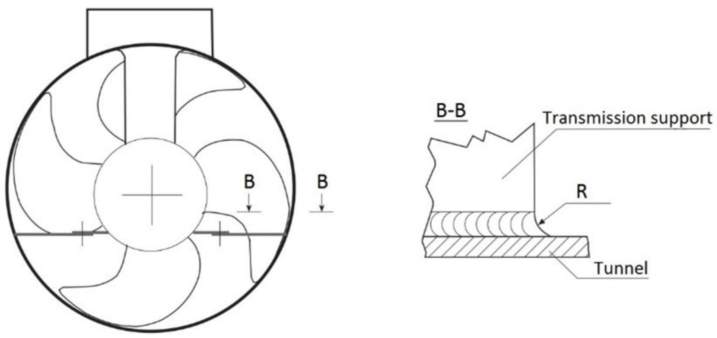

Figure 8.1: Connection between gear housing support bracket and thruster tunnel

3. Special designs

If suction or draining ducts are arranged in the ship's bottom the design bottom slamming pressure p_{SL} 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 24, 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*

F. Docking Calculation

1. General

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.

Note:

The arrangement of the keel blocks and their contact areas are to be defined under consideration of the ship size.

2. Simplified docking calculation

The local forces of the keel blocks acting on the bottom structures can be calculated in a simplified manner using the nominal keel block load q_0. Based on these forces sufficient strength 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.8.2.

$$q_0 = \frac{G_s \cdot C}{L_{KB}} \quad [kN/m]$$

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 $2 \cdot e$

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 C.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.

3. Direct docking calculation

If the docking block forces are determined by direct calculation, e.g. by a finite element calculation, considering the stiffness of the ship's body and the weight distribution, the ship has to be assumed as elastically bedded at the keel blocks. The stiffness of the keel blocks has to be determined including the wood layers.

If a floating dock is used, the stiffness of the floating dock is to be taken into consideration.

Transitory docking conditions need also to be considered.

4. Permissible stresses

The permissible equivalent stress σ_V is:

$$\sigma_V \quad \leq \frac{R_{eH}}{1,05} \quad [N/mm^2]$$

5. 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.

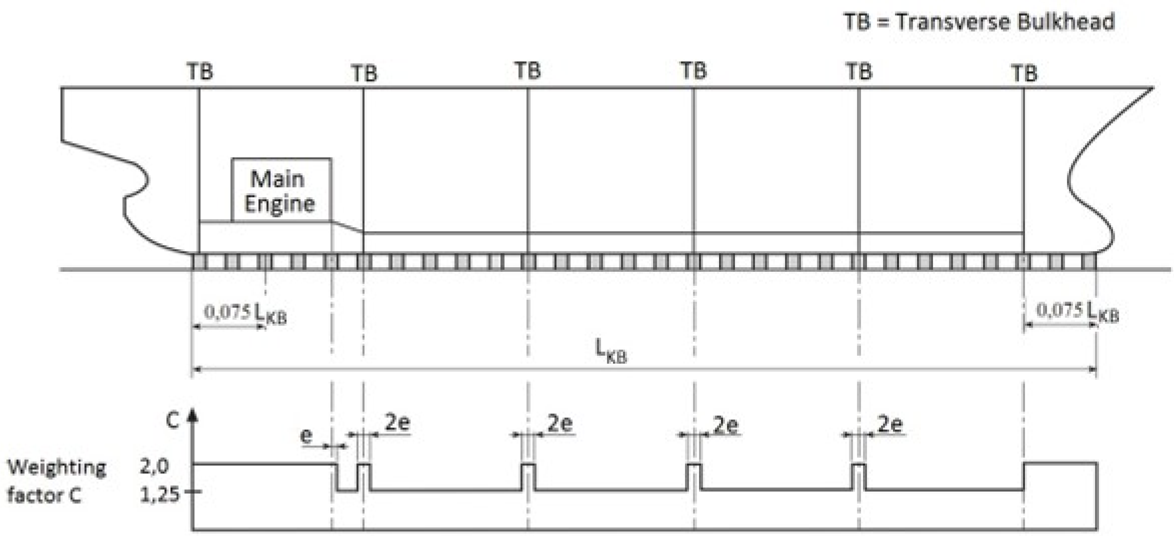

Figure 8.2: Load on keel block

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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

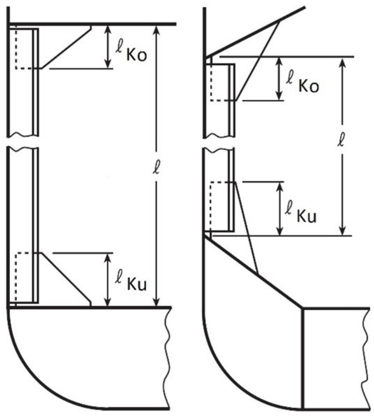

Figure 9.1: Unsupported span of transverse frames

m_a = $0,204\,\frac{a}{\ell}\left[4 - \left(\frac{a}{\ell}\right)^2\right]$, where, $\frac{a}{\ell} \le 1$

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

$= 1,0 - 2\,\frac{s}{\ell}$

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:

$$W_R = n \cdot c \cdot \left[1 - m_a^2\right] \cdot c_r \cdot \mathbf{a} \cdot \ell^2 \cdot p \cdot k \qquad [cm^3]$$

upper end shear area :

$$A_{RO} = [1 - 0,817 \cdot m_a] \cdot 0,04 \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \qquad [cm^2]$$

lower end shear area :

$$A_{RU} = [1 - 0,817 \cdot m_a] \cdot 0,07 \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \qquad [cm^2]$$

$n = 0,9 - 0,0035 \cdot \mathbf{L}$ for **L** < 100 m

$= 0,55$ for **L** ≥ 100 m

$$c = 1,0 - \left(\frac{\ell_{Ku}}{\ell} + 0,4 \cdot \frac{\ell_{Ko}}{\ell}\right)$$

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: $\sigma_b \leq \frac{150}{k}$ [N/mm^2]
- shear stress: $\tau \leq \frac{100}{k}$ [N/mm^2]
- equivalent stress: $\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} \leq \frac{180}{k}$ [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, H)

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 :

$$W_1 = \left(1 - m_a^2\right) \cdot n \cdot c \cdot \mathbf{a} \cdot \ell^2 \cdot p_1 \cdot c_r \cdot k \quad [cm^3]$$

$$W_2 = \left(1 - m_a^2\right) \cdot 0,44 \cdot c \cdot \mathbf{a} \cdot \ell^2 \cdot p_2 \cdot c_r \cdot k \quad [cm^3]$$

$$A_1 = (1 - 0,817 \cdot m_a) \cdot 0,05 \cdot c \cdot \mathbf{a} \cdot \ell \cdot p_1 \cdot k \quad [cm^2]$$

$$A_2 = (1 - 0,817 \cdot m_a) \cdot 0,04 \cdot c \cdot \mathbf{a} \cdot \ell \cdot p_2 \cdot k \quad [cm^2]$$

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:

$$W_t = 0,55 \cdot m \cdot \mathbf{a} \cdot \ell^2 \cdot p \cdot c_r \cdot k \quad [cm^3]$$

$$A_t = (1 - 0,817 \cdot m_a) \cdot 0,05 \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \quad [cm^2]$$

p is not to be taken less than:

$$p_{min} = 0,4 \cdot p_L \cdot \left(\frac{B}{\ell}\right)^2 \quad [kN/m^2]$$

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.

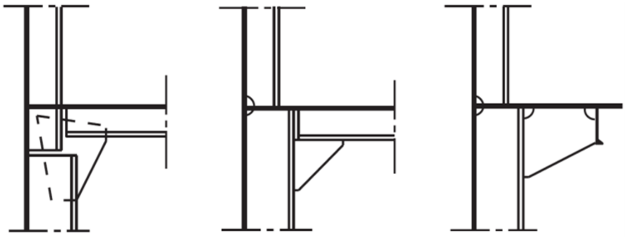

Figure 9.2: Typical ends attachments of tween deck and superstructure frames

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

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 $b = 75 \cdot \sqrt{\mathbf{L}}$ [mm]
- thickness $t = 6{,}0 + \frac{\mathbf{L}}{40}$ [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:

$$W = 0,55 \cdot e \cdot \ell^2 \cdot p \cdot n_c \cdot k \qquad [cm^3]$$

Web sectional area at the supports:

$$A_W = 0,05 \cdot e \cdot \ell_1 \cdot p \cdot k \qquad [cm^2]$$

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
≥ 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 :

$$p_{sdyn} = p_o \cdot c_F \cdot \left(1 + \frac{z}{T}\right) \qquad [kN/m^2]$$

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.

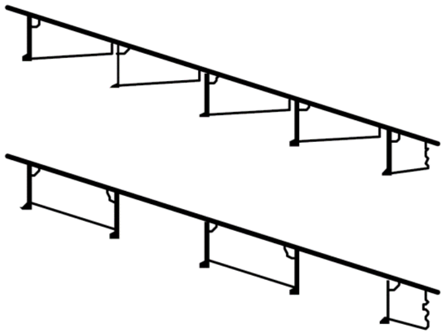

Figure 9.3: Tripping brackets

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, D.

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:

$$I = \mathbf{H} \cdot (7,25\,\mathbf{H} - 31) \cdot c_i \cdot 10^2 \quad [cm^4]$$

$$c_i = 1 + (H_u - 4) \cdot 0,07$$

The scantlings of the webs are to be calculated as follows :

depth $h = 50 \cdot \mathbf{H}$ [mm]

thickness $t = \dfrac{h}{32 + 0,03 \cdot h}$ [mm]

6.2.2 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 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)

1.4 For buckling strength of longitudinals see Rules for Hull (Pt.1, Vol.II) 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

$$p_1 - (10 \cdot \mathbf{T}_{min} - p_0 \cdot c_F) \qquad [kN/m^2]$$

For side longitudinals below $\mathbf{T}_{min}$ p need not to be taken larger than:

$$p_1 - 10 \cdot (T_{min} - z) + p_0 \cdot c_F \left(1 + \frac{z}{T_{min}}\right) \quad [kN/m^2]$$

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 = $\left(m_k^2 - m_a^2\right)$; $m \geq \frac{m_k^2}{2}$

m_a = see A.1.2

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

ℓ_{KI}, ℓ_{KJ} = effective supporting length [mm] due to heel stiffeners and brackets at frame I and J (see Fig. 9.4)

ℓ_K = $h_s + 0,3 \cdot h_b + \frac{1}{c_1} \leq (\ell_b + h_s)$

c_1 = $\frac{1}{\ell_b - 0,3 \cdot h_b} + \frac{c_2\,(\ell_b - 0,3 \cdot h_b)}{h_e^2}$ $\left[\frac{1}{mm}\right]$ For $\ell_b \leq 0,3 \cdot h_b$, $\frac{1}{c_1}$ = 0 is to be taken

h_s, ℓ_b, h_b, h_e see Fig. 9.4

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 · 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)).

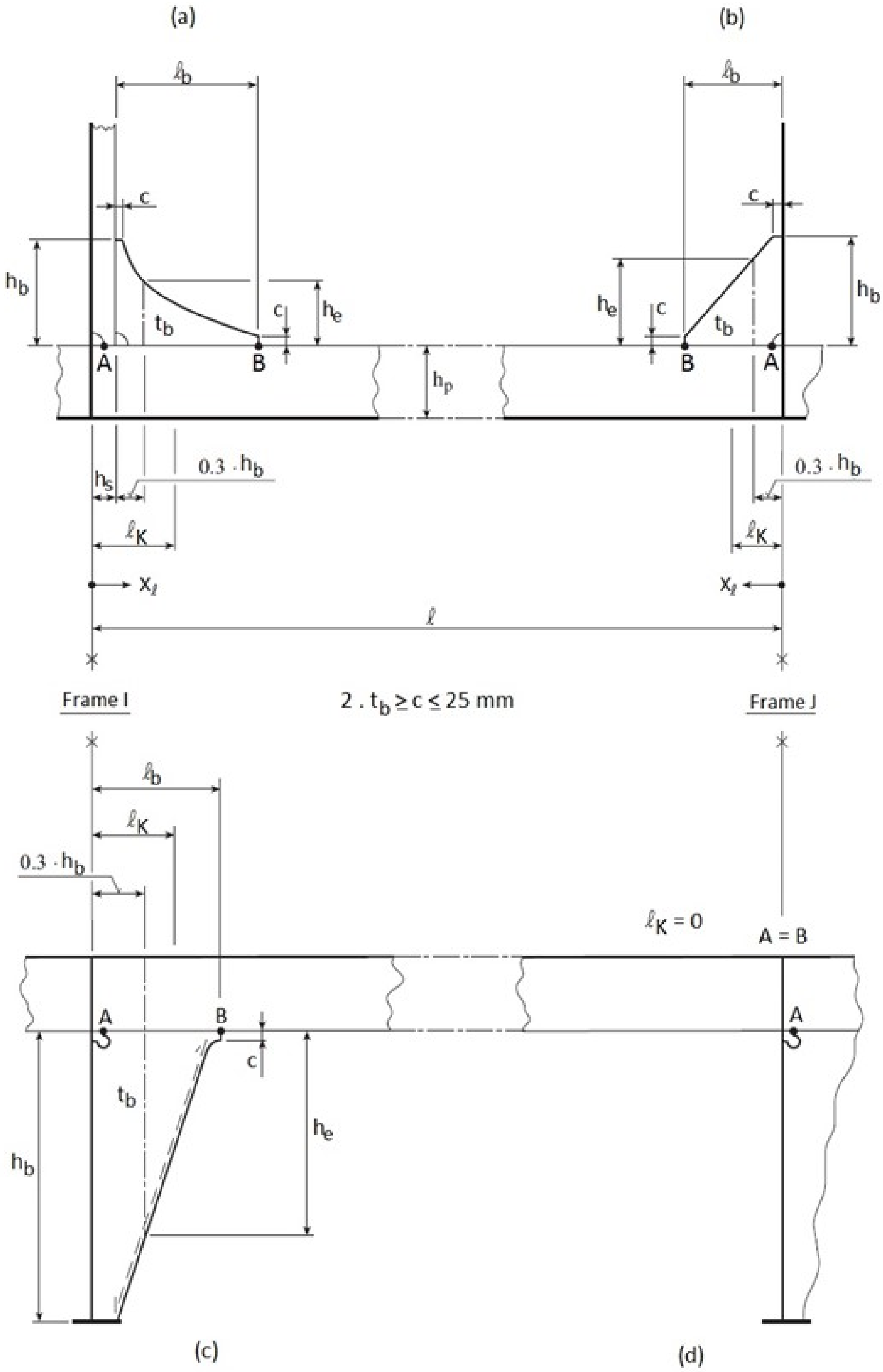

Figure 9.4: End attachment

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:

$\sigma_{pr} = \sigma_{perm} - |\sigma_L|$ [N/mm²]

$\sigma_{pr} \leq \frac{150}{k}$ [N/mm²]

$\sigma_{perm} = \left(0,8 + \frac{\mathbf{L}}{450}\right) \cdot \frac{230}{k}$ [N/mm²]

$\sigma_{permmax} \leq \frac{230}{k}$ [N/mm²]

For side longitudinals W_ℓ and A_ℓ shall not be less than:

$$W_{\ell min} = \frac{83}{\sigma_{permax} - |\sigma_L|} \cdot m \cdot \mathbf{a} \cdot \ell^2 \cdot p_{s1} \quad [cm^3]$$

$$A_{\ell_{min}} = (1 - 0,817 \cdot m_a) \cdot 0,037 \cdot \mathbf{a} \cdot \ell \cdot p_{s1} \cdot k \quad [cm^2]$$

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 $0 \leq x_\ell \leq \ell_k$

$$\sigma_A = \frac{83 \cdot m \cdot \mathbf{a} \cdot \ell^2 \cdot p}{W_a} + \sigma_h \quad [N/mm^2]$$

for $x_\ell = h_s + \ell_b$

$\sigma_B = \sigma_A \cdot m_1$ [N/mm²]

W_a = section modulus of the profile [cm³] including effective plate width according to Rules for Hull (Pt.1, Vol.II) 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.

$$C_R = \frac{1,0}{1,0 + \frac{\mathbf{a} \cdot \ell^4 \cdot t}{0,006 \cdot I_a \cdot R^2}}$$

t = thickness of shell plating [mm]

I_a = moment of inertia of the longitudinal frame [cm⁴], 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), $z_{Ro} < \mathbf{T}$

C_T = correction regarding location of the profile i to the waterline

$$= 1,1 - \frac{z}{\mathbf{T}} \qquad 0 \le C_T \le 0,1$$

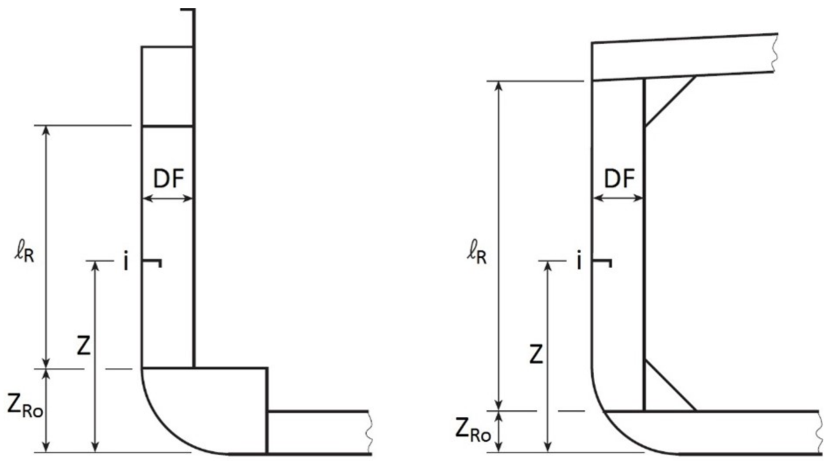

Figure 9.5: Definitions

3.6 Where struts are fitted between bottom and inner bottom longitudinals, see Section 8, C.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 :

$$P_f = D/100 \quad [kN]$$

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

$= \frac{P_f}{16}(\ell - 0,5)$ [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:

$$P = (1 - 0,817 \cdot m_a) \cdot \mathbf{a} \cdot \ell \cdot p \quad [kN]$$

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.

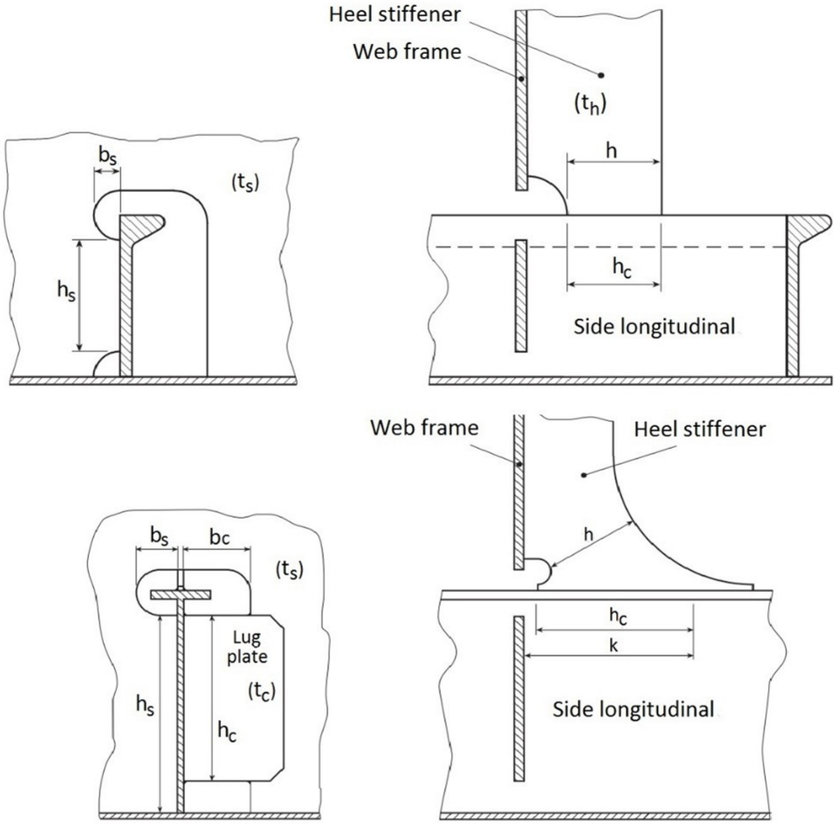

Figure 9.6: Typical intersections of longitudinals and transverse support members

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:

$$P_h = \varepsilon_h \cdot P \quad [kN]$$

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:

$$P_s = \varepsilon_s \cdot P \quad [kN]$$

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:

$$\sigma_{axial} = \frac{P_h}{\ell_h \cdot t_h} \cdot 10^3 \quad [N/mm^2] \quad \text{with} \quad \sigma_{axial} \leq \frac{150}{k} \, [N/mm^2]$$

– normal stress in the fillet weld connection of heel stiffener:

$$\sigma_{weld} = \frac{P_h}{2 \cdot a \cdot (\ell_{hc} + t_h + a)} \cdot 10^3 \quad [N/mm^2] \quad \text{with} \quad \sigma_{weld} \le \sigma_{vp} \; [N/mm^2]$$

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:

$$\tau_i = \frac{P_i}{h_i \cdot t_i} \cdot 10^3 \quad [N/mm^2] \quad \text{with} \quad \tau_i \le \frac{100}{k} \quad [N/mm^2]$$

– shear stress in the shear connections in way of fillet welds:

$$\tau_{weld,i} = \frac{P_i}{2 \cdot a \cdot h_i} \cdot 10^3 \quad [N/mm^2] \quad \text{with} \quad \tau_{weld,i} \le \tau_p \quad [N/mm^2]$$

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::

$$\sigma_c = \frac{3 \cdot P_c \cdot b_c}{h_c^2 \cdot t_c} \cdot 10^3 \quad [N/mm^2] \quad \text{with} \quad \sigma_c \le \frac{150}{k} \quad [N/mm^2]$$

– bending stress in the fillet weld connection of the lug plate:

$$\sigma_{weld,c} = \frac{1,5 \cdot P_c \cdot b_c}{h_c^2 \cdot a} \cdot 10^3 \quad [N/mm^2] \quad \text{with} \quad \sigma_{weld,c} \le \sigma_{vp} \quad [N/mm^2]$$

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:

$$\sigma_b \le \frac{150}{k} \quad [N/mm^2]$$

$$\tau \le \frac{100}{k} \quad [N/mm^2]$$

$$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} \le \frac{180}{k} \quad [N/mm^2]$$

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:

$$P_f \le P_{fu}$$

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

= $\dfrac{\ell_s}{i_s . \pi}\sqrt{\dfrac{R_{eH}}{E}} \geq 0,2$

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

= $\sqrt{\dfrac{I_s}{A_s}}$ [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.4.

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 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:

$$W = c \cdot e \cdot \ell^2 \cdot p \cdot k \quad [cm^3]$$

$$A_W = 0{,}05 \cdot p \cdot e \cdot \ell \cdot k \quad [cm^2]$$

$$I = c_I \cdot W \cdot \ell \quad [cm^4]$$

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:

$$\sigma_b \leq \frac{200}{k} \quad [N/mm^2]$$

$$\tau \leq \frac{120}{k} \quad [N/mm^2]$$

$$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} \leq \frac{220}{k} \quad [N/mm^2]$$

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 affected by tension loads doublings are not permitted.

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:

$t_w = 4{,}5 + 0{,}015\, d_a$ [mm] for $d_a \leq 300$ mm

$t_w = 0{,}03\, d_a$ [mm] for $d_a > 300$ 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 specialy considered.

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

$= \frac{1}{\Phi + \sqrt{\Phi^2 - \lambda_s^2}}$

$\Phi = 0{,}5 \cdot \left[1 + n_p \cdot (\lambda_s - 0{,}2) + \lambda_s^2\right]$

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:

$$\sigma_b \leq \frac{125}{k} \quad [N/mm^2] \quad \text{for bending stress}$$

$$\tau \leq \frac{80}{k} \quad [N/mm^2] \quad \text{for shear stress}$$

— Where several cantilevers are fitted at smaller distances (e.g. at every frame):

$$\sigma_b \leq \frac{150}{k} \quad [N/mm^2] \quad \text{for bending stress}$$

$$\tau \leq \frac{100}{k} \quad [N/mm^2] \quad \text{for shear stress}$$

$$\sigma_v = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} \leq \frac{180}{k} \quad [N/mm^2] \quad \text{for equivalent stress}$$

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 : $\sigma_\ell \leq \frac{150}{k}$ [N/mm²] deck level: $\sigma_\ell \leq \frac{70}{k}$ [N/mm²]	$\sigma_\ell \leq \frac{150}{k}$ [N/mm²]

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:

$$\sigma_L + \sigma_\ell \leq \frac{200}{k} \quad [N/mm^2]$$

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:

$\sigma_\ell \le \frac{150}{k}$ [N/mm^2] for stresses in ship's longitudinal direction

$\sigma_t \le \frac{150}{k}$ [N/mm^2] for stresses in ship's transvers direction

$\tau \le \frac{90}{k}$ [N/mm^2] for shear stresses

$\sigma_v = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \cdot \sigma_y + 3 \cdot \tau^3} \le \sigma_{v,perm}$ for equivalent stresses

$\sigma_{v,perm}$ = permissible equivalent stress [N/mm^2], defined as:

$= \left(0,8 + \frac{L}{450}\right)\frac{230}{k}$ for **L** < 90 m

$= \frac{230}{k}$ [N/mm^2] for **L** ≥ 90 m

σ_x, σ_y = stress component of equivalent stress, defined as :

$\sigma_x = \sigma_L + \sigma_\ell$

$\sigma_y = \sigma_t$

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.

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**

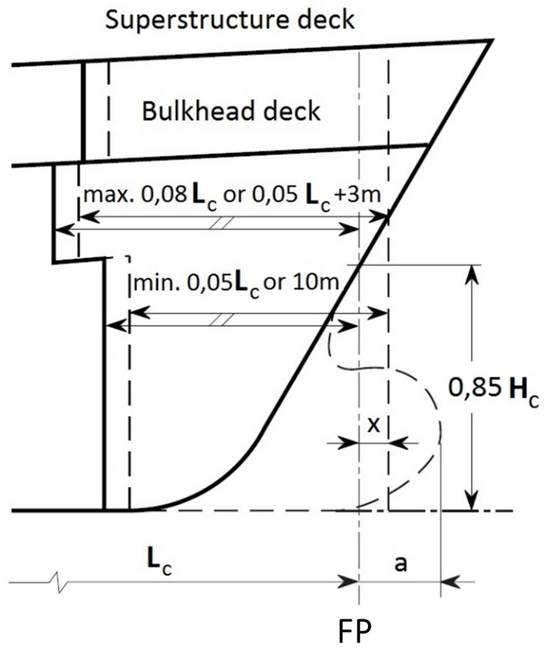

Figure 11.1: Location of collision bulkhead

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 Except as provided in 2.1.7 the collision bulkhead may be pierced below the bulkhead deck by not more than one pipe for dealing with fluid in the forepeak tank, provided that the pipe is fitted with a 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. 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 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, 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, 12.6.2)

2.1.8 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.

(SOLAS II-1, 12.10)

2.2.2 In all cases stern tubes shall be enclosed in watertight spaces of moderate volume.

(SOLAS II-1, 12.11)

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 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:

$$t = c_p \cdot \mathbf{a} \cdot \sqrt{p} + t_k \quad \text{[mm]}$$

$$t_{min} = 6{,}0 \cdot \sqrt{f} \quad \text{[mm]}$$

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:

$$t = c \cdot \sqrt[3]{\frac{\Delta\ell}{F_{tran} \cdot R_{eH} \cdot \left(\frac{1}{a^2} + \frac{1}{b^2}\right)} \cdot \sqrt{\frac{\mathbf{H}}{2}\left(\frac{\mathbf{H}}{2} - \mathbf{H}\right) + \mathbf{T}^2}} + t_k \quad \text{[mm]}$$

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 Rules for Hull (Pt.1, Vol.II) 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 The stern tube bulkhead is to be provided with a strengthened plate in way of the stern tube.

2.3 In areas where concentrated loads due to ship manoeuvres at terminals, may be expected, the buckling, strength of bulkhead plate fields directly attached to the side shell, is to be examined according to Section 9, B.5.4 and 5.5.

2.4 When determining the bulkhead scantlings of tanks, connected by cross-flooding arrangements, the increase in pressure head at the immerged side that may occur at maximum heeling in the damaged condition shall be taken into account.

3. Stiffeners

3.1 The section modulus of bulkhead stiffeners is not to be less than:

$$W = c_s \cdot m \cdot \mathbf{a} \cdot \ell^2 \cdot p \quad \text{[cm}^3\text{]}$$

m see Section 9, B

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. primary Supporting Members

4.1 General

Primary supporting members are to be dimensioned using direct calculation as to ensure the stress criteria according to 4.3.1 for normal operation and the criteria according to 4.3.2 if any cargo hold is flooded.

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.

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.

4.2 Load assumptions

4.2.1 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.

4.2.2 Loads in damaged condition

The loads in case of hold flooding result from 1.3 considering 5.3.2.

4.3 Strength criteria

4.3.1 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]

For a non-linear or a linear girder grillage calculation the equivalent stresses σ_v are not to exceed the following value:

$\sigma_v \leq R_{eH}$

k = material factor according Section 2, B.

If necessary Section 5, F.2 shall be observed in addition.

4.3.2 Load case "hold flooding"

The thickness of webs shall not be smaller than:

$$t_w = \frac{10^3 \cdot Q}{\tau_{perm} \cdot h_w} + t_k \quad [mm]$$

$$\tau_{perm} = 727 \sqrt{\frac{Q}{b \cdot h_w} \sqrt{R_{eH} \left(1 + 0,75 \frac{b^2}{a^2}\right)}} \leq \frac{R_{eH}}{2,08} \quad [N/mm^2]$$

Q = shear force [kN]

h_w = height of web [mm]

a, b = lengths of stiffeners of the unstiffened web field, where $h_w \geq b \leq a$

4.3.3 Dimensioning of Primary Supporting Members

The plastic moments M_p and shear forces Q_p as boundary conditions are to be determined by the following formulae:

For girders built up by one element (e.g. FB and HP Section):

$$M_p = \frac{W_p \cdot R_{eH}}{c \cdot 1200} \quad [kNm]$$

$$Q_p = \frac{A_s \cdot R_{eH}}{c \cdot 2080} \quad [kN]$$

c = 1,1 for the collision bulkhead
= 1,0 for cargo hold bulkheads

For girders built up by several elements :

$$M_p = \frac{\sum_{i=1}^{n} A_{si} \cdot R_{eHi} \cdot e_{pi}}{c \cdot 1,2 \cdot 10^6} \quad [kNm]$$

The plastic shear forces are:

$$Q_p = \frac{\sum_{i=1}^{n} A_{si} \cdot R_{eHi}}{c \cdot 2080} \quad [kN]$$

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 Rules for Hull (Pt.1, Vol.II) 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 $\geq t_w$

5. 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 Section 23, E.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 The section modulus of shaft tunnel stiffeners is to be determined according to B.3.1.

2.4 Horizontal parts of the tunnel are to be treated as horizontal parts of bulkheads and as cargo decks respectively.

2.5 Shaft tunnels in tanks are to comply with the requirements of Section 12.

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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, E.

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, D.5.

4.3 For testing of tanks, see Section 3, M.

4.4 Where tanks are provided with cross flooding arrangements the increase of the pressure head is to be taken into consideration (see also Section 23, 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. 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)].

5.2.2 Fuel oil tanks adjacent to lubricating oil circulation tanks are not permitted.

5.2.3 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.

[1)] For Indonesian flag ship, the cofferdams are also required between accommodation spaces and oil tanks.

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:

$$t_{min} = 5{,}5 + 0{,}02 \cdot \mathbf{L} \qquad [mm]$$

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 t_{min} need not be taken greater than 9,0 mm.

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]*

$$= \frac{1}{60} \cdot n \cdot z \qquad [Hz]$$

[2)] The natural frequencies of plate fields and stiffeners can be estimated by approved computer program

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.

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* $f_{plate} > 1,1 \cdot f_{ignition}$

[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.

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 :

$$p = p_1 - \left[10\,(\mathbf{T}_{min} - z) - p_0 \cdot c_f \left(1 + \frac{z}{\mathbf{T}_{min}}\right)\right] \quad [\text{kN/m}^2] \quad \text{with } p \le p_1$$

$\mathbf{T}_{min}$ = 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]

$$\sigma_{p\ell} = \sqrt{\left(\frac{235}{k}\right)^2 - 3 \cdot \tau_L^2} - 0,89 \cdot \sigma_L \quad [\text{N/mm}^2]$$

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:

$$t_1 = 1,1 \cdot \mathbf{a} \cdot \sqrt{p \cdot k} + t_k \quad [\text{mm}]$$

$$t_2 = 0,9 \cdot \mathbf{a} \cdot \sqrt{p_2 \cdot k} + t_k \quad [\text{mm}]$$

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:

$$t = 16,8 \cdot n_f \cdot \mathbf{a} \sqrt{\frac{p}{\sigma_{p\ell}}} + t_k \quad [\text{mm}]$$

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:

$$W_1 = 0,55 \cdot m \cdot \mathbf{a} \cdot \ell^2 \cdot p \cdot k \quad [cm^3]$$

$$W_2 = 0,44 \cdot m \cdot \mathbf{a} \cdot \ell^2 \cdot p_2 \cdot k \quad [cm^3]$$

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:

$$A_{w1} = (1 - 0,817 \cdot ma) \cdot 0,05 \cdot \mathbf{a} \cdot \ell \cdot p \cdot k \quad [cm^2]$$

$$A_{w2} = (1 - 0,817 \cdot ma) \cdot 0,04 \cdot \mathbf{a} \cdot \ell \cdot p_2 \cdot k \quad [cm^2]$$

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 0,1ℓ.

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 :

$$\sigma_b \le \frac{150}{k} \quad [N/mm^2]$$

$$\tau \le \frac{100}{k} \quad [N/mm^2]$$

$$\sigma_v = \sqrt{\sigma_b^2 + 3\,\tau^2} \le \frac{180}{k} \quad [N/mm^2]$$

— if subjected to load p_2 :

$$\sigma_b \le \frac{180}{k} \quad [N/mm^2]$$

$$\tau \le \frac{115}{k} \quad [N/mm^2]$$

$$\sigma_v = \sqrt{\sigma_b^2 + 3\,\tau^2} \le \frac{200}{k} \quad [N/mm^2]$$

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:

$$\sigma_{axial} = \frac{10^3 \cdot P_h}{\ell_h \cdot t_h} \leq \frac{150}{k} \quad \text{for load p} \quad [N/mm^2]$$

$$\sigma_{axial} \leq \frac{180}{k} \quad \text{for load } p_2 \quad [N/mm^2]$$

- normal stress in the fillet weld connection of heel stiffener:

$$\sigma_{weld} = \frac{10^3 \cdot p_h}{2 \cdot a \cdot (\ell_{hc} + t_h + a)} \leq \sigma_{vp} \quad \text{for load p} \quad [N/mm^2]$$

$$\sigma_{weld} \leq \frac{\sigma_{vp}}{0,8} \quad \text{for load } p_2 \quad [N/mm^2]$$

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:

$$\tau_i = \frac{10^3 \cdot P_i}{h_i \cdot t_i} \leq \frac{100}{k} \quad \text{for load p} \quad [N/mm^2]$$

$$\tau_i \leq \frac{115}{k} \quad \text{for load } p_2 \quad [N/mm^2]$$

— shear stress in the shear connections in way of fillet welds:

$$\tau_{weld,i} = \frac{10^3 \cdot P_i}{2 \cdot a \cdot h_i} \leq \tau_p \quad \text{for load p} \quad [N/mm^2]$$

$$\tau_{weld,i} \leq \frac{\tau_p}{0,8} \quad \text{for load } p_2 \quad [N/mm^2]$$

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

$$\sigma_c = \frac{3 \cdot 10^3 \cdot P_c \cdot b_c}{h_c^2 \cdot t_c} \leq \frac{150}{k} \quad \text{for load p } [N/mm^2]$$

$$\sigma_c \leq \frac{180}{k} \quad \text{for load } p_2$$

— bending stress in the fillet weld connection of the collar plate

$$\sigma_{weld,c} = \frac{1,5 \cdot 10^3 \cdot P_c \cdot b_c}{h_c^2 \cdot t_c} \leq \sigma_{vp} \quad \text{for load p } [N/mm^2]$$

$$\sigma_{weld,c} \leq \frac{\sigma_{vp}}{0,8} \quad \text{for load } p_2$$

a, σ_{vp} according to 3.7.2

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

$\overline{GM}$ ≈ 0,07 · **B** in general

D. 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 · 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 · ρ [m]

ρ = density [t/m^3] of liquid to carry

2.3 For minimum thickness the requirements of A.7 apply in general.

E. 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.

F. 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.

G. 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, C.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. Plate stem and bulbous bows

1.1 Plating

1.1.1 The thickness is not to be less than:

$$t = (0{,}6 + 0{,}4\, a_B) \cdot (0{,}08 \cdot \mathbf{L} + 6{,}0)\sqrt{k} \quad [mm]$$

$$t_{max} = 25\sqrt{k} \quad [mm]$$

The minimum plate thickness shall not be less than the required thickness according to Section 6, C.2.

1.1.2 The extension ℓ of the stem plate from its trailing edge afterwards shall not be smaller than:

$$\ell = 70\sqrt{\mathbf{L}} \quad [mm]$$

1.1.3 Starting from 600 mm above the load waterline up to **T** + c_0, the plate thickness may gradually be reduced to 0,8t.

1.2 Stiffeners and girders

1.2.1 Dimensioning of the stiffening has to be done according to Section 9.

1.2.2 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.

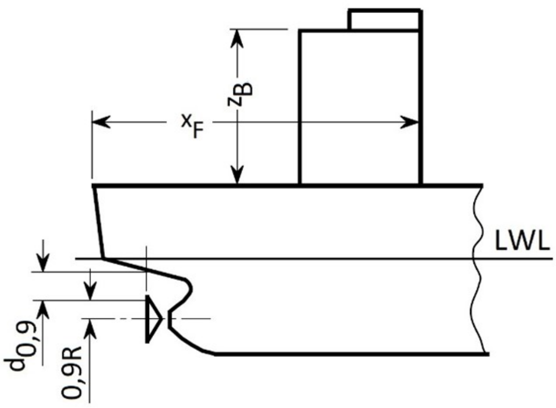

Figure 13.1: Propeller clearance $d_{0,9}$

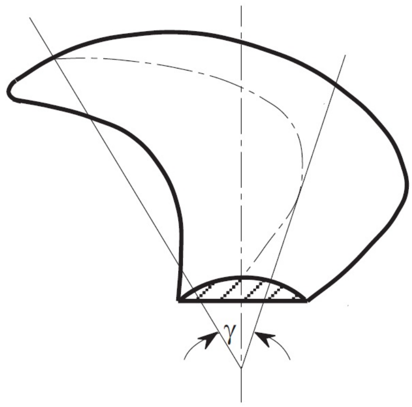

Figure 13.2: Skew angle

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:

$$t = (0,07 \cdot \mathbf{L} + 5,0)\sqrt{k} \quad [mm]$$

$$t_{max} = 22\sqrt{k} \quad [mm]$$

2. Propeller post

2.1 The scantlings of propeller posts of welded construction are to be determined according to the following formulae:

$$\ell = 50\sqrt{L} \quad [mm]$$

$$b = 36\sqrt{L} \quad [mm]$$

$$t = 2,4\sqrt{L \cdot k} \quad [mm]$$

2.2 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:

$$W_X = 1,2 \cdot L^{1,5} \cdot k \quad [cm^3]$$

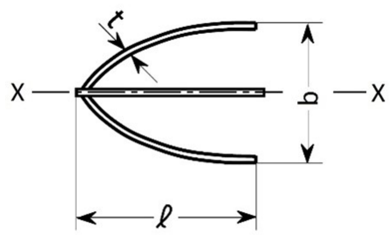

Figure 13.3: Length ℓ_{50} of a sole piece

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.

2.3 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. Rudder horn of semi spade rudders

3.1 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 :

$$W_X = \frac{M_b \cdot k}{67} \quad [cm^3]$$

3.2 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].

3.3 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/mm²] 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 [mm²] enclosed by the rudder horn at the location considered

t_h = thickness of the rudder horn plating [mm]

3.4 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)

3.5 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. 13.4.

Brackets or stringer are to be fitted internally in horn, in line with outside shell plate, as shown in Fig. 13.4.

(IACS UR S10.9.2.3)

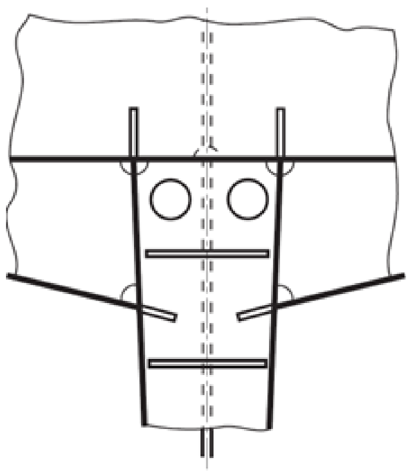

Figure 13.4: Rudder horn integration into the aft ship structure

3.6 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.

3.7 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.

3.8 The centre line bulkhead (wash-plate) in the afterpeak is to be connected to the rudder horn.

3.9 Scallops are to be avoided in way of the connection between transverse webs and shell plating

3.10 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)

3.11 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. 13.5.

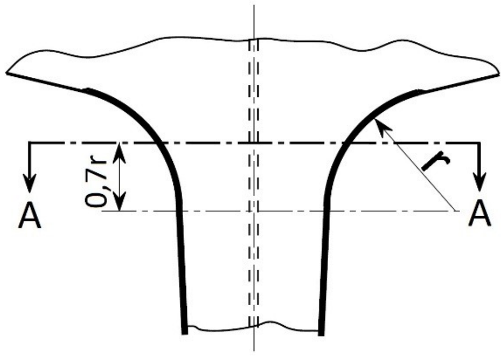

Figure 13.5: Transition between rudder horn and shell

4. Rudder horn of semi spade rudders with one elastic support

4.1 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 :

$$B_1 = C_R \cdot \frac{b}{c} \quad [N]$$

b, c, d, e(z) and z see Fig. 13.6 and Fig. 13.7.

b result from the position of the centre of gravity of the rudder area.

(IACS UR S10.5 ANNEX)

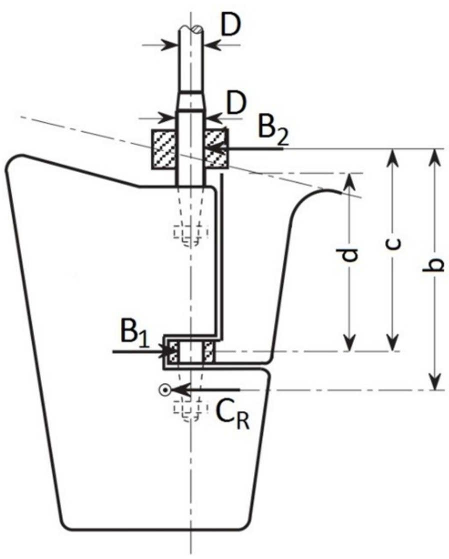

Figure 13.6: Arrangement of bearings of a semi spade rudder

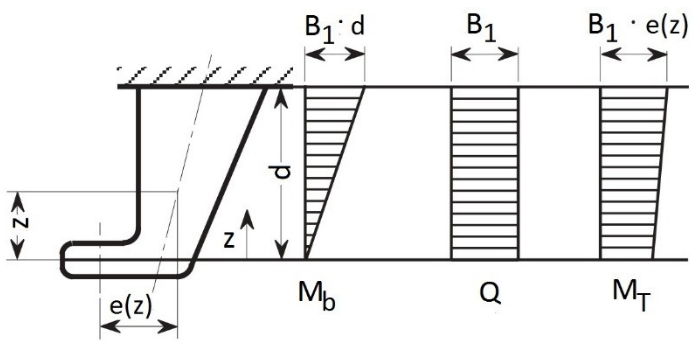

Figure 13.7: Loads on the rudder horn (rudder with one elastic support)

(IACS URS10.5 ANNEX Figure A5)

5. Rudder horn of semi-spade rudders with two conjugate elastic supports

5.1 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. 13.8, and taken equal to B_1.

F_{A2} = Support force at the rudder horn upper-support [N] to be obtained according to Fig. 13.8, and taken equal to B_2.

z = Distance, in m, defined in Fig. 13.8, 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, $d_{lu} = d - \lambda$).

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. 13.8

(IACS UR S10.6 ANNEX)

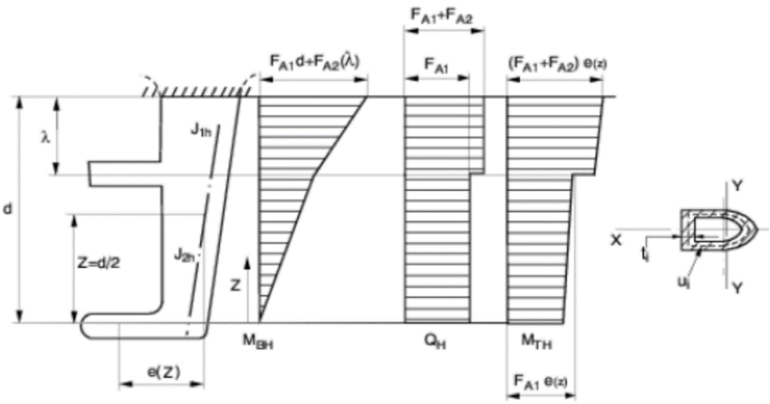

Figure 13.8: Loads on the rudder horn (rudder with two elastic supports

(IACS URS10.5 ANNEX Figure A7)

5.2 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)

5.3 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. 13.8).

(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.

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 $0{,}35 \cdot R_{eH}$.

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} = $0{,}40 \cdot R_{eH}$ for R_{eH} = 235 N/mm^2

σ_{perm} = $0{,}35 \cdot R_{eH}$ 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).

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Section 14 Rudder and Manoeuvring Arrangement

A. General

1. Applications

1.1 Each ship is to be provided with a manoeuvring arrangement which will guarantee sufficient manoeuvring capability.

1.2 Rudder stock, rudder coupling, rudder bearings and the rudder body are dealt with in this Section.

2. References

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

IACS UR S10 Rev.7, Corr.1

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

2.2 The steering gear is to comply with Rules for Machinery Installations (Pt.1, Vol.III) Sec.14..

2.3 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.)

2.4 For ice-strengthening see Section 15.

3. 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
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. 14.1
c	=	mean breadth of rudder area [m] (see Fig. 14.1)

Λ = aspect ratio of rudder area A_t

= $\frac{b^2}{A_t}$

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} = $\frac{(v_0 + 20)}{3}$ [kn]

v_a = astern speed of ship [kn], as defined in SOLAS Regulation II-1/3.15; however in no case taken less then $0{,}5 \cdot v_0$

k = material factor according to Section 2, B

For ships strengthened for navigation in ice Section 15, B.9 have to be observed.

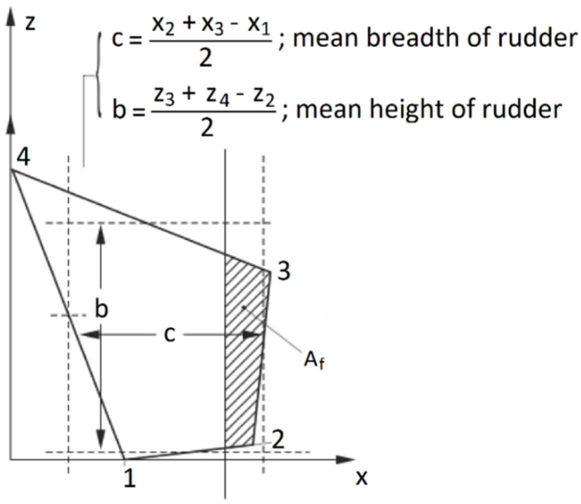


Figure 14.1: Rudder area geometry

4. *Recommended size of rudder area*

In order to achieve sufficient manoeuvring capability the size of the movable rudder area A is recommended to be not less than obtained from the following formula:

$$A = c_2 \cdot c_3 \cdot c_4 \frac{1{,}75 \cdot L \cdot T}{100} \quad [m^2]$$

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%.

5. Structural details

5.1 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)

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

(IACS UR S10.1.2.2)

5.3 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)

5.4 Connections of rudder blade structure with solid parts in forged or cast steel, which are used as rudder stock housing, are to be suitably designed to avoid any excessive stress concentration at these areas.

Note:

The following measures are recommended 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.*

6. Materials and Welding

6.1 Welded parts of rudders are to be made of approved rolled hull materials.

(IACS UR S10.1.3.1)

6.2 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)

6.3 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).

(IACS UR S10.1.3.4)

Special material requirements are to be observed for the ice Class Notations **ES3** and **ES4**.

6.4 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:

$$k_r = \left(\frac{235}{R_{eH}}\right)^{0,75} \quad \text{for } R_{eH} > 235 \quad [\text{N/mm}^2]$$

$$= \frac{235}{R_{eH}} \quad \text{for } R_{eH} \leq 235 \quad [\text{N/mm}^2]$$

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)

6.5 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)

6.6 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)

6.7 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. 14.2. The bevel angle is to be at least 15° for one sided welding.

(IACS UR S10.1.4.3)

6.8 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)

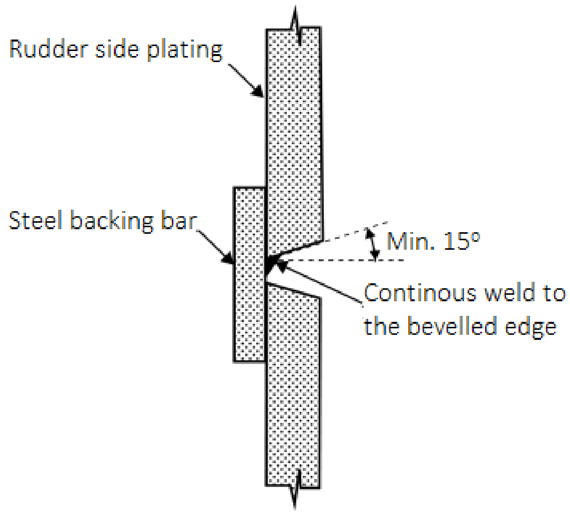


Figure 14.2: Use of steel backing bar in way of full penetration welding of rudder side plating

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:

$$C_R = 132 \cdot A \cdot v^2 \cdot \kappa_1 \cdot \kappa_2 \cdot \kappa_3 \quad [N]$$

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

1.2 The rudder torque is to be determined by the following formula:

$$Q_R = C_R \cdot r \quad [Nm]$$

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.

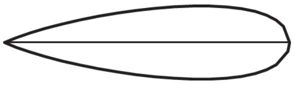
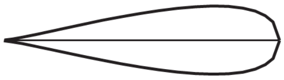
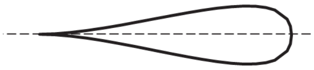
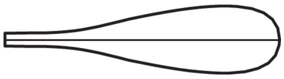
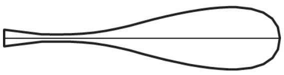
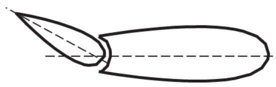
k_b = balance factor as follows:

$= \frac{A_f}{A}$

r_{min} = $0{,}1 \cdot c$ [m] for ahead condition.

(IACS UR S10.2.1.2)

Table 14.1: Coefficient κ_2

	Profile Type	κ_2	
		Ahead Condition	**Astern Condition**
1	NACA-00 series Göttingen profiles 	1,1	0,80
2	Flat side profiles (e.g. NACA-series 63A, 64A) 	1,1	0,90
3	Moderate hollow profiles (e.g. NACA-series 63, 64; HSVA MP71, MP73) 	1,21	0,90
4	Hollow profiles (e.g. IFS-profile) 	1,35	0,90
5	Fishtail profiles 	1,4	0,8
6	High lift rudders 	1,7	1,3

(IACS UR S10.2.1.1)

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:

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

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

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

$r_1 = c_1 (\alpha - k_{bl})$ [m]

$r_2 = c_2 (\alpha - k_{b2})$ [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)

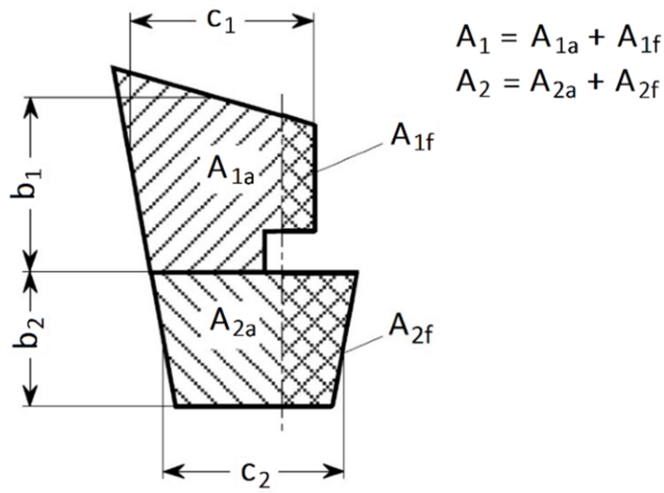


Figure 14.3: - Partial area A_1 and A_2

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 :

$$= \frac{0,1}{A}(c_1 \cdot A_1 + c_2 \cdot A_2) \quad [m] \quad \text{for ahead condition}$$

(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:

$$D_t = 4,2 \cdot \sqrt[3]{Q_R \cdot k_r} \quad [mm]$$

Q_R see B.1.2 and B.2.2 - 2.3.

The related torsional stress is:

$$\tau \leq \frac{68}{k_r} \quad [N/mm^2]$$

k_r see A.6.4.

(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 Spade Rudder

3.2.1 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]

Load p_R on rudder body is to be determined by the following formula :

$$p_R = \frac{C_R}{\ell_{10} \cdot 10^3} \quad [kN/m]$$

3.2.2 Moment and forces

For spade rudders the moments and 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. 14.4 is applicable for the connection between the rudder and the rudder stock.

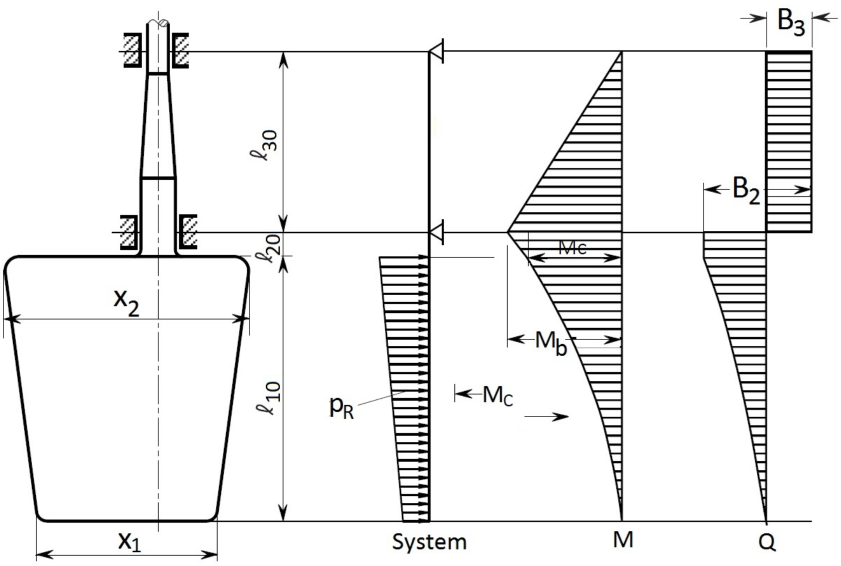


Figure 14.4: Spade rudder

(IACS UR S10.2 ANNEX)

3.3 Spade Rudder with Trunk

3.3.1 Data for the analysis

ℓ_{10} - ℓ_{50} = lengths of the individual girders of the system [m], see Fig. 14.5a and b

I_{10} – I_{50} = moments of inertia of these girders [cm^4]

Load p_R on rudder body is to be determined by the following formula :

$$p_R = \frac{C_R}{(\ell_{10} + \ell_{20}) \cdot 10^3} \quad [kN/m]$$

3.3.2 Moment and forces

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. 14.5a 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]

$$M_{CR1} = C_{R1} \cdot (CG_{1Z} - \ell_{10}) \quad [Nm]$$

$$M_{CR2} = C_{R2} \cdot (\ell_{10} - CG_{2Z}) \quad [Nm]$$

CG_{1Z} = vertical position of the centre of gravity of the rudder blade area A_1 from base

CG_{2Z} = vertical position of the centre of gravity of the rudder blade area A_2 from base

M_b = bending moment [Nm], as defined in Fig. 14.5a and b

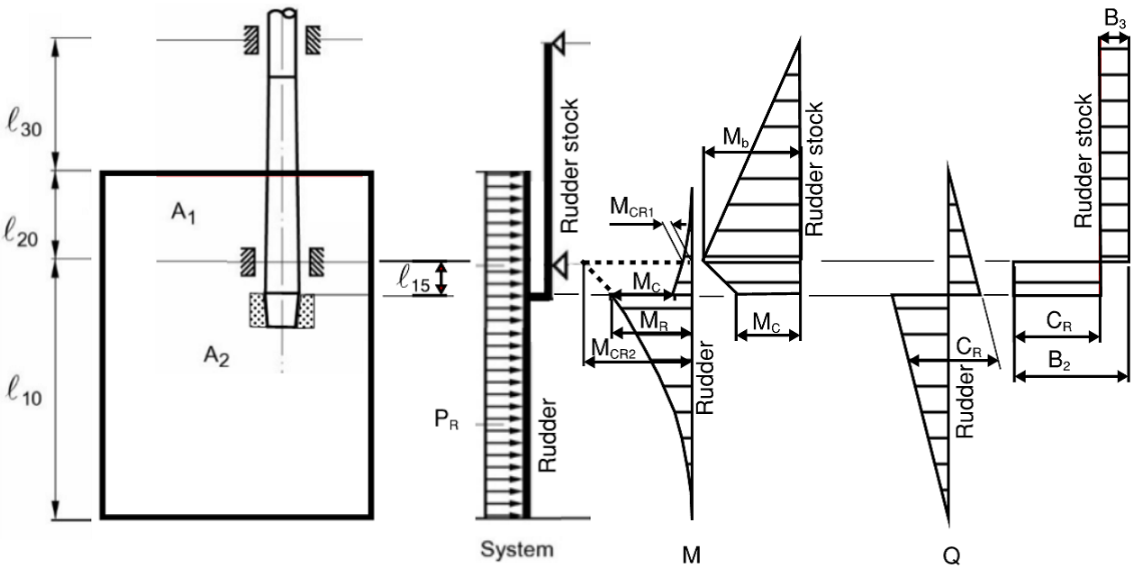
$$C_R = C_{R1} + C_{R2}$$

$$B_3 = \frac{M_{CR2} - M_{CR1}}{\ell_{20} + \ell_{30}} \quad [N]$$

$$B_2 = C_R + B_3 \quad [N]$$

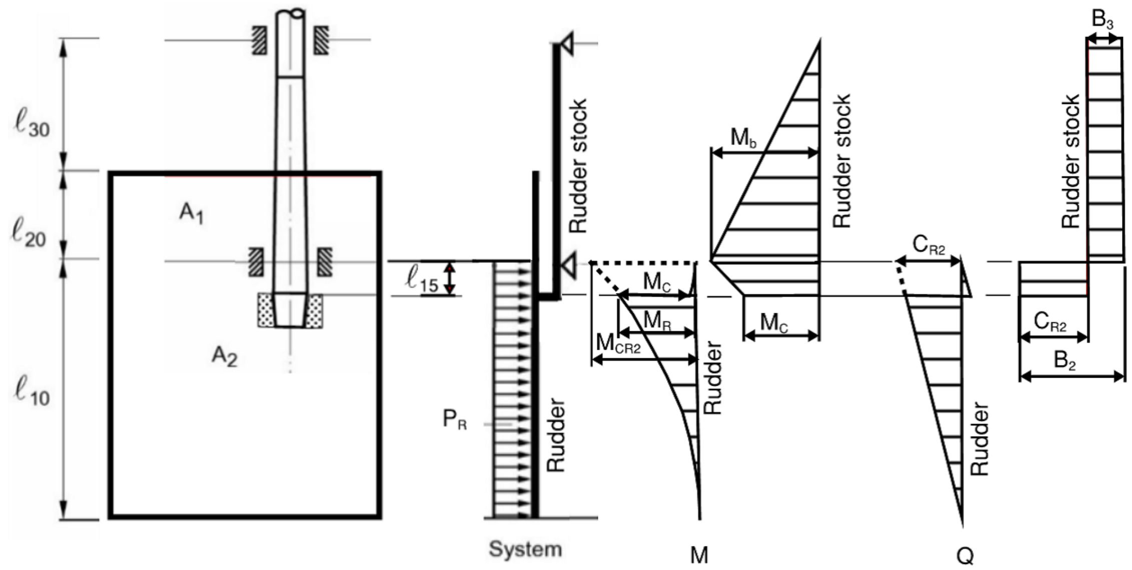
C_R, C_{R1}, C_{R2} see B.1 and B.2.

(IACS UR S10.3 ANNEX)



Full rudder force $C_R = C_{R1} + C_{R2}$ and total rudder torque $Q_R = Q_{R1} + Q_{R2}$ with rudders stock bending moment $M_b = M_{CR2} - M_{CR1}$

Figure 14.5a: 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 $M_b = M_{CR2}$

Figure 14.5b: Spade rudders with rudder trunks inside the rudder body

3.4 Semi-spade rudder with one elastic support

3.4.1 Data for the analysis

ℓ_{10} - ℓ_{50} = lengths of the individual girders of the system [m], see Fig. 14.6

$I_{10} - I_{50}$ = moments of inertia of these girders [cm^4]

Z = spring constant of support in the sole piece or rudder horn respectively

$= \dfrac{1}{f_b + f_t}$ [kN/m] for the support in the rudder horn (one elastic support) (Fig. 14.6)

f_b = unit displacement of rudder horn [m] due to a unit force of 1,0 kN acting in the centre of support

= $0,21\,\dfrac{d^3}{I_n}$ [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. 14.6)

f_t = unit displacement due to torsional moment of the amount $1 \cdot e$ [kNm]

= $\dfrac{d \cdot e^2}{G \cdot J_t}$ [m/kN] in general

= $\dfrac{d \cdot e^2 \cdot \Sigma u_i/t_i}{3,14.10^8 \cdot F_T^2}$ [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]

Load p_{R10} and p_{R20} on rudder body is to be determined by the following formula:

$$p_{R10} = \frac{C_{R2}}{\ell_{10} \cdot 10^3} \quad [kN/m]$$

$$p_{R20} = \frac{C_{R1}}{\ell_{20} \cdot 10^3} \quad [kN/m]$$

C_R, C_{R1}, C_{R2} see B.1 and B.2.

3.4.2 Moment and forces

For semi spade rudder with one elastic support the moment and shear force are indicated in Fig. 14.6. The calculation of the rudder horn may be determined using the requirements in Section 13, C.4.

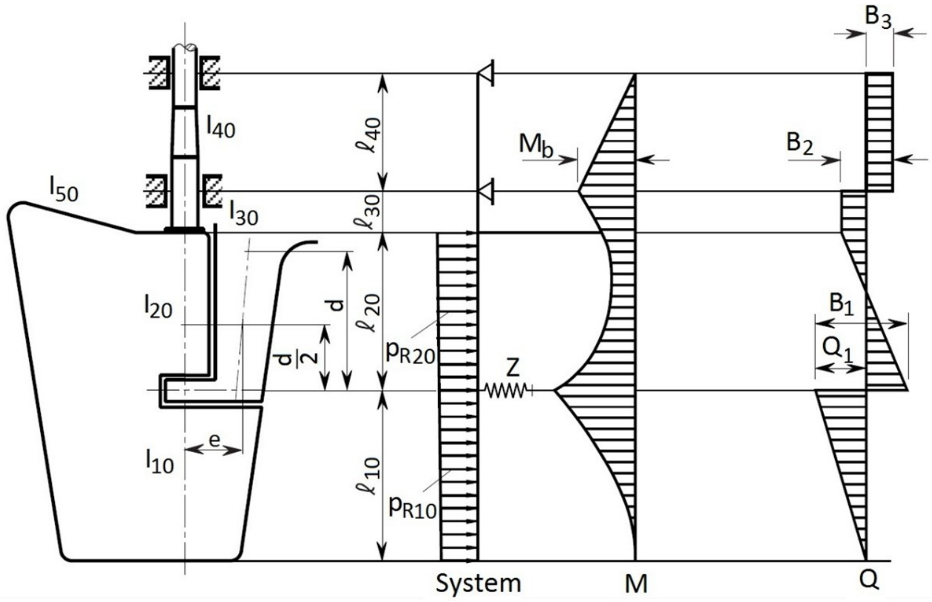


Figure 14.6: Semi-spade rudder with one elastic support

(IACS UR S10.5 ANNEX)

3.5 Semi-spade rudder with two elastic support

3.5.1 Data for the analysis

K_{11}, K_{22}, K_{12} = rudder horn compliance constants calculated for rudder horn with 2-conjugate elastic supports (Fig. 14.7). 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_{22}, K_{12} = obtained [m/kN] from the following formulae:

$$K_{11} = 1,3\frac{\lambda^3}{3E\ J_{1h}} + \frac{e^2\ \lambda}{G\ J_{th}}$$

$$K_{22} = 1,3\left[\frac{\lambda^3}{3E\ J_{1h}} + \frac{\lambda^2(\ d\lambda)}{2E\ J_{1h}}\right] + \frac{e^2\ \lambda}{G\ J_{th}}$$

$$K_{12} = 1,3\left[\frac{\lambda^3}{3\ E\ J_{1h}} + \frac{\lambda^2(\ d\lambda)}{E\ J_{1h}} + \frac{\lambda(d\lambda)^2}{E\ J_{1h}} + \frac{(d\lambda)^3}{3\ E\ J_{2h}}\right] + \frac{e^2\ d}{G\ J_{th}}$$

d = height if the rudder horn [m] according to Fig. 14.7. 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 [m], as defined in Fig. 14.7. 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 λ = 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. 14.7 (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. 14.7).

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. 14.7).

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.

Load p_{R10} and p_{R20} on rudder body is to be determined by the following formulae :

$$p_{R10} = \frac{C_{R2}}{\ell_{10} \cdot 10^3} \quad [kN/m]$$

$$p_{R20} = \frac{C_{R1}}{\ell_{20} \cdot 10^3} \quad [kN/m]$$

C_R, C_{R1}, C_{R2} see B.1 and B.2 and ℓ_{10}, ℓ_{20} are indicated in Fig. 14.7.

3.5.2 Moment and forces

For semi spade rudder with two elastic support the moment and shear force are indicated in Fig. 14.7. The calculation of the rudder horn may be determined using the requirements in Section 13, C.5.

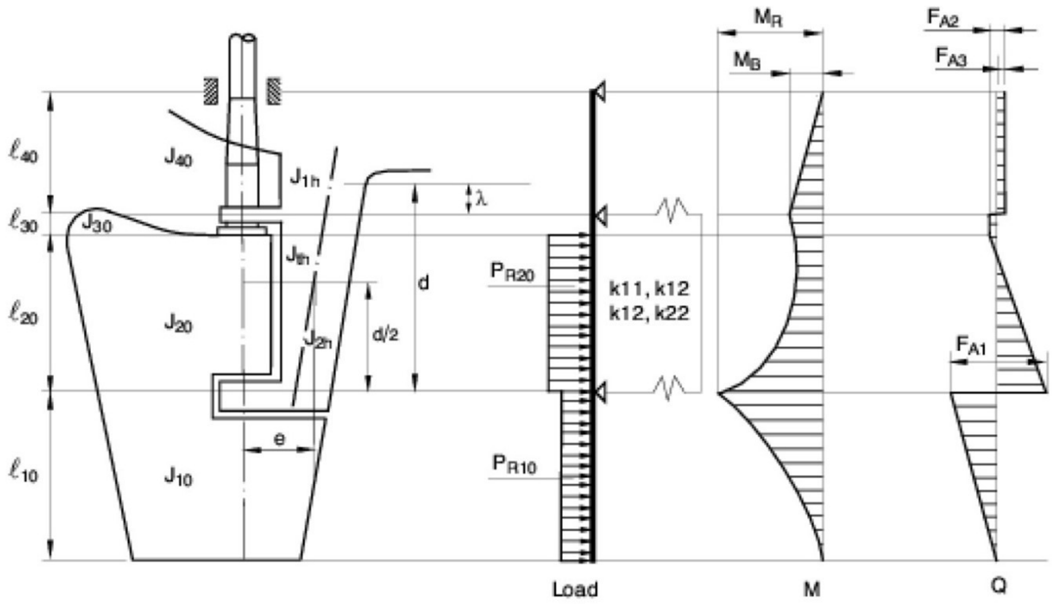


Figure 14.7: Semi-spade rudders with two elastic supports

(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 $0{,}35 \cdot R_{eH}$.

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. 14.8) 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:

$r = 60$ [mm] when $\sigma \geq 40 / k$ [N/mm^2]

$r = 30$ [mm] when $\sigma < 40 / k$ [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.6.4 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.

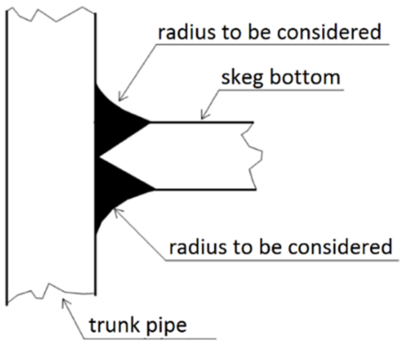


Figure 14.8: Fillet shoulder radius

(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:

$$d_b = 0,62 \cdot \sqrt{\frac{D^3 \cdot k_b}{k_r \cdot n \cdot e}} \quad \text{[mm]}$$

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.6.4

k_b = material factor for the bolts analogue to A.6.4

(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:

$$t_f = 0,62 \cdot \sqrt{\frac{D^3 \cdot k_f}{k_r \cdot n \cdot e}} \quad \text{[mm]}$$

$$t_{fmin} = 0,9 \cdot d_b \quad \text{[mm]}$$

k_f = material factor for the coupling flanges analogue to A.6.4

The thickness of the coupling flanges clear of the bolt holes is not to be less than $0,65 \cdot t_f$.

The width of material outside the bolt holes is not to be less than $0,67 \cdot d_b$.

(IACS UR S10.6.1.2 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:

$$S = 0,00043 \cdot D^3 \quad [cm^3]$$

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. 14.9 and the cone length, ℓ_C [mm], is defined in Fig. 14.10b.

The cone shapes should fit very exact. The nut is to be carefully secured, e.g. by securing plate as shown in Fig. 14.9

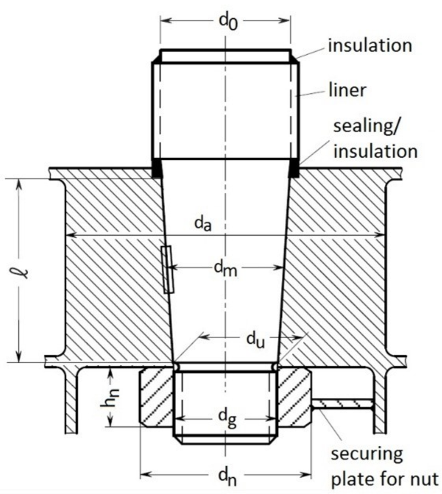


Figure 14.9: Cone coupling with key and securing plate

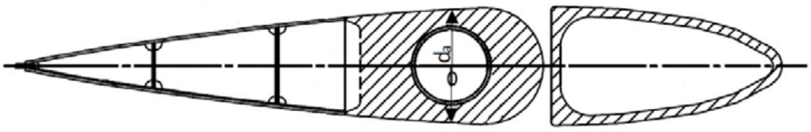


Figure 14.10a: Gudgeon outer diameter(d_a) measurement

(IACS UR S10.6.3.1)

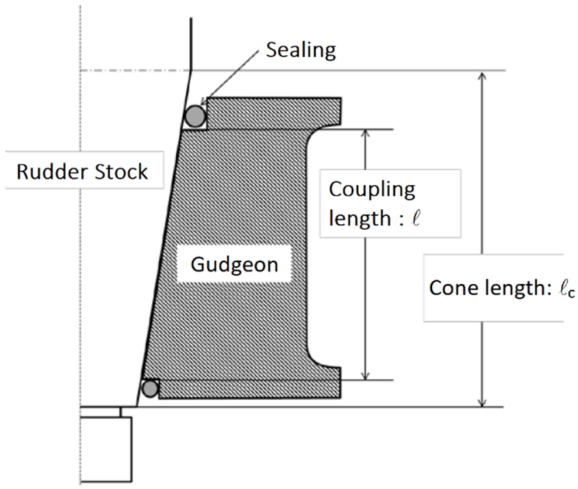


Figure 14.10b: Cone length and coupling length

(IACS UR S10.6.3.1)

4.1.2 The coupling length ℓ [mm] shall, in general, not be less than $1{,}5 \cdot d_0$.

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)

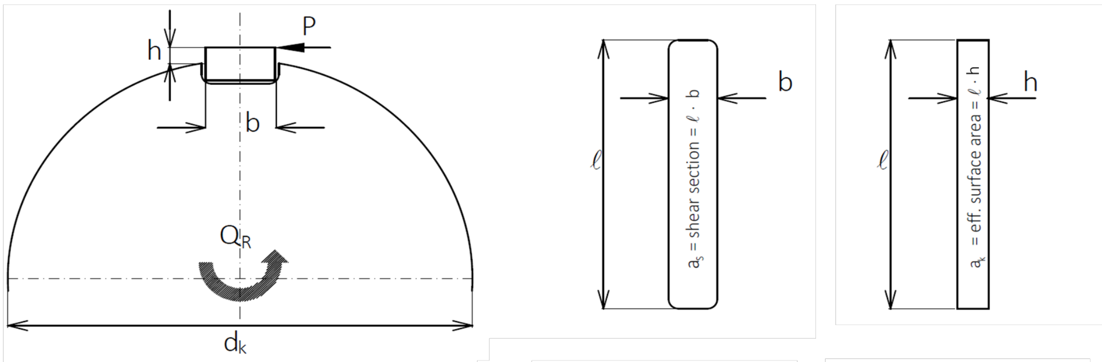
4.1.4 The effective surface area of the key (without rounded edges) between key and rudder stock or cone coupling, is not to be less than:

$$a_k = \frac{5 \cdot Q_F}{d_k \cdot R_{eH,2}} \quad [cm^2]$$

$R_{eH,2}$, = 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.



A cut view of rudder stock with a key

The shear area of the key (a_s)

The effective surface area of the key (a_k)

4.1.5 The dimensions of the slugging nut are to be as follows, see Fig. 14.9:

— height:

$$h_n \geq 0{,}6.\ d_g$$

— outer diameter (the greater value to be taken):

$$d_n \geq 1{,}2 \cdot d_u \text{ or } d_n \geq 1{,}5 \cdot d_g$$

— 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)

4.1.7 Notwithstanding the requirements in 4.1.3 and 4.1.6, where a key is fitted to the coupling between stock and rudder and it is considered that the entire rudder torque is transmitted by the key at the couplings, the scantlings of the key as well as the push-up force and push-up length are to be at the discretion of BKI.

(IACS UR S10.6.3.5)

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. 14.11.

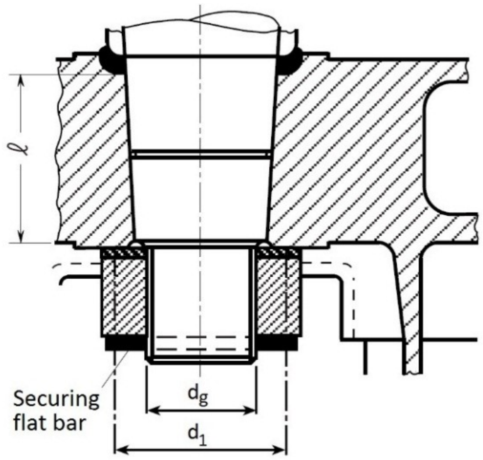


Figure 14.11: Cone coupling without key and with securing flat bar

A securing flat bar will be regarded as an effective securing device of the nut, if its shear area is not less than:

$$A_s = \frac{P_s \cdot \sqrt{3}}{R_{eH}} \quad [mm^2]$$

P_s = shear force as follows

$$= \frac{P_e}{2} \cdot \mu_1 \cdot \left[\frac{d_1}{d_g} - 0,6\right] \quad [N]$$

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. 14.11

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 :

$$p_{req1} = \frac{2 \cdot Q_F \cdot 10^3}{d_m^2 \cdot \ell \cdot \pi \cdot \mu_0} \quad [N/mm^2]$$

$$p_{req2} = \frac{6 \cdot M_c \cdot 10^3}{\ell^2 \cdot d_m} \quad [N/mm^2]$$

Q_F = design yield moment of rudder stock according to F [Nm]

d_m = mean cone diameter [mm], see Fig. 14.9

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/mm^2] of the material of the gudgeon

α = d_m / d_a (see Fig. 14.9)

d_a = the outer diameter of the gudgeon [mm], see Fig. 14.9 and Fig. 14.10a. The diameter shall not be less than values below (the least diameter is to be considered):

= 1,25 · d_o [mm]

For d_o, see Fig. 14.9.

(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

E = Young's modulus (2,06 · 10^5 N/mm^2)

Notwithstanding the above, the push-up length is not to be less than 2 mm.

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.

(IACS UR S10.6.4.3)

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:

$$\sigma_b \leq \frac{110}{k} \quad [N/mm^2]$$

shear stress due to Q_l:

$$\tau \leq \frac{50}{k} \quad [N/mm^2]$$

stress due to bending and shear:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\,\tau^2} \leq \frac{120}{k} \quad [N/mm^2]$$

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 · 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 :

$$\sigma_b \leq 75 \quad [N/mm^2]$$

shear stress due to Q_l :

$$\tau \leq 50 \quad [N/mm^2]$$

torsional stress due to M_t :

$$\tau_t \leq 50 \quad [N/mm^2]$$

equivalent stress due to bending and shear and equivalent stress due to bending and torsion:

$$\sigma_{v1} = \sqrt{\sigma_b^2 + 3\,\tau^2} \leq 100 \quad [N/mm^2]$$

$$\sigma_{v2} = \sqrt{\sigma_b^2 + 3\,\tau_T^2} \leq 100 \quad [N/mm^2]$$

(IACS UR S10.5.1(b))

$$M_R = C_{R2} \cdot f_1 + B_1 \cdot \frac{f_2}{2} \quad [Nm]$$

$$Q_1 = C_{R2} \quad [N]$$

f_1, f_2 see Fig. 14.12.

As first approximation the torsional stress may be calculated in a simplified manner as follows:

$$\tau_t = \frac{M_T}{2 \cdot \ell \cdot h \cdot t} \quad [N/mm^2]$$

$$M_t = C_{R2} \cdot e \quad [Nm]$$

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. 14.12. 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. 14.12

The distance ℓ between the vertical webs should not exceed 1,2 · h.

The radii in the rudder plating are not to be less than 4 - 5 times the plate thickness, but in no case less than 50 mm.

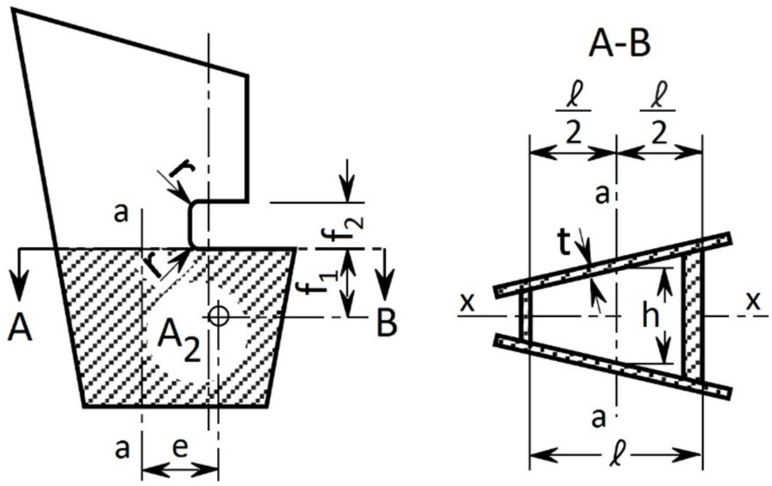


Figure 14.12: Geometry of semi-spade rudder

2. Rudder plating

2.1 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.

2.2 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.

2.3 The thickness of the webs is not to be less than 70% of the thickness of the rudder plating according to 2.1, 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.

3. Transmitting of the rudder torque

For transmitting the rudder torque, the rudder plating according to 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.

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

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. 14.7 [N]

q = allowable surface pressure according to Table 14.2

Table 14.2: Allowable surface pressure q

Bearing material	q [N/mm^2]
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:

$$d = 0,35 \cdot \sqrt{B_1 \cdot k_r} \quad [mm]$$

B_1 = support force [N] in the rudder horn according to 4.4

k_r = see A.6.4

(IACS UR S10.7.1)

5.2 The thickness of any liner or bush shall not be less than:

$$t = 0,01 \cdot \sqrt{B_1} \quad [mm]$$

B_1 = support force [N] in the rudder horn according to 4.4

t_{min} = minimum thickness of bearings liners and bushes according to 4.1

(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 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. 14.9.

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)

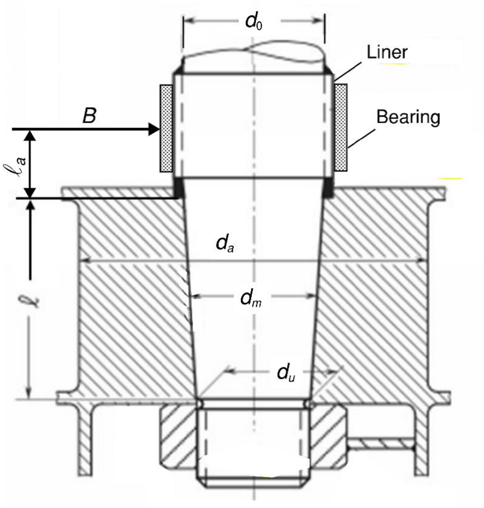


Figure 14.13: Pintle cone coupling indicating ℓ_a

(IACS UR S10 Figure 9)

5.5 The pintles are to be arranged in such a manner as to prevent unintentional loosening and falling out. For nuts and threads the requirements of 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:

$$\frac{d_b}{1000} + 1,0 \quad [mm]$$

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:

$$W_S = c_s \cdot d_c^3 \cdot \left(\frac{H_E - H_X}{H_E}\right)^2 \cdot \frac{k}{k_s} \cdot 10^{-4} \quad [cm^3]$$

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.6.4

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:

$$b = s_V + \frac{2\,H_X}{3} \quad [m]$$

s_V = spacing between the two vertical webs [m] (see Fig. 14.14)

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate, they are to be deducted.

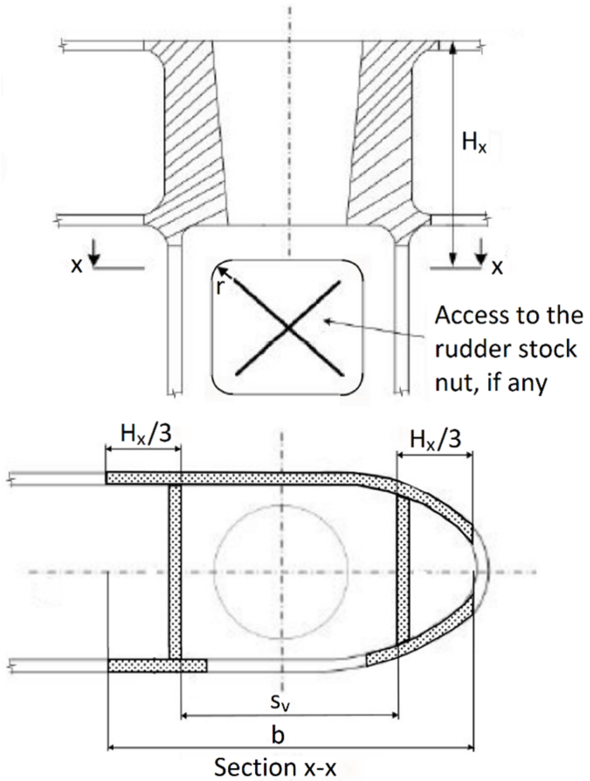


Figure 14.14: Cross-section of the connection between rudder blade structure and rudder stock housing, example with opening in only one side shown

(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

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:

$$Q_F = 0,02664 \cdot \frac{D_t^3}{k_r} \quad [Nm]$$

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 $1,145 \cdot D_t$.

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. 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.

I. 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)

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 Ships intended for navigation in arctic waters may have the ice Class Notations **PC7** - **PC1** affixed to their Character of Classification if the requirements given in requirement for the Construction of Polar Class Ships are complied with.

(IACS UR I.2)

1.8 If the scantlings required by this Section are less than those required for ships without ice strengthening, the scantlings required by the other Sections of these Rules are to be maintained.

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:

$$T_{min} = h_0 \cdot (2 + 2,5 \cdot 10^{-4} \cdot D) \quad [m] \quad \text{or}$$

$$T_{min} = 4 \cdot h0 \quad [m]$$

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

$f_1 \cdot f_2 \geq 0,85$

φ_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_μ = $0,15 \cdot \cos\varphi_2 + \sin\Psi \cdot \sin\alpha$; $C_\mu \geq 0,45$

C_Ψ = $0,047 \cdot \Psi - 2,115$; $C_\Psi = 0$ 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.

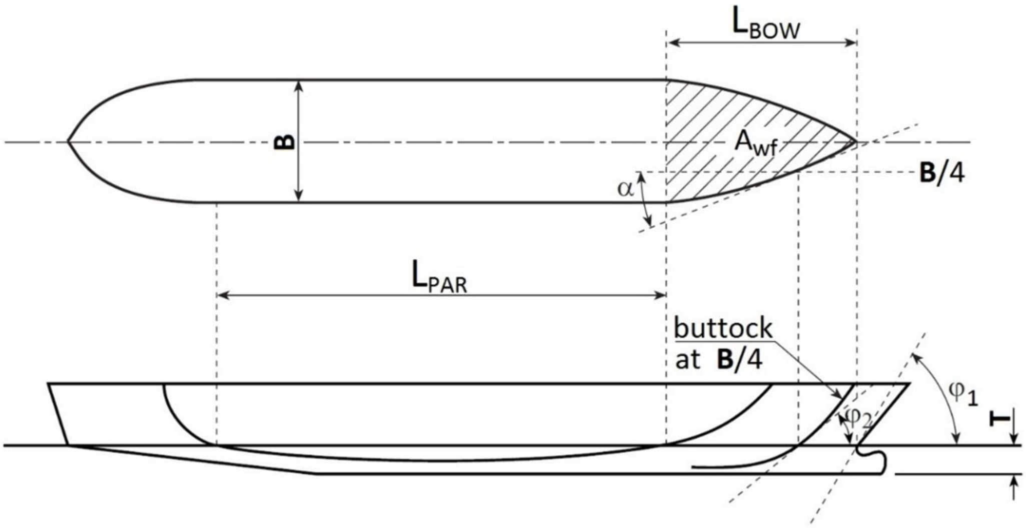


Figure 15.1: Rake of the stem φ_1 and rake of the bow φ_2 at B/4 from CL

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 = 1 530	[N]
f_2	=	45,8	[N/m],	g_2 = 170	[N/m]
f_3	=	14,7	[N/m],	g_3 = 400	[N/m1,5]
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 $D_P/\mathbf{T}$, **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.

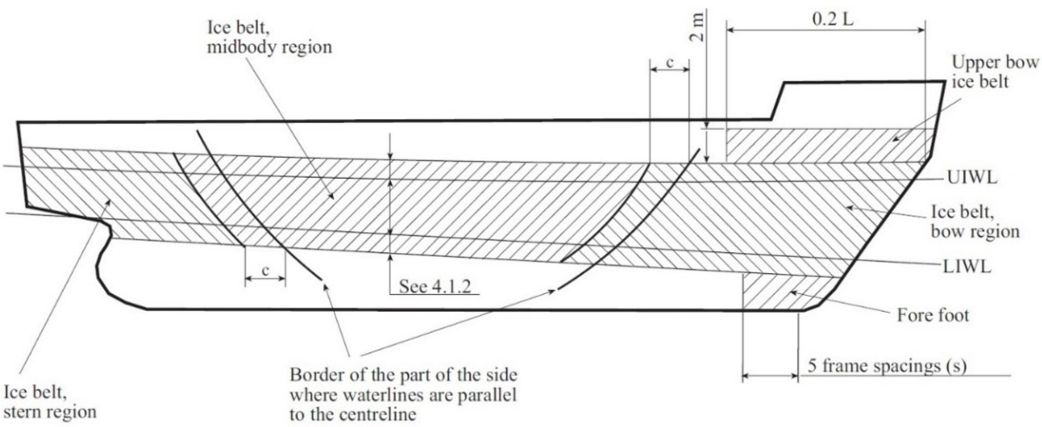


Figure 15.2: Ice belt

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.

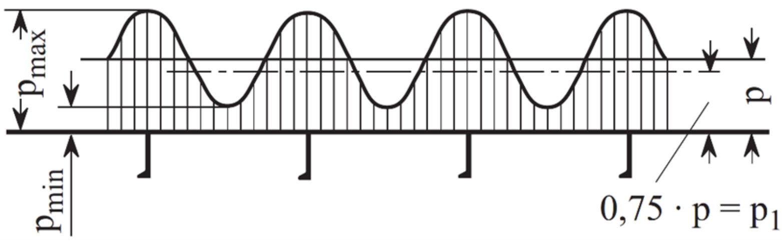


Figure 15.3: Ice load distribution

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 $\tau_y = R_{eH} / \sqrt{3}$.

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:

$$p = c_d \cdot c_1 \cdot c_a \cdot p_0 \quad [N/mm^2]$$

$$c_d = \frac{a \cdot k + b}{1000}$$

$$k = \frac{\sqrt{D \cdot P}}{1000}$$

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:

$$W = \frac{p \cdot a \cdot h \cdot \ell}{m_t \cdot R_{eH}} 10^6 \quad [cm^3]$$

$$m_t = \frac{7 \cdot m_0}{7 - 5 \cdot \frac{h}{\ell}}$$

2. shear area:

$$A = \frac{\sqrt{3} \cdot f \cdot p \cdot h \cdot a}{2 \cdot R_{eH}} 10^4 \quad [cm^2]$$

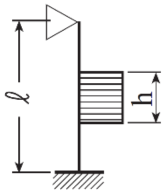
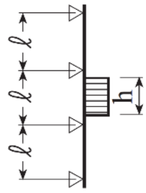
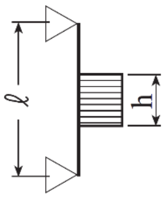
m_0 = coefficient according to Table 15.10.

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
	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:

$$A = \frac{\sqrt{3} \cdot f_5 \cdot f_{5a} \cdot f_{5b} \cdot p \cdot h \cdot \ell}{2 \cdot R_{eH}} \cdot 10^4 \qquad [cm^2]$$

$p \cdot h$ 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 = maximum calculated shear force under the ice load P

$= P \cdot k_1$ [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.

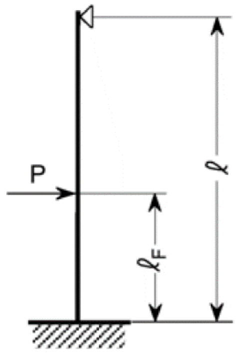


Figure 15.4: Lengths ℓ and ℓ_F

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 :

$$W = \frac{M}{R_{eH}} \cdot \sqrt{\frac{1,0}{1 - \left[\gamma \cdot \frac{A}{A_a}\right]^2}} \cdot 10^3 \quad [cm^3]$$

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).

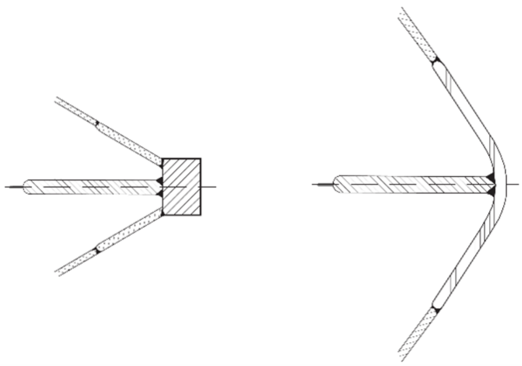


Figure 15.5: Stem

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.

10.3 The section modulus W_c of continuous bars, is not to be less than determined by the following formula:

$$W_c = \frac{s_c \cdot D^2}{4 \cdot R_{eH}} \cdot (1 - \varkappa) \cdot 10^{-4} \quad [\text{cm}^3] \qquad W_c \geq 35 \text{ cm}^3$$

s_c = spacing [mm] of continuous bars

D = diameter [mm] of thruster tunnel

κ = coefficient, defined as:

$$= 0,4 \cdot \frac{I_i}{I_c} \cdot \frac{s_c}{s_i} \qquad \kappa \leq 0,5$$

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

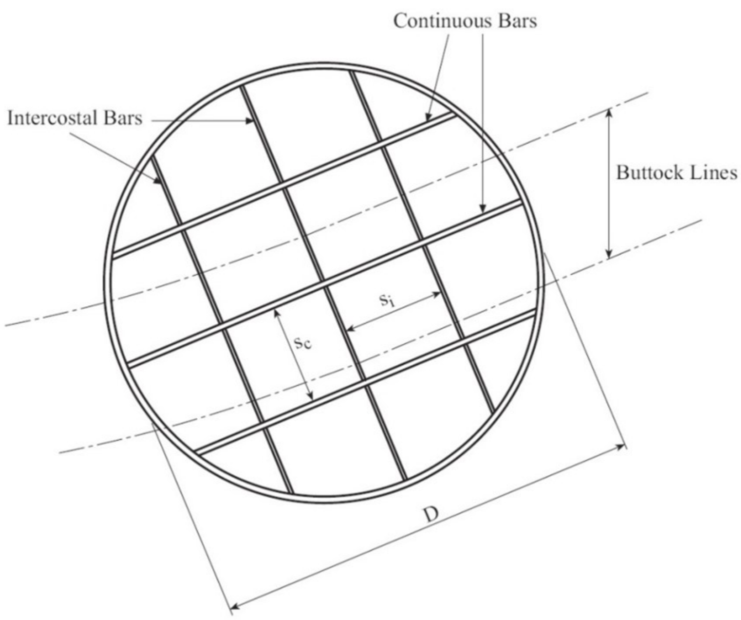


Figure 15.6: Standard construction of lateral thruster grid

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 Scantlings of external funnels are to be determined as for deckhouses.

1.8 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

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.

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 E.

(IACS UR S3.1)

2. Definitions

The design load for determining the scantlings is:

$$p_A = n \cdot c\,(b \cdot f - z) \qquad [\mathrm{kN/m^2}]$$

for weather deck hatch cover and of hatch coamings:

$f = c_L \cdot c_0$

for superstructure end bulkheads and deckhouse walls:

$$f = \frac{L}{10} e^{-L/300} - \left[1 - \left(\frac{L}{150}\right)^2\right] \qquad \text{for } L < 150 \text{ m}$$

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

$$= 11{,}03 \qquad \text{for } L > 300 \text{ m}$$

$p_{A,min}$ = 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 $1{,}8 \le h_N \le 2{,}3$

$n = 20 + \frac{L}{12}$ 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

$= 10 + \frac{L}{12}$ 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

$= 5 + \frac{L}{15}$ 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

$= 7 + \frac{L}{100} - 8\frac{x}{L}$ for aft ends of superstructures and deckhouses walls abaft of amidships

$= 5 + \frac{L}{100} - 4\frac{x}{L}$ 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.

$$b = 1{,}0 + \left(\frac{\frac{x}{L} - 0{,}45}{C_B + 0{,}2}\right)^2 \qquad \text{for } \frac{x}{L} < 0{,}45$$

$$b = 1{,}0 + 1{,}5\left(\frac{\frac{x}{L} - 0{,}45}{C_B + 0{,}2}\right)^2 \qquad \text{for } \frac{x}{L} \ge 0{,}45$$

$0{,}60 \le C_B \le 0{,}80$; 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}

<table>
<tr><th rowspan="3">L</th><th colspan="5">p_{Amin} [kN/m^2] for</th></tr>
<tr><th colspan="2">Unprotected fronts</th><th colspan="3">Other area</th></tr>
<tr><th>lowest tier</th><th>higher tier</th><th>tier ≤ 3^{rd}</th><th>4^{th} tier</th><th>tier ≥ 5^{th}</th></tr>
<tr><td>≤ 50</td><td>30</td><td rowspan="4">12,5 but not less than in other area</td><td>15</td><td rowspan="4">12,5</td><td rowspan="4">8,5</td></tr>
<tr><td>> 50</td><td rowspan="2">$25 + \frac{L}{10}$</td><td>$12,5 + \frac{L}{20}$</td></tr>
<tr><td>≤ 250</td><td></td></tr>
<tr><td>> 250</td><td>50</td><td>25</td></tr>
</table>

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:

$$t = 0,9 \cdot \mathbf{a} \sqrt{p_a \cdot k} + t_k \quad [mm]$$

$$t_{min} = \left(5,0 + \frac{\mathbf{L}}{100}\right)\sqrt{k} \quad [mm] \quad \text{for the lowest tier}$$

$$= \left(4,0 + \frac{\mathbf{L}}{100}\right)\sqrt{k} \quad [mm] \quad \text{for the upper tiers, however not less than 5,0 mm}$$

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:

$$t = 8,0 \cdot \mathbf{a} \sqrt{k} + t_K \quad [mm]$$

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. 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.

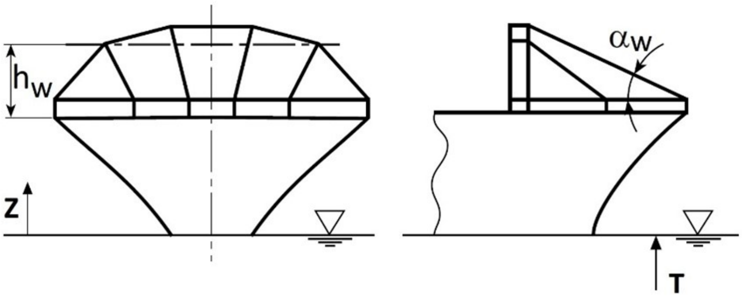


Figure 16.1: Whaleback

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:

$$t = 0,9 \cdot \mathbf{a} \cdot \sqrt{p_{BW} \cdot k} + t_k \quad \text{[mm] with} \quad t \geq t_{min}$$

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 $\alpha_W \leq 90°$ and whalebacks with $\alpha_W > 20°$

The section modulus W of the stiffeners is to be determined by the following formula:

$$W = 0,35 \cdot \mathbf{a} \cdot \ell^2 \cdot p_{BW} \cdot k \ [cm^3]$$

3.2.3 Whalebacks with $\alpha_W < 20°$

The scantlings of stiffeners are to be the same as for deck beams of non-effective superstructures according to B.3.

3.3 Primary supporting structure

3.3.1 General

Sufficient supporting structures are to be provided.

3.3.2 Breakwaters with $\alpha_W \leq 90°$ and whalebacks with $\alpha_W > 20°$

For primary supporting members of the structure a stress analysis has to be carried out. The equivalent stress is not to exceed the following permissible stress σ_{perm}:

$$\sigma_{perm} = \frac{230}{k} \quad [N / mm]$$

3.3.3 Whalebacks with $\alpha_W < 20°$

The scantlings of primary supporting members are to be the same as for primary supporting members of decks of non-effective superstructures accordant to 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 $\alpha_W \le 90°$ and whalebacks with $\alpha_W > 20°$

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

$$p_{BW} = n \cdot d\,(b \cdot c_L \cdot c_0 - z) \quad [kN/m^2]$$

$p_{BW,min}$ = 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 $\alpha_W < 20°$

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

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

p_D = load on forecastle decks according to Section 4, B.1

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

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, A.3.6.7.

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 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.

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 For hatch covers on lower decks and within superstructures the application of the steel with R_{eH} > 355 N/ mm² is to be agreed with BKI.

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

g	=	gravitional acceleration [m/s²], defined as:
	=	9,81 m/s²
p	=	design load [kN/m²] 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, see B.2.1.3
	=	liquid pressure p_1, p_2 according to Section 4, D.1
R_{eH}	=	minimum nominal upper yield point of the steel used [N/mm²] according to Section 2, B

R_m = tensile strength of the steel used [N/mm²]

For normal strength hull structural steel:

R_m = 400 N/mm² with R_{eH} = 235 N/mm²

For higher strength hull structural steel:

R_m = 440 N/mm² with R_{eH} = 315 N/mm²

= 490 N/mm² with R_{eH} = 355 N/mm²

ℓ = unsupported span of stiffener [m], to be taken as the spacing of main girders or the distance betwen a main girder and the edge support for hatch covers and as the spacing coaming stays for hatch coamings, as applicable

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

p_D = load on weather decks according to Section 4, B.1

p_L = load on cargo decks according to Section 4, C.1

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	Hatch covers:	1,0
	Hatch coamings	according to Section 3, K.1
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/mm² 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, in kN/m², on for weather deck hatch covers is to be taken from Table 17.2.

In Fig. 17.1 for the position 1 and 2 are illustrated for an example ship.

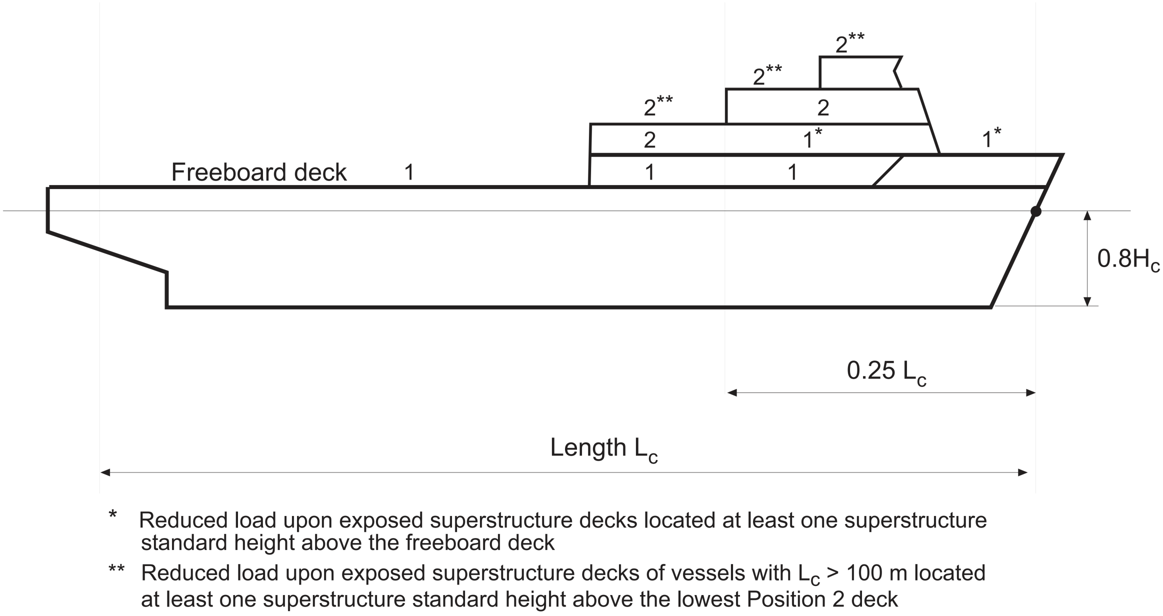
Where an increased freeboard is assigned, the design load for hatch covers according to Table 17.2 on the actual freeboard deck may be as required for a superstructure deck, provided the summer freeboard is such that the resulting draught will not be greater than that corresponding to the minimum freeboard 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)

Table 17.2: Design load of weather deck hatches

Position	Design load p_H [kN/m^2]	
	$\frac{x}{L_C} \leq 0,75$	$0,75 < \frac{x}{L_C} \leq 1,0$
1	9,81 · 3,5	On freeboard deck for type B ships according to ICLL $9,81 \cdot \left[(0,0296 \cdot L_1 + 3,04) \cdot \frac{x}{L_C} - 0,0222 \cdot L_1 + 1,22\right]$
		upon exposed superstructure decks located at least one superstructure standard height h_N above the freeboard deck 9,81 · 3,5
		$L_1 = L_C$, but not more than 340 m
2	9,81 · 2,6	
	upon exposed superstructure decks located at least one superstructure standard height h_N above the lowest Position 2 deck 9,81 · 2,1	

(IACS UR S21.2.1)



(IACS UR S21 Figure 1)

Figure 17.1: Positions 1 and 2

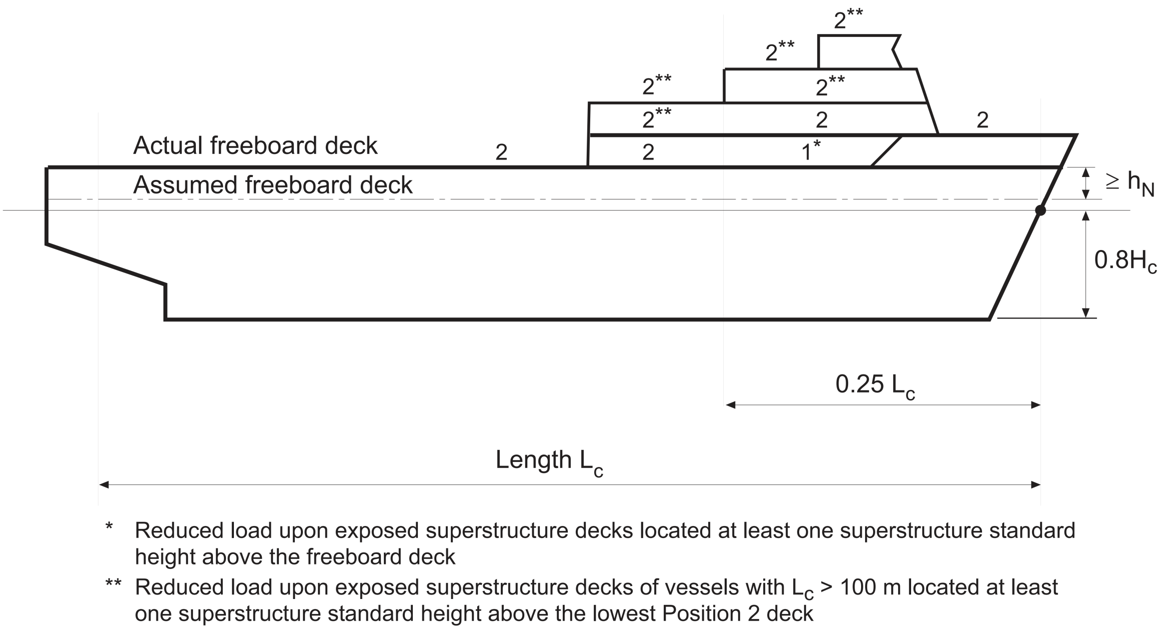


Figure 17.2: Positions 1 and 2 for an increased freeboard

(IACS UR S21 Figure 2)

2.1.2 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.

2.1.3 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)

2.2 Load case C: Container loads

2.2.1 The loads defined in 2.2.2 to 2.2.4 shall be applied where containers are stowed on the hatch covers.

(IACS UR S21 2.4.1)

2.2.2 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 stackk [t]

(IACS UR S21 2.4.2)

2.2.3 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

$= \frac{\sum (z_i \cdot W_i)}{M}$

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]

A_z, B_z, B_y = support forces in y-, z- direction at the stack corners

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)

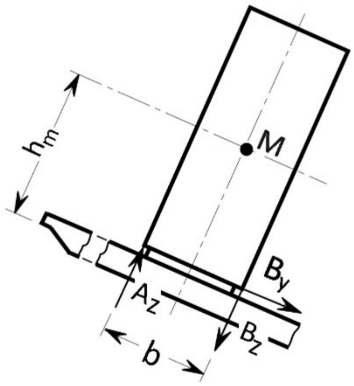


Figure 17.3: Forces due to load case C acting on hatch cover

(IACS UR S21.2.4.3)

2.2.4 Load cases with partial loading

The load cases in 2.2.2 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)

2.2.5 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.

2.3 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)

2.4 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:

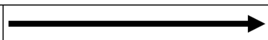
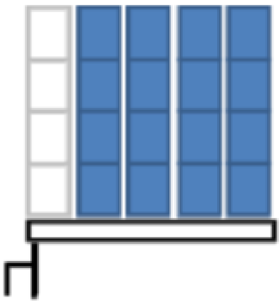
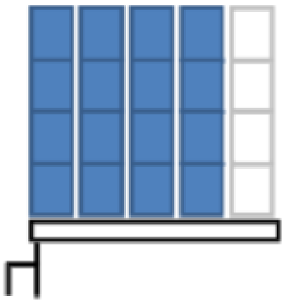
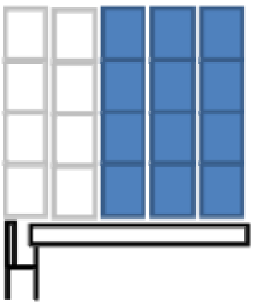
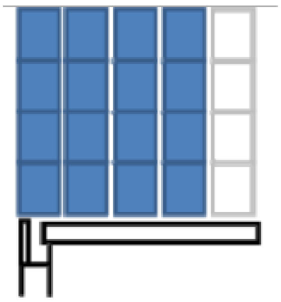
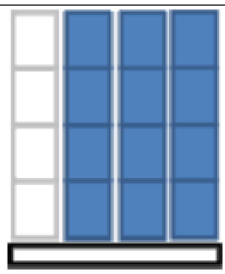
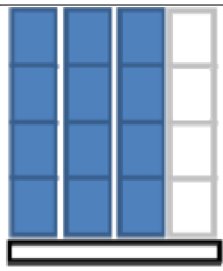
$$F_h = m \cdot a_i$$

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)

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)

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 C 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:

$$\sigma_V = \sqrt{\sigma^2 + 3 \cdot \tau^2} \quad [\text{N/mm}^2]$$

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:

$$\sigma_v = \sqrt{\sigma_x^2 - \sigma_x \cdot \sigma_y + \sigma_y^2 + 3 \cdot \tau^2} \quad [N/mm^2]$$

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 hatch cover structures sufficient buckling strength is to be demonstrated. Verifications of buckling strength according to Section 3, F are to be based on $t = t_{net}$ and stresses corresponding to t_{net} applying the following safety factor S:

- S = 1,25 for hatch covers when subjected to the vertical design load pH according to 2.1
- S = 1,10 for hatch covers when subjected to the horizontal design load p_A according to 2.1 as well as to load cases B to E according to 2.2 through 2.5.

For verification of buckling strength of plate panels stiffened with U-type stiffeners a correction factor F_1 = 1,3 may be applied.

(IACS UR S21.3.1)

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.

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 Rules for Hull (Pt.1, Vol.II) 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 Rules for Hull (Pt.1, Vol.II) 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.

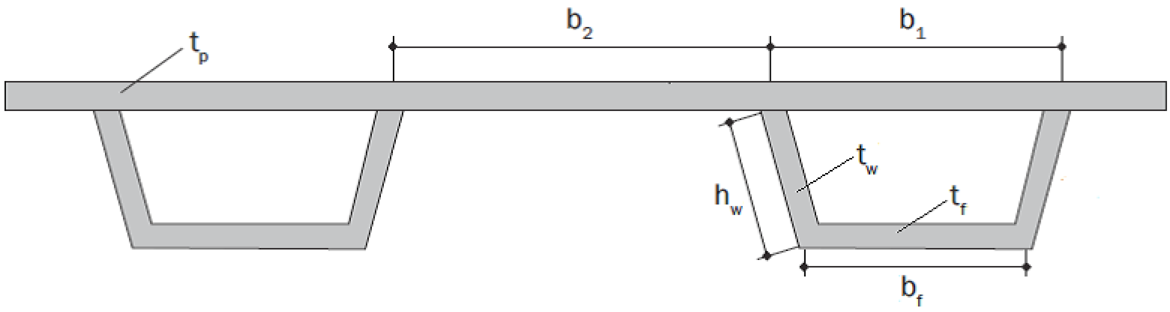


Figure 17.4: Example of hatch cover fitted with U-type stiffeners

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 Rules for Hull (Pt.1, Vol.II) 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 Rules for Hull (Pt.1, Vol.II) 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 Rules for Hull (Pt.1, Vol.II) Section 3, F.1.3.7. Assessment Method A (-A) and Method B (-B) as defined in Rules for Hull (Pt.1, Vol.II) 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 Rules for Hull (Pt.1, Vol.II) 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)

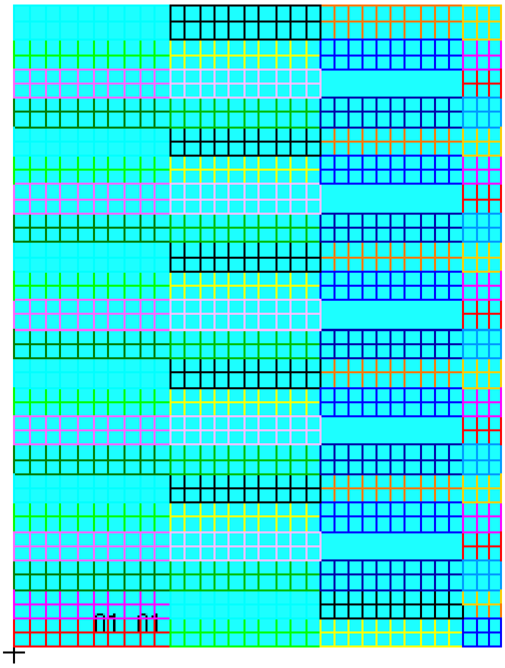


Figure 17.5: Example of hatch cover fitted with U-type stiffeners

(IACS UR S21.Figure 6)

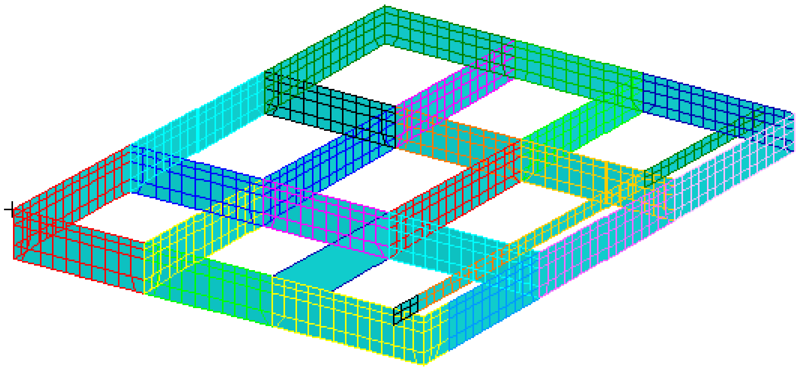


Figure 17.6: Example of hatch cover fitted with U-type stiffeners

(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 Rules for Hull (Pt.1, Vol.II) Section 3, F.5.2.2 and 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 Rules for Hull (Pt.1, Vol.II) Section 3, F.1.3.9 and F.4, and calculated per Rules for Hull (Pt.1, Vol.II) 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 2.3:

= 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 :

$$t = \max\left[t_1 \,;\, t_2\right] \quad [\text{mm}]$$

$$t_1 = c_p \cdot 16,2 \cdot a \cdot \sqrt{\frac{p}{R_{eH}}} + t_K \quad [\text{mm}]$$

$$t_2 = 10 \cdot a + t_K \quad [\text{mm}]$$

$$t_{min} = 6,0 + t_K \quad [\text{mm}]$$

$$c_p = 1,5 + 2,5\left(\frac{|\sigma_x|}{R_{eH}} - 0,64\right) \geq 1,5 \quad \text{for } p_H \text{ or } p_L$$

$$= 1,0 + 2,5\left(\frac{|\sigma_x|}{R_{eH}} - 0,64\right) \geq 1,0 \quad \text{for } p_D;\, p_d;\, p_1;\, p_2$$

σ_x = maximum normal stress [N/mm²] of hatch cover plating, determined according to Fig. 17.7

p = design load [kN/m²], 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.

(IACS UR S21.3.2)

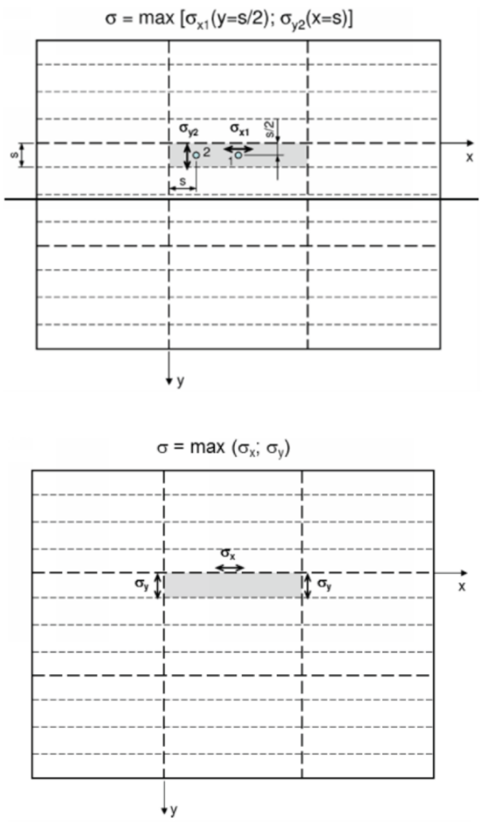


Figure 17.7: Determination of normal stress of the hatch cover plating

(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]	

(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:

$$t = 16{,}2 \cdot a \cdot \sqrt{\frac{p_A}{R_{eH}}} + t_K \quad [mm]$$

$$t = 8{,}5 \cdot a + t_k \quad [mm]$$

$$t_{min} = 5{,}0 + t_K \quad [mm]$$

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:

$$I = 6{,}0 \cdot q \cdot s^4 \quad [cm^4]$$

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 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:

$$W_{net} = \frac{p \cdot a \cdot \ell^2}{f_{bc} \cdot \sigma_a} \quad [cm^3]$$

$$A_{net} = \frac{8{,}7 \cdot p \cdot a \cdot \ell}{\sigma_a} \cdot 10^{-3} \quad [cm^2]$$

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

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.

For flat bar stiffeners and buckling stiffeners, the ratio h/t_w is to be not greater than $15\sqrt{k}$, where:

— h = height of the stiffener

— t_w = net thickness of the stiffener

Stiffeners parallel to main girder webs and arranged within the effective breadth according to Section 3, 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 - 2.4, 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 2.2.4)

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:

$$p_{n,max} = 3{,}0 \cdot p_n \quad [N/mm^2]$$

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

$$k_\ell = \left(\frac{235}{R_{eH}}\right)^e$$

R_{eH} is not to be taken greater than $0{,}70 \cdot R_m$.

e = 0,75 for $R_{eH} > 235$ [N/mm²]

= 1,00 for $R_{eH} \le 235$ [N/mm²]

Rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5,0 m² 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 2.3, 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)

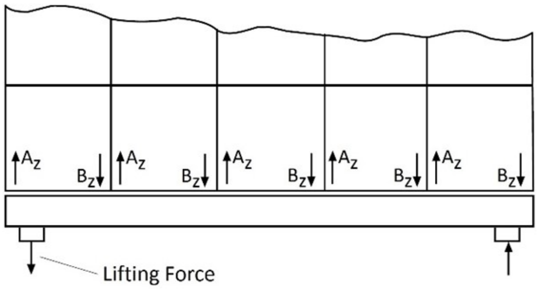


Figure 17.8 Lifting forces at a hatch cover

(IACS UR S21 Figure 10)

5.6.6 Hatch covers consisting of several parts have to be secured against accidental lifting.

5.7 Hatch cover stoppers

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/m² according to 2.1.5.

Design forces for the stoppers are obtained from the loads according to 2.1.5 and 2.4.

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)

5.8 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 C 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 2.4 acting at the position h_E using the equivalent stress level $\sigma_v = R_{eH}$ [N/mm²].

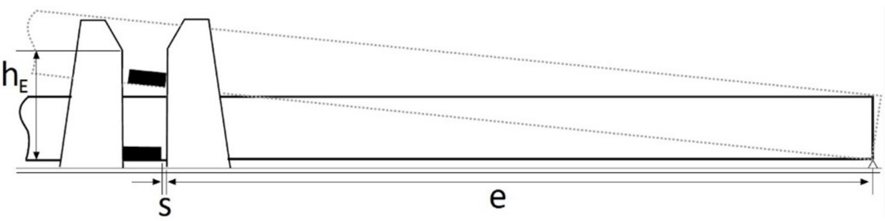


Figure 17.9 Height of transverse cover guides

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 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)

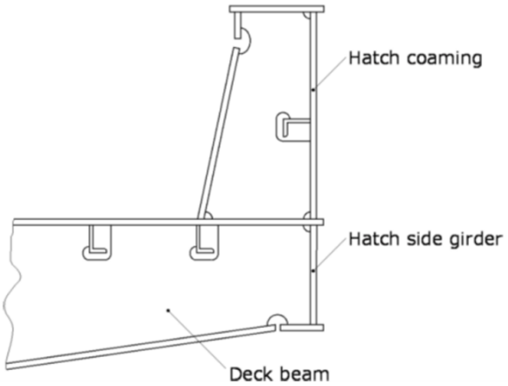


Figure 17.10: Example for a hatch side girder

(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 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:

$$t = t_{net} + t_K \quad [mm]$$

$$= 14,6 \cdot a \cdot \sqrt{\frac{p_A}{R_{eH}}} + t_K \quad [mm]$$

$$t_{min} = 6,0 + \frac{\mathbf{L}}{100} + t_K \quad [mm],$$ **L** need not be taken greater than 300 m

p_A = horizontal design load [kN/m^2], as defined in B.2.1.5

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)

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 Rules for Hull (Pt.1, Vol.II) 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 $a = 0{,}44 \cdot t_W$.

For toes of stay webs within $0{,}15 \cdot h_W$ the throat thickness is to be increased to $a = 0{,}7 \cdot t_W$ for $t_W \le 10$ mm.

For $t_W > 10$ mm deep penetration double bevel welds are to be provided in this area.

(IACS UR S21.5.3.1)

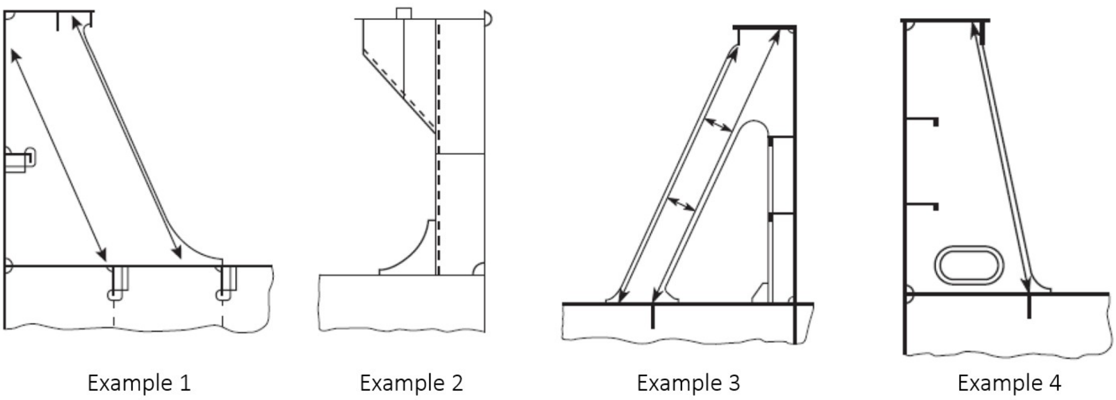


Figure 17.11 Examples of coaming stays

(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 S21.5.3.2)

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:

$$W_{net} = \frac{1000 \cdot a \cdot \ell^2 \cdot p_A}{f_{bc} \cdot R_{eH}} \quad [cm^3]$$

$$A_{net} = \frac{10 \cdot a \cdot \ell \cdot p_A}{R_{eH}} \quad [cm^2]$$

where:

p_A	=	horizontal design load [kN/m^2], as defined in B.2.1.5
f_{bc}	=	boundary coefficient:
	=	8 for the end spans of stiffeners sniped at the coaming corners
	=	12 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 container ships that are contracted for construction on or after 1st January 2004 on the exposed deck over the forward 0,25**L**, applicable to:

- 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 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 and 2.5)

1) For ships contracted for construction prior to 1st January 2004 refer to IACS UR S26, para. 3.

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)

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)

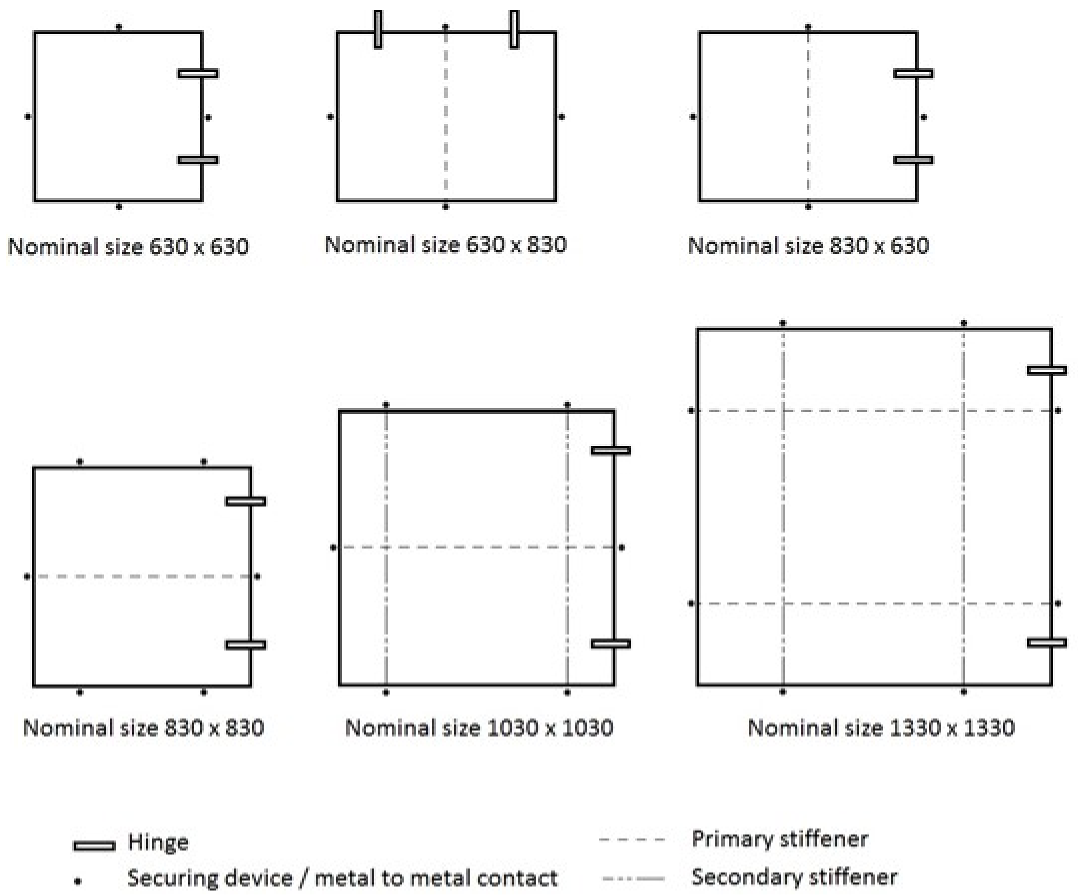


Figure 17.12 Arrangement of stiffeners

(IACS UR S26. Figure 1)

1 : butterfly nut
2 : bolt
3 : pin
4 : center of pin
5 : fork (clamp) plate
6 : hatch cover
7 : gasket
8 : hatch coaming
9 : bearing pad welded on the bracket of a toggle bolt for metal to metal contact
10 : stiffener
11 : inner edge stiffener

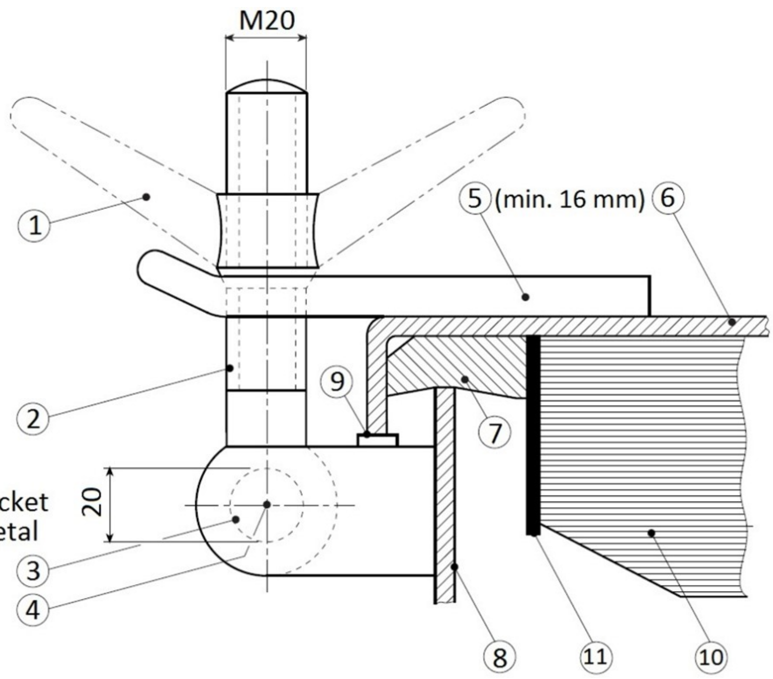


Figure 17.13 Example of a primary securing method

(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

(IACS UR S26.5.1)

2.4.2 Dogs (twist tightening handles) with wedges are not acceptable.

(IACS UR S26.5.2)

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 is not less than 2,3.

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.

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.

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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. Design of the anchoring equipment

3.1 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.

3.2 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.

3.3 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.

3.4 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.

3.5 It is assumed that under normal circumstances a ship will use only one bow anchor and chain cable at a time.

3.6 Manufacture of anchors and anchor chain cables is to be in accordance with Rules for Materials (Pt.1, Vol.V) Sec.12 and 13.

3.7 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

(IACS UR A1.1)

4. 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.

5. Structural requirements associated with towing and mooring equipments

5.1 These requirements applies to the 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.

5.2 For container ships, 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 the design and construction of those shipboard fittings and supporting hull structures.

6. References

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

IACS UR A1 Rev.7 Corr.1

IACS UR A2 Rev.5

IACS UR L4 Rev.3 Corr.2

IACS Rec. 10 Rev.4

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

6.2 For the substructures of windlasses and chain stoppers, see Section 10, B.5.

7. Definitions

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 at wihch 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} [m²]

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 h_F. 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 [m²], 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 hF. 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.

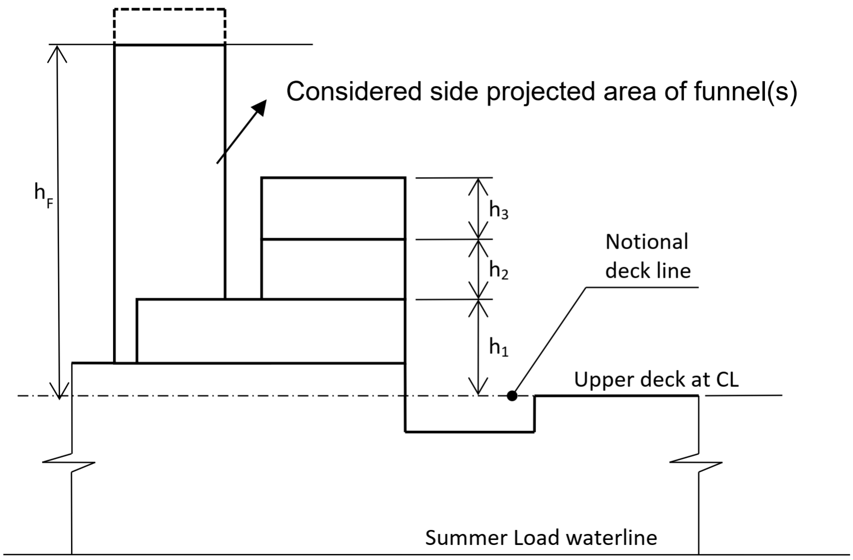

Figure 18.1a: Side Projected Area

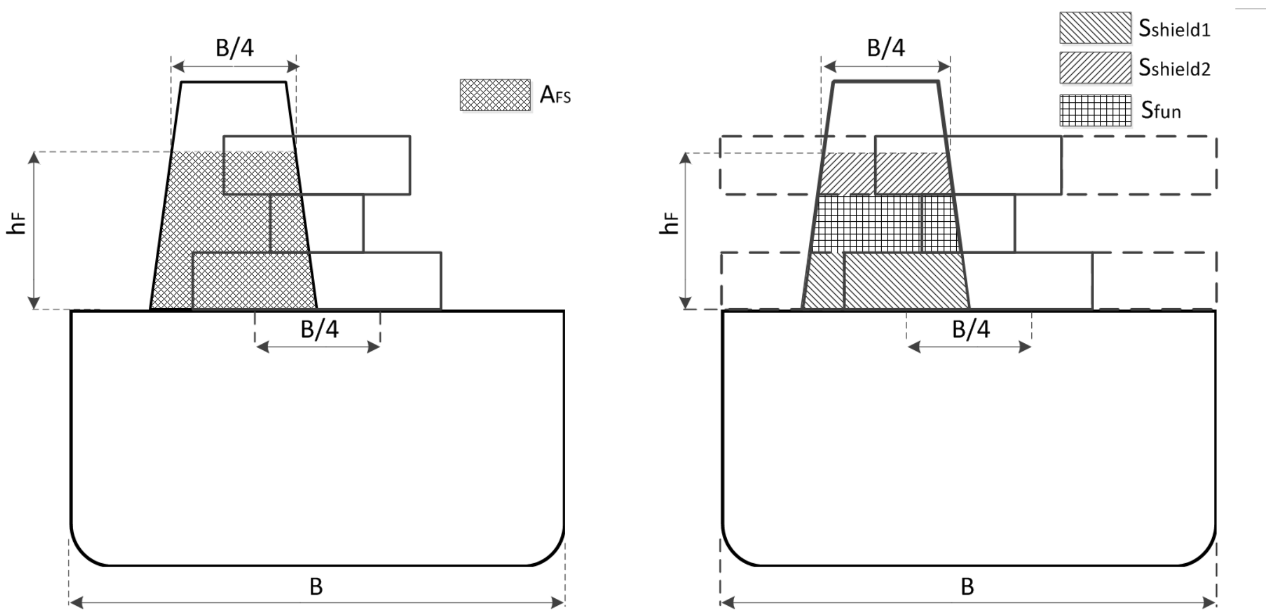

Figure 18.1b: Front projected area

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.*

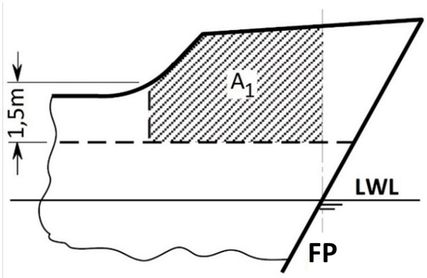

Figure 18.2: Effective area A_1 of bulwark

(IACS UR A1.2)

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 nominal capacity condition should be included for the determination of side-projected area A. The nominal capacity condition is defined in A.7.

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.7.

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 5.

(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.

(IACS UR A1.4.1.3)

5. 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.

6. Anchor holding power tests for HHP

6.1 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.

6.2 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.

6.3 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.

6.4 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.

6.5 The holding power test load is not to exceed the proof load of the anchor.

(IACS UR A1.4.2)

7. Testing of anchors

The testing of all type of anchor shall be accordance with Rules of Materials (Pt.1, Vol.V) Sec.12. F.

8. 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.

3. Grade K-2 and K-3 chain cables shall be post production quenched and tempered and purchased from recognized manufacturers only.

4. The total length of chain given in the Table 18.2 is to be divided in approximately equal parts between the two bower anchors.

5. Either stud link or short link chain cables may be used for stream anchors.

6. Bower anchors are to be associated with stud link chain cables for one of the grades listed under Rules for Material (Pt.1, Vol.V) Sec.13, Table 13.2.

(IACS UR A1.5.2)

7. 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 Material (Pt.1,Vol.V) Sec.13, Table 13.7.

(IACS UR A1.5.3)

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. 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 · d. As an alternative, circular base areas may be selected, the diameter of which shall not exceed (30 to 35) · 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))

2.1 Special requirements to minimize the ingress of water

2.1.1 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)

Figure 18.3: Chain locker arrangement

2.1.2 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)

2.1.3 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"*

2.1.4 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)

3. Adequate drainage facilities of the chain locker are to be provided.

(IACS Rec. 10 1.3.1 (c))

4. Where the chain locker boundaries are also tank boundaries their scantlings of stiffeners and plating are to be determined as for tanks in accordance with Section 12.

Where this is not the case the plate thickness is to be determined as for t_2 and the section modulus as for W_2 in accordance with Section 12, B.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.

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.7.*

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.*

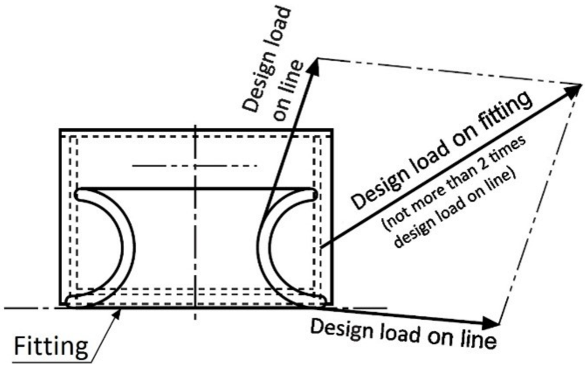

Figure 18.4: Application of design loads

(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)

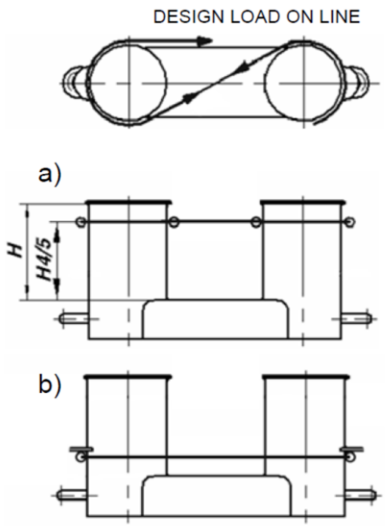

Figure 18.5: Attachment point of mooring line

(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

(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:

- The ballast draft should be considered for the calculation of the side-projected area A.
- 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.

— 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.7.

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 = 25 [m/s]:

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.*

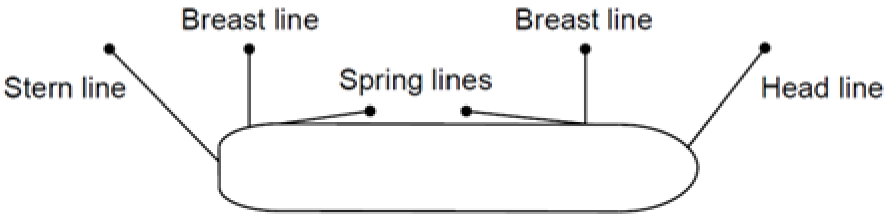

Figure 18.6: mooring line

(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:

$$MBL_{SD} = 0{,}1 \cdot A + 350 \quad [kN] \quad \text{with } MBL_{SD} \leq 1275 \text{ kN}$$

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 $MBL_{SD}^* \geq MBL_{SDmin}^*$

$$MBL_{SDmin}^* \geq \left(\frac{21}{v_W}\right)^2 \cdot MBL_{SD}$$

MBL_{SDmin}^* = ship design minimum breaking load corresponding to an acceptable wind speed $v_W{}^*$ of 21 m/s

if $v_W{}^* > v_W$

$$MBL_{SDmin}^* \geq \left(\frac{v_W^*}{v_W}\right)^2 . MBL_{SD}$$

(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:

$$n = 8{,}3 \cdot 10^{-4} \cdot A + 6$$

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:

$$MBL_{SD}{}^{**} = 1{,}2 \cdot MBL_{SD} \cdot \frac{n}{n^{**}} \leq MBL_{SD} \qquad \text{for increased number of lines}$$

$$MBL_{SD}{}^{**} = MBL_{SD} \cdot \frac{n}{n^{**}} \qquad \text{for reduced number of lines}$$

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. Ropes

5.1 The following items 5.2 to 5.3 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.

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

5.2 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.

5.3 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.

6. 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)

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.7.*

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.*

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.

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.

(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.

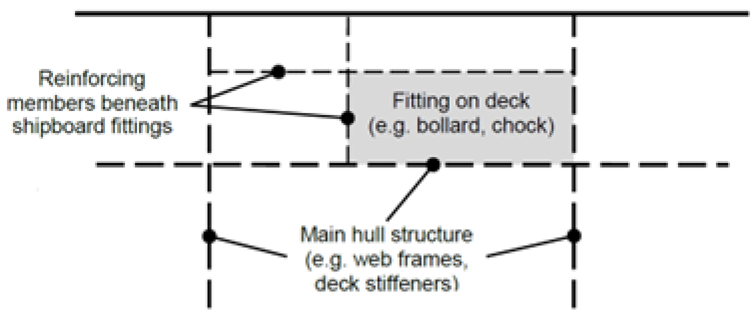

Figure 18.7: Sample arrangement of reinforced members beneath shipboard fittings

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.

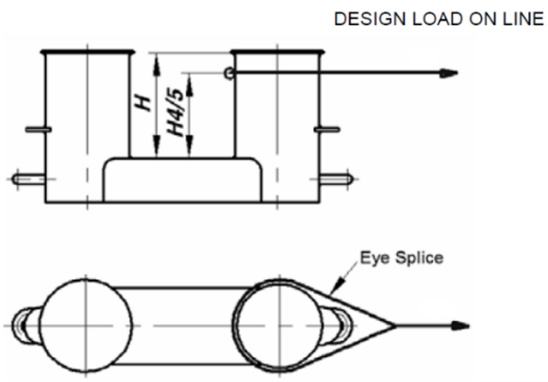

Figure 18.8: Attachment point of towing line

(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:

$$TOW \leq .\ 0,8\frac{F_D}{1,25}$$

F_D = 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.

(IACS UR A2.2)

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)

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 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:

1) the arrangement of mooring lines showing number of lines (N);
2) ship design minimum breaking load (MBL_{SD});
3) 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:

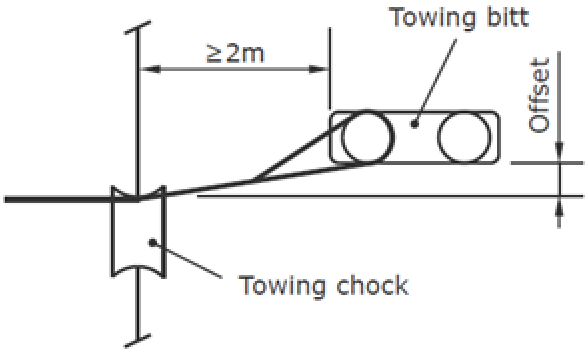

Figure 18.9: Typical towing arrangement

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 container ships it is recommended to provide towing arrangements fore and aft of sufficient strength for 'other towing' service as defined in A.5.2.

(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	d_2	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]			[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			Length	Break load[2)]	Length	Ship Design Minimum Break Load[2)]	Number	Length[3)]	Ship Design Minimum Break Load[2)]
						d_1	d_2	d_3							
			[kg]		[m]	[mm]			[m]	[kN]	[m]	[kN]		[m]	[kN]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
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

(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.

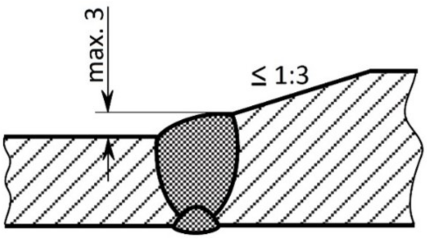


Figure 19.1: Accommodation of differences of thickness

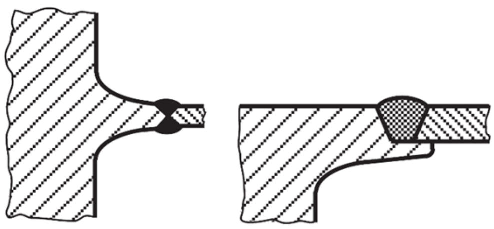


Figure 19.2: Welding flanges on steel castings or forgings

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} = $170 + 3(t - 10) \geq 170$ 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).

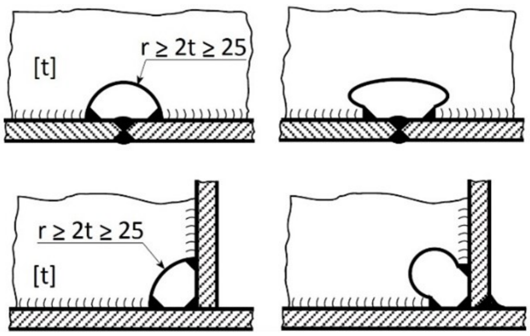


Figure 19.3: Welding cut-outs

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.

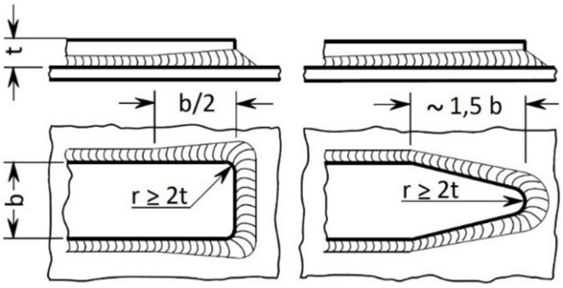


Figure 19.4: Welding at the ends of doubling plates

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”.

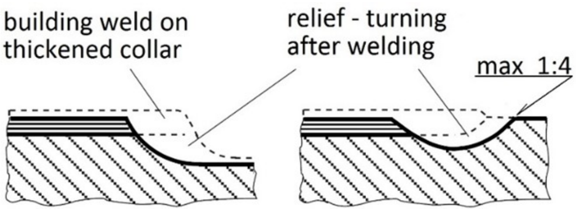


Figure 19.5: Build-up welds applied to rudderstocks and pintles

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.

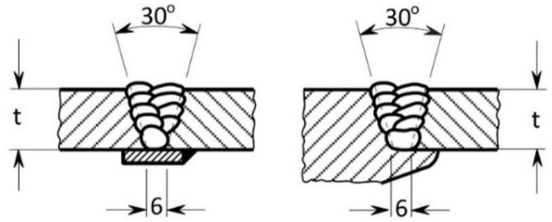


Figure 19.6: Single-side welds with permanent weld pool support (backings)

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.

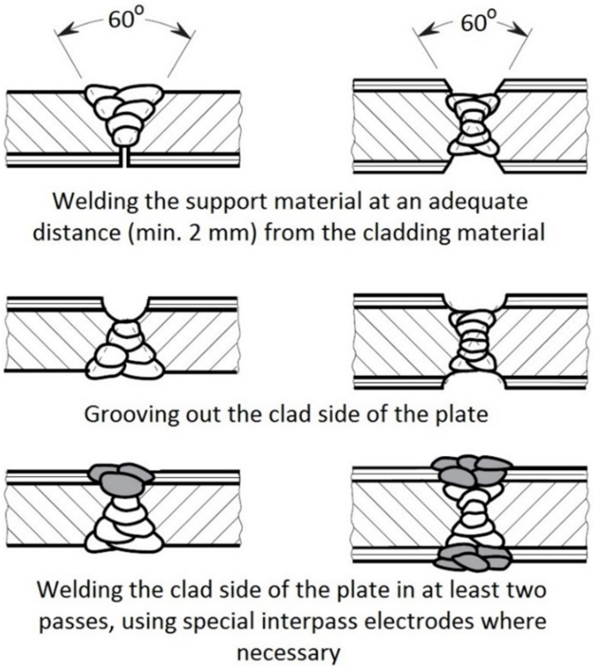


Figure 19.7: Weld shapes for welding of clad plates

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.

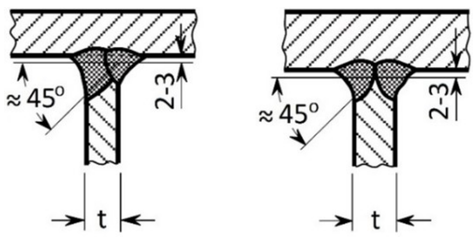


Figure 19.8: Single and double-bevel welds with full root penetration

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.

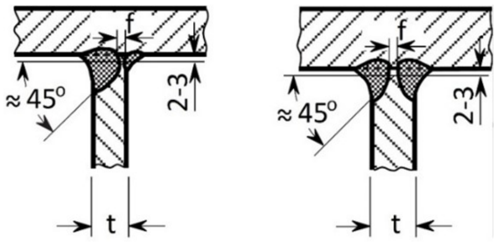


Figure 19.9: Single and double-bevel welds with defined incomplete root penetration

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.

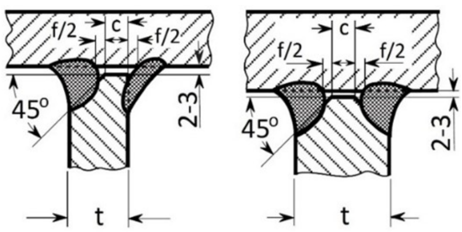


Figure 19.10: Single and double-bevel welds with unwelded root face and defined incomplete root penetration

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).

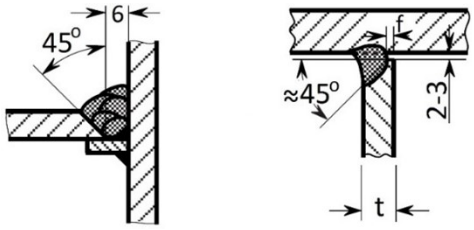


Figure 19.11: Single-side welded T joints

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.

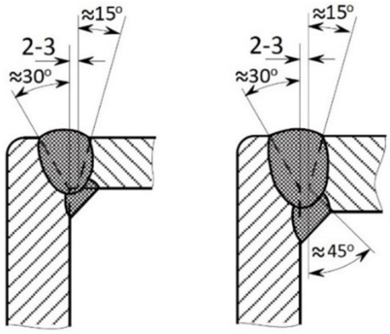


Figure 19.12: Flush fitted corner joints

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.

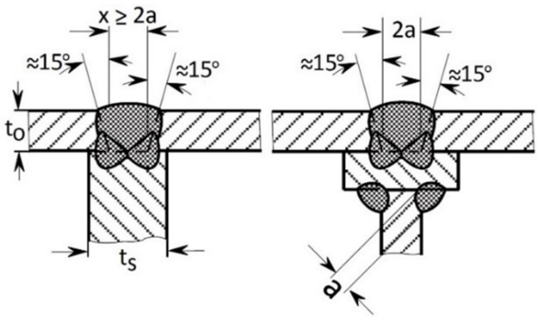


Figure 19.13: Welding together three plates

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:

$$a_{min} = \sqrt{\frac{t_1 + t_2}{3}} \text{ [mm]} \qquad \text{with} \quad a_{min} \geq 3{,}0 \text{ mm}$$

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.

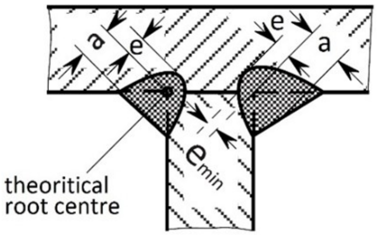


Figure 19.14: Fillet welds with increased penetration

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.

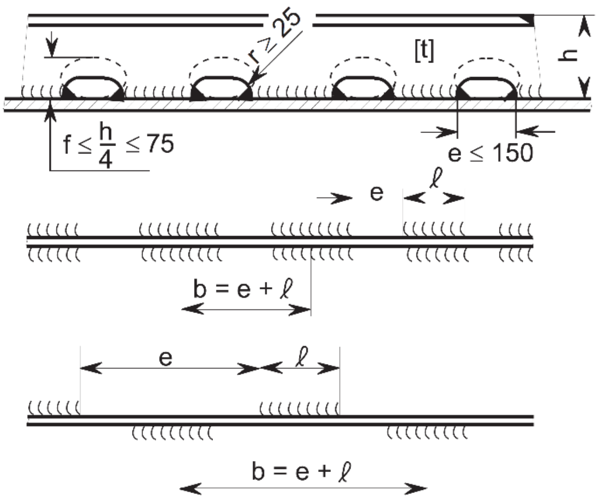


Figure 19.15: Scallop, chain and staggered welds

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:

$a_u = 1,1 \cdot a \cdot \left[\frac{b}{\ell}\right]$ [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 - ℓ with scallop and chain welds, or b/2 - ℓ 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 · 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.

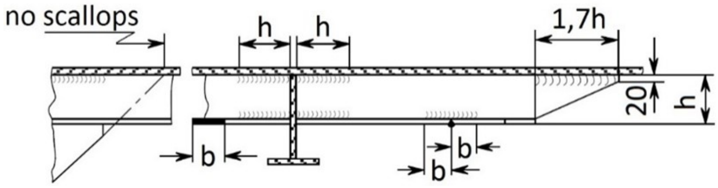


Figure 19.16: Welds at the ends of girders and stiffeners

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.

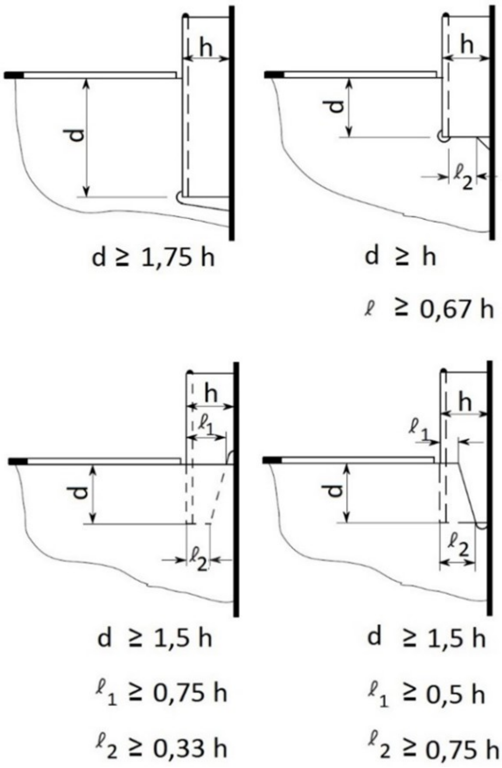


Figure 19.17: Joints uniting section ends and plates

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.

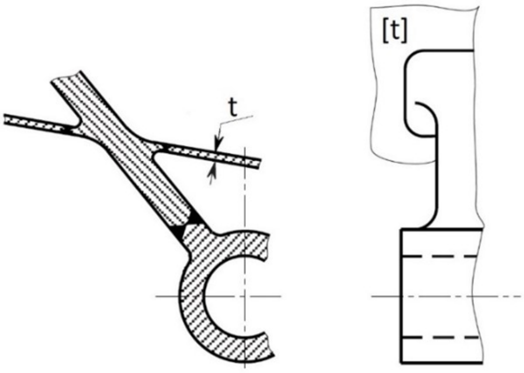
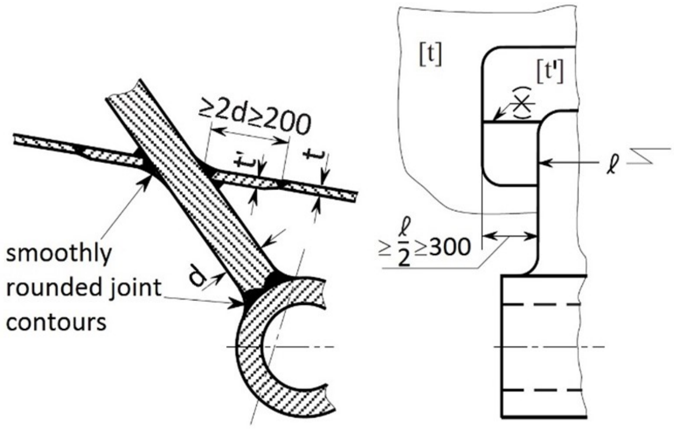


Figure 19.18: Shaft bracket with integrally cast welding flanges



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.

Figure 19.19: Shaft bracket without integrally cast welding flanges

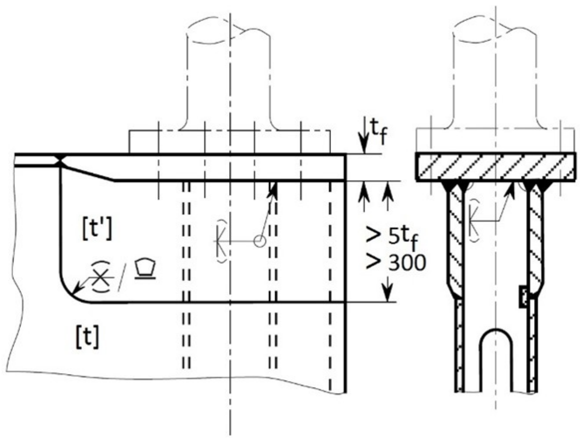
4.4 Rudder coupling flanges

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 ≥ 50 mm

Figure 19.20: Horizontal rudder coupling flanges

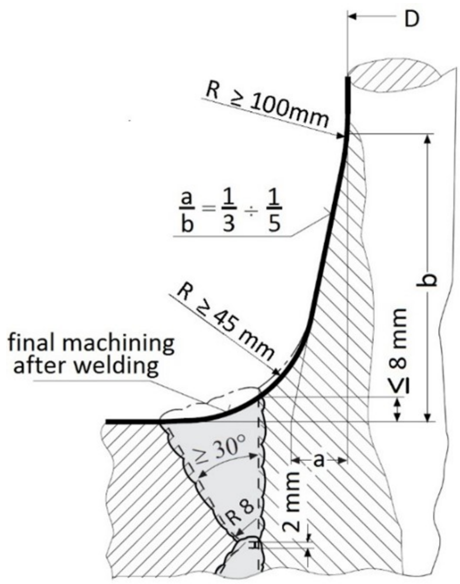


Figure 19.21a: Welded joint between rudder stock and coupling flange

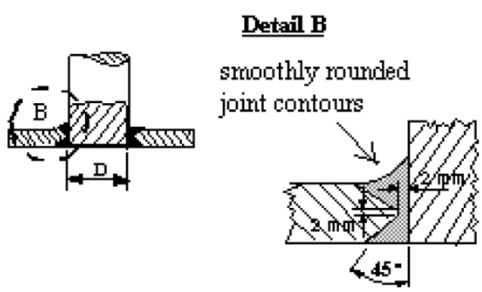


Figure 19.21b: Welded joint between rudder stock and coupling flange for small stock diameter

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]

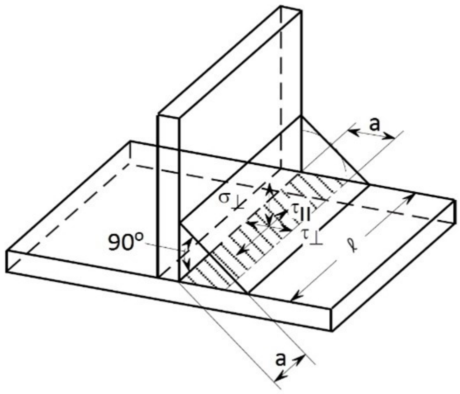


Figure 19.22: Stresses in a fillet weld

Normal stresses acting in the direction of the weld seam need not be considered.

For calculation purposes the weld seam area is a $\cdot\ \ell$

Due to equilibrium condition the following applies to the flank area vertical to the shaded weld seam area

$$\tau_\perp = \sigma_\perp \quad [\text{N/mm}^2]$$

The equivalent stress is to be calculated by the following formula:

$$\sigma_v = \sqrt{\sigma_\perp^2 + \sigma_\perp^2 + \tau_\|^2} \quad [\text{N/mm}^2]$$

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:

$$\sigma_v = \sqrt{\tau_{\perp}^2 + \tau_{\|}^2} \quad [N/mm^2]$$

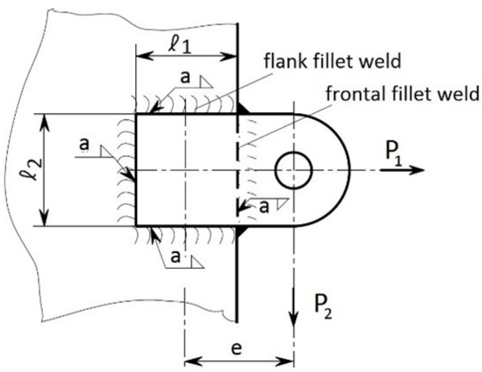


Figure 19.23: Weld joint of an overlapped lifting eye

- 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 :

$$\sigma_v = \sqrt{\tau_{\perp}^2 + \tau_{\|}^2} \quad [N/mm^2]$$

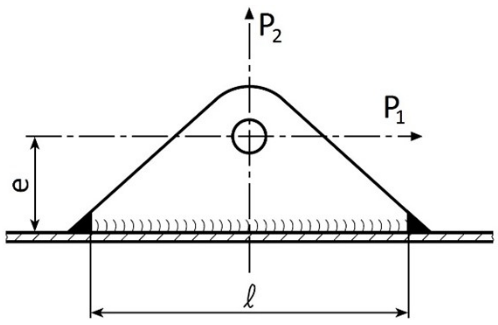


Figure 19.24: Weld joint of a vertically mounted lifting eye

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):

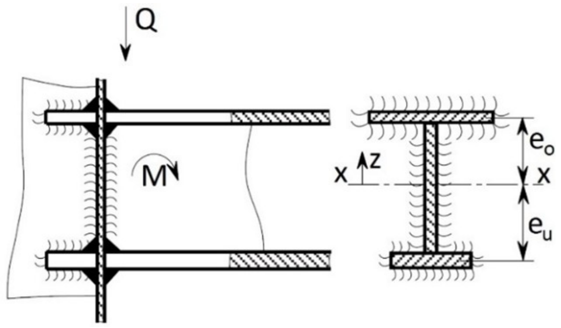


Figure 19.25: Fixing point of cantilever beam

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".

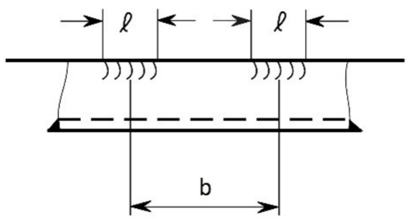


Figure 19.26: Intermittent fillet weld joint

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):

$$\tau_{\perp} = \frac{Q}{2 \cdot a \cdot d} \quad [N/mm^2]$$

$$\tau_{||} = \frac{M \cdot 10^3}{2 \cdot a \cdot c \cdot d} \quad [N/mm^2]$$

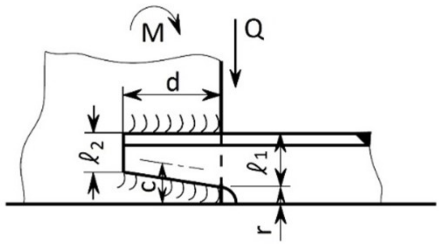


Figure 19.27: Profile joined by means of two flank fillet joints

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 :

$$a_{req} = \frac{W \cdot 10^3}{1,5 \cdot c \cdot d \left[1 + \frac{\ell_1 + \ell_2}{2.d}\right]} \text{ [mm]}$$

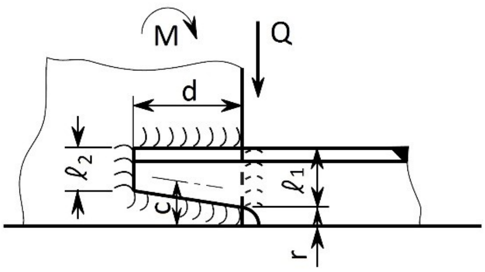


Figure 19.28: - Profile joined by means of two flank and two frontal fillet welds (all round welding)

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]

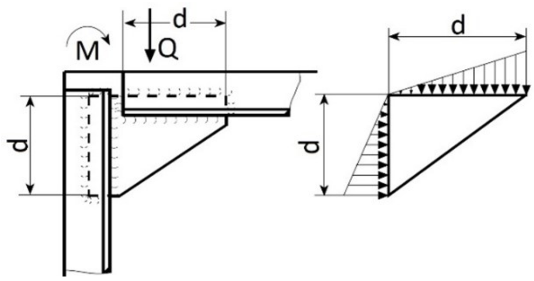


Figure 19.29: Bracket joint with idealized stress distribution resulting from moment M and shear force Q

The required fillet weld thickness is to be calculated from the section modulus of the profile as follows:

$$a_{req} = \frac{1000 \cdot W}{d^2} \quad \text{[mm]}$$

(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	KI - A/B/D/E	235	115
higher strength hull structural steel	KI - A/D/E/F 32	315	145
	KI - A/D/E/F 36	355	160
	KI - 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

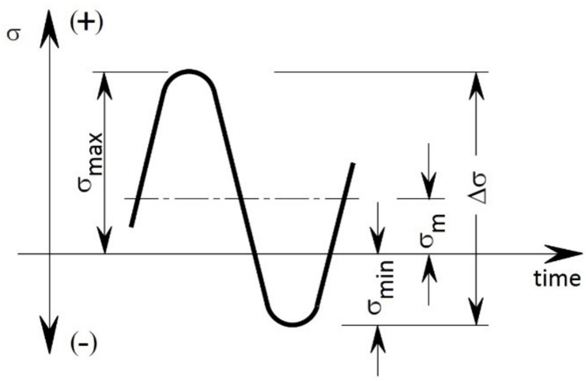


Figure 20.1: Dynamic Load cycle

$\Delta\sigma$ = 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:

$$\Delta\sigma_{max} \leq 2{,}5 \cdot \Delta\sigma_R \quad [\text{N/mm}^2]$$

— sum of the peak stress ranges due to seaway-induced dynamic loads and due to changes of draught or loading condition, respectively:

$$\Delta\sigma_{max} \leq 4{,}0 \cdot \Delta\sigma_R \quad [\text{N/mm}^2]$$

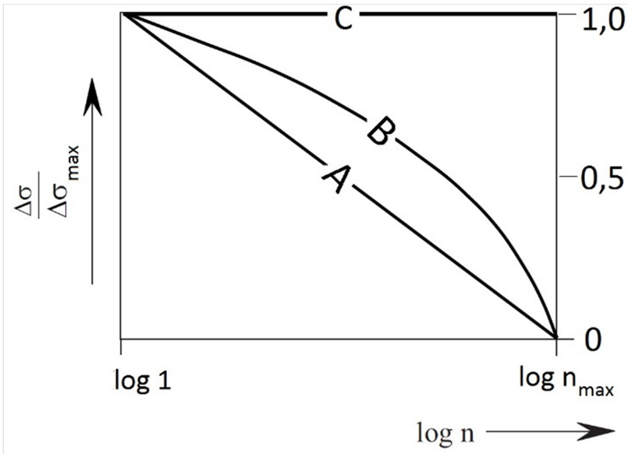
Note

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).

Figure 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]	$9{,}81 \cdot h_1 \cdot \rho(1 + a_v) + 100 \cdot p_v$	$9{,}81 \cdot h_1 \cdot \rho(1 - a_v) + 100 \cdot p_v$
Liquid pressure in completely filled tanks (Section 4, D.1): 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)	$p\,(1 + a_v)$	$p\,(1 - a_v)$
	$p \cdot a_x \cdot 0{,}7$	$- p \cdot a_x \cdot 0{,}7$
	$p \cdot a_y \cdot 0{,}7$	$- p \cdot a_y \cdot 0{,}7$
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	$- C_R$
	Q_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/**L** ≤ 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. 3.6 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.

$$\Delta\sigma_{max} \leq \Delta\sigma_p$$

Table 20.2: Factor f_n for the determination of the permissible range for standard stress range spectra

<table>
<tr><th rowspan="4">stress range spectrum</th><th colspan="5">Welded Joints</th><th colspan="15">Plates Edges</th></tr>
<tr><th colspan="5">(m_0 = 3)</th><th colspan="5">type E1 (m_0 = 5)</th><th colspan="5">type E2, E2a (m_0 = 4)</th><th colspan="5">type E3 (m_0 = 3,5)</th></tr>
<tr><th colspan="5">n_{max} =</th><th colspan="5">n_{max} =</th><th colspan="5">n_{max} =</th><th colspan="5">n_{max} =</th></tr>
<tr><th>10^3</th><th>10^5</th><th>5×10^7</th><th>10^8</th><th>3×10^8</th><th>10^3</th><th>10^5</th><th>5×10^7</th><th>10^8</th><th>3×10^8</th><th>10^3</th><th>10^5</th><th>5×10^7</th><th>10^8</th><th>3×10^8</th><th>10^3</th><th>10^5</th><th>5×10^7</th><th>10^8</th><th>3×10^8</th></tr>
<tr><td rowspan="2">A</td><td rowspan="2"></td><td rowspan="2">(17,2)</td><td rowspan="2">3,53</td><td rowspan="2">3,02</td><td rowspan="2">2,39</td><td rowspan="2"></td><td rowspan="2">(8,1)</td><td rowspan="2">3,63</td><td rowspan="2">3,32</td><td rowspan="2">2,89</td><td rowspan="2"></td><td>(8,63)</td><td rowspan="2">3,66</td><td rowspan="2">3,28</td><td rowspan="2">2,76</td><td rowspan="2"></td><td>(10,3)</td><td rowspan="2">3,65</td><td rowspan="2">3,19</td><td rowspan="2">2,62</td></tr>
<tr><td>(9,20) 3)</td><td>(12,2) 2)</td></tr>
<tr><td rowspan="2">B</td><td rowspan="2"></td><td rowspan="2">(9,2)</td><td rowspan="2">1,67</td><td rowspan="2">1,43</td><td rowspan="2">1,15</td><td rowspan="2">(9,5)</td><td rowspan="2">5,0</td><td rowspan="2">1,95</td><td rowspan="2">1,78</td><td rowspan="2">1,55</td><td>(10,3)</td><td>5,50</td><td rowspan="2">1,86</td><td rowspan="2">1,65</td><td rowspan="2">1,40</td><td rowspan="2"></td><td>6,6</td><td rowspan="2">1,78</td><td rowspan="2">1,55</td><td rowspan="2">1,28</td></tr>
<tr><td>(11,2) 3)</td><td>5,90 3)</td><td>7,5 2)</td></tr>
<tr><td rowspan="2">C</td><td rowspan="2">(12,6)</td><td rowspan="2">2,71</td><td>0,424</td><td>0,369</td><td>0,296</td><td rowspan="2">(4,57)</td><td rowspan="2">1,82</td><td>0,606</td><td>0,561</td><td>0,500</td><td rowspan="2">(4,57)</td><td rowspan="2">1,82</td><td>0,532</td><td>0,482</td><td>0,411</td><td rowspan="2">(4,57)</td><td rowspan="2">1,82</td><td>0,483</td><td>0,430</td><td>0,358</td></tr>
<tr><td>0,543 1)</td><td>0,526 1)</td><td>0,501 1)</td><td>0,673 1)</td><td>0,653 1)</td><td>0,621 1)</td><td>0,621 1)</td><td>0,602 1)</td><td>0,573 1)</td><td>0,587 1)</td><td>0,569 1)</td><td>0,541 1)</td></tr>
</table>

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)

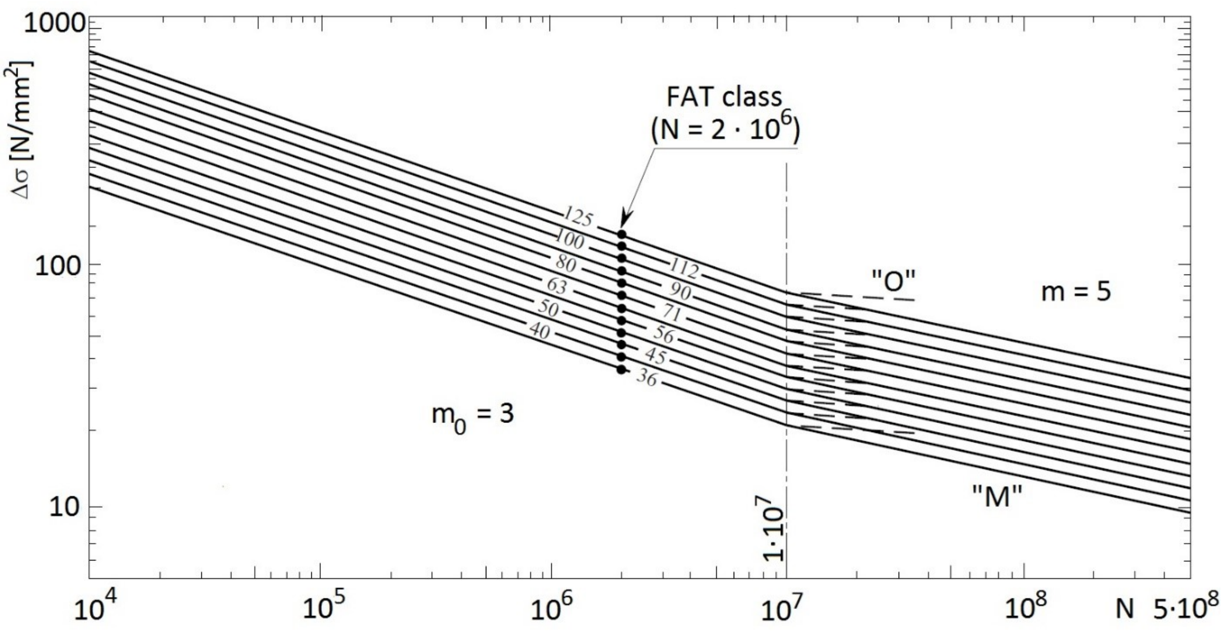


Figure 20.3: S-N Curves for welded joint steel

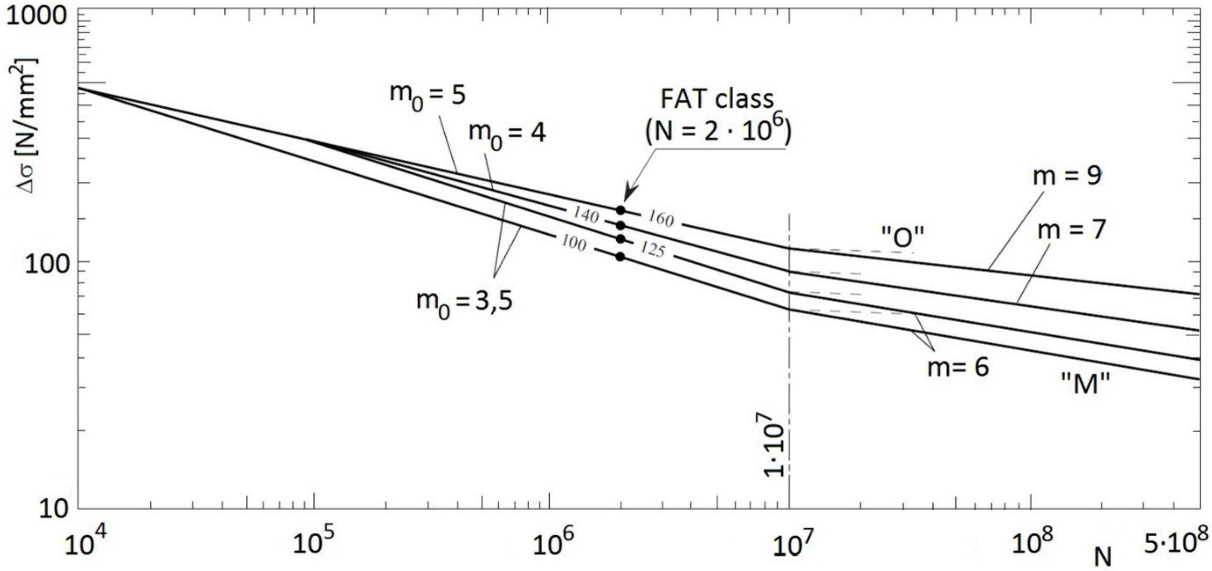


Figure 20.4: S-N Curves for notch at plate edge steel plate

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.

$$f_R = 1{,}0 \quad \text{for} \quad \sigma_m \geq \frac{\Delta\sigma_{max}}{2}$$

— in the range or alternating stresses, i.e.

$$f_R = 1 + c\left[1 - \frac{2.\sigma_m}{\Delta\sigma_{max}}\right] \quad \text{for} \quad -\frac{\Delta\sigma_{max}}{2} \leq \sigma_m \leq \frac{\Delta\sigma_{max}}{2}$$

— in the range of compressive pulsating stresses, i.e.

$$f_R = 1 + 2 \cdot c \quad \text{for} \quad \sigma_m \leq -\frac{\Delta\sigma_{max}}{2}$$

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.

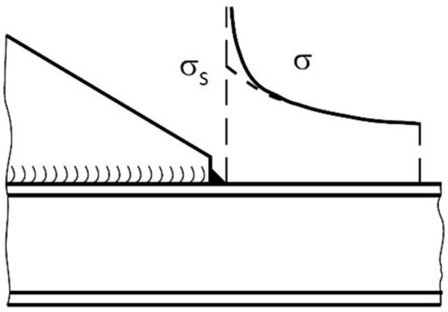


Figure 20.5: Structural stress

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

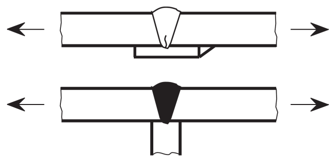
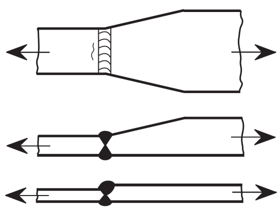
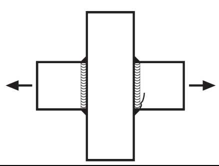
A. Butt welds, transverse loaded				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
A1		Transverse butt weld ground flush to plate, 100% NDT (Non Destructive Testing)	11	45
A2		Transverse 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)*

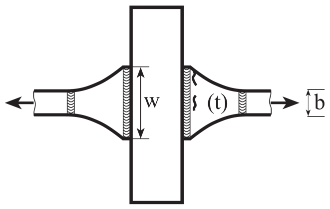
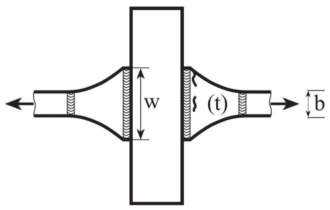
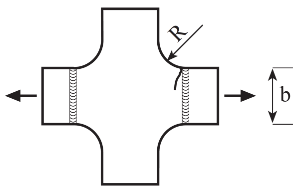
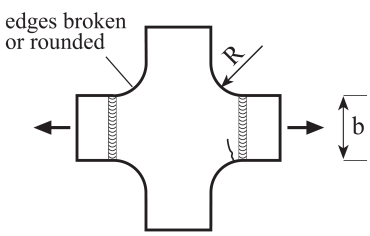
A. Butt welds, transverse loaded				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
A9		Full penetration butt weld at crossing flanges Welded from both sides, Cutting edges in the quality 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)*

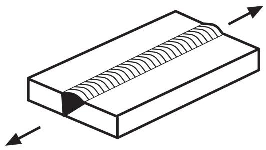
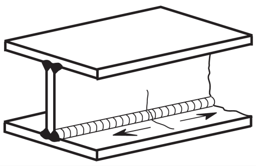
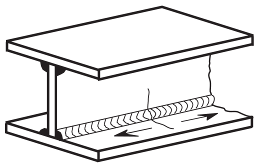
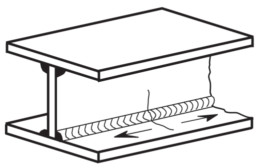
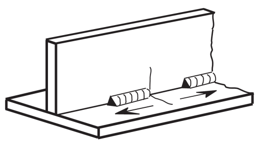
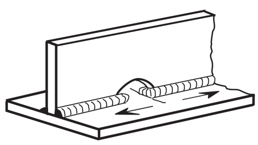
B. Longitudinal load-carrying weld				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
B1		Longitudinal butt welds both sides ground flush parallel to load direction without start/stop positions, 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)*

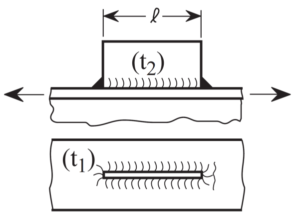
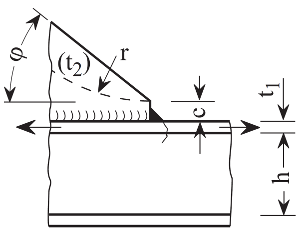
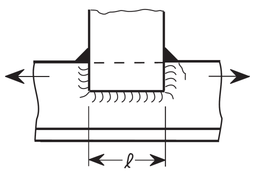
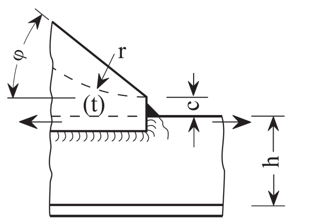
C. Non-load-carrying attachments				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
C1		Longitudinal gusset welded on beam flange, bulb or plate : ℓ ≤ 50 mm 50 mm < ℓ ≤ 150 mm 150 mm < ℓ ≤ 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 ≥ 0,5 × h r < 0,5 × h or j ≤ 20° φ > 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 ℓ ≥ 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 ≤ 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)*

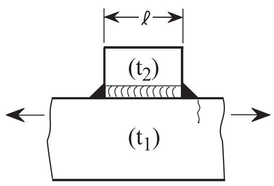
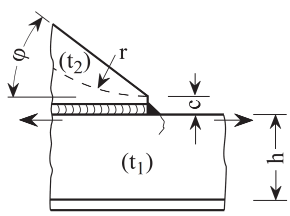
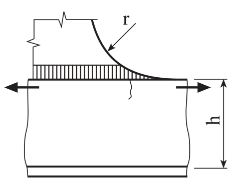
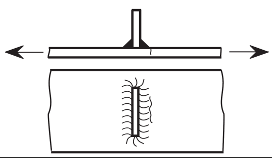
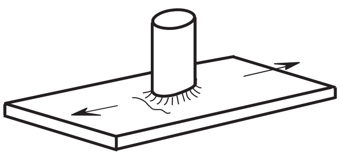
C. Non-load-carrying attachments				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
C5		Longitudinal flat side gusset welded on plate or beam flange edge ℓ ≤ 50 mm 50 mm < ℓ ≤ 150 mm 150 mm < ℓ ≤ 300 mm ℓ > 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); $c \le 2\ t_2$, 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)*

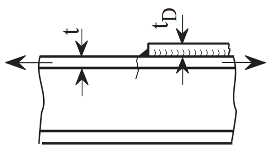
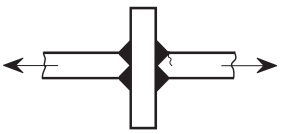
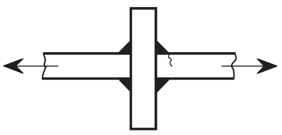
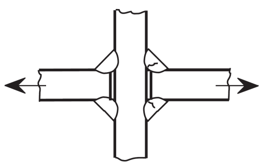
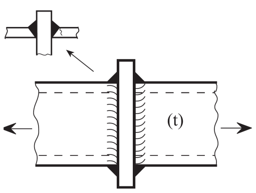
Type No.	Joint configuration showing mode of fatigue cracking and stress σ considered	Description of joint	FAT class $\Delta\sigma_R$ Steel	FAT class $\Delta\sigma_R$ Al
C. Non-load-carrying attachments				
C9		End of long doubling plate on beam, welded ends (based on stress range in flange at weld toe) $t_D \le 0{,}8 \cdot t$ $0{,}8 \cdot t < t_D \le 1{,}5 \cdot t$ $t_D > 1{,}5 \cdot t$ 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				
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 $a < 0{,}7 \cdot t$, 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 $a \ge t/3$ $a < t/3$ ***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 $t \le 8{,}0$ mm, $\Delta\sigma_R$ has to be decreased by one category.	 56 50	 20 18

Table 20.3: Catalogue of Details *(continued)*

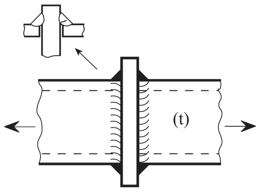
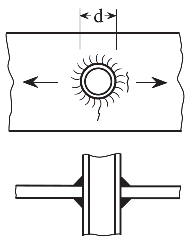
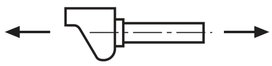
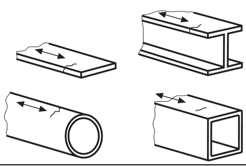
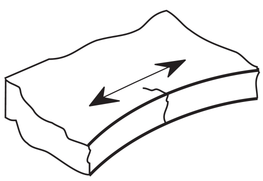
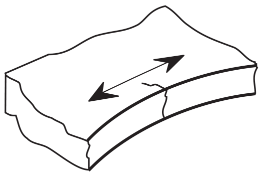
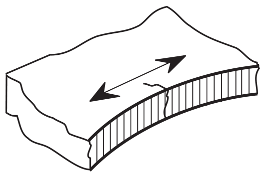
D. Cruciform joints and T-joints				
Type No.	**Joint configuration showing mode of fatigue cracking and stress σ considered**	**Description of joint**	**FAT class $\Delta\sigma_R$**	
			Steel	**Al**
D5		Fillet weld at the connection between a hollow section (e.g. pillar) and a plate, for tubular section 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:

$$\Delta\sigma_{max} = K_t \cdot \Delta\sigma_N$$

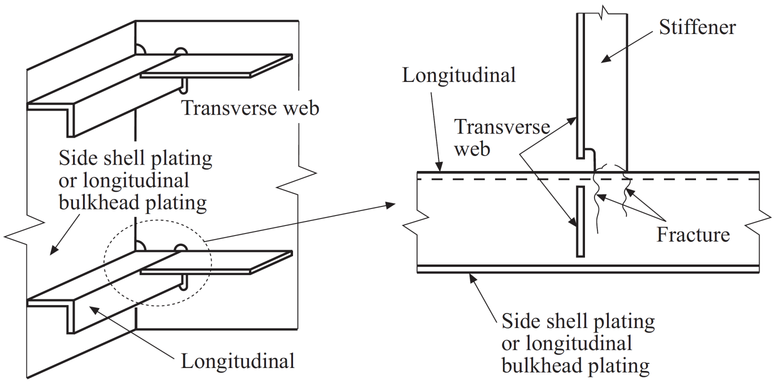
K_t = Notch factor according to Section 3, J

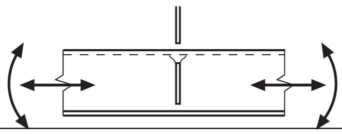
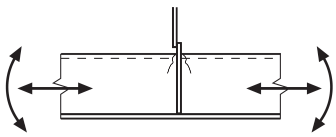
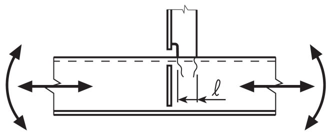
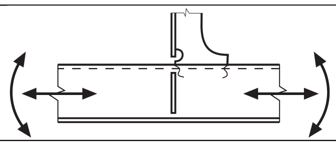
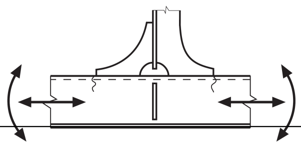
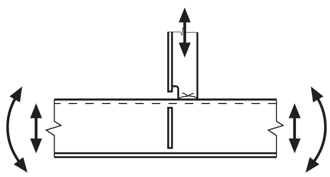
$\Delta\sigma_N$ = Nominal stress range related to net section

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 $\ell \le 150$ connection $\ell > 150$ Overlapping $\ell \le 150$ connection $\ell > 150$	45 40 50 45	56 50 50 45	56 50 45 40	63 56
 [2]	With heel stiffener and integrated bracket	45	56	56	63
	With heel stiffener and integrated bracket and with backing bracket direct connection overlapping connection	50 56	63 56	63 50	71
	With heel stiffener but considering the load transferred to the stiffener (see Section 9, B.4.9) crack initiation at weld toe crack initiation at weld root stress increase due to eccentricity and shape 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

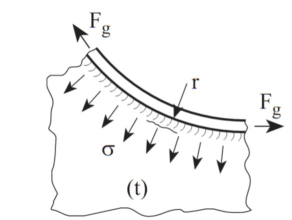
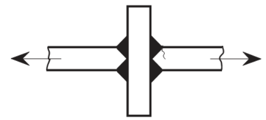
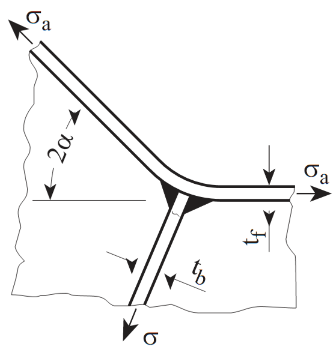
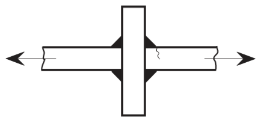
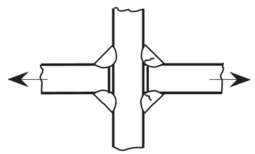
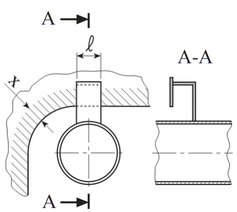
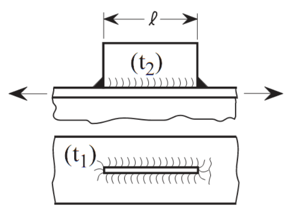
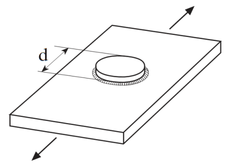
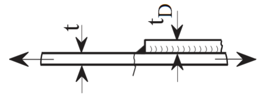
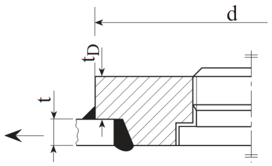
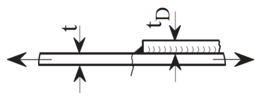
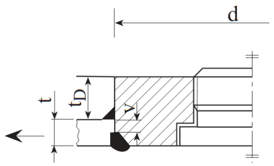
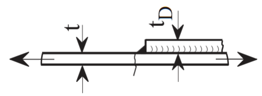
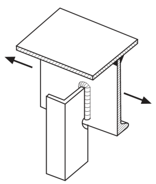
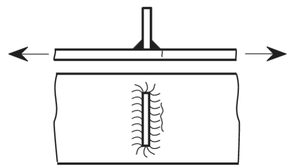
Structure or equipment detail	Description of structure or equipment detail	Type No.	Join configuration showing mode of fatigue cracking and stress σ considered	Description of joint	FAT class $\Delta\sigma_R$ steel
	Unstiffened flange to web joint, to be assessed according to type D1, D2 or D3, depending 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.

C. 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 nonopening 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))

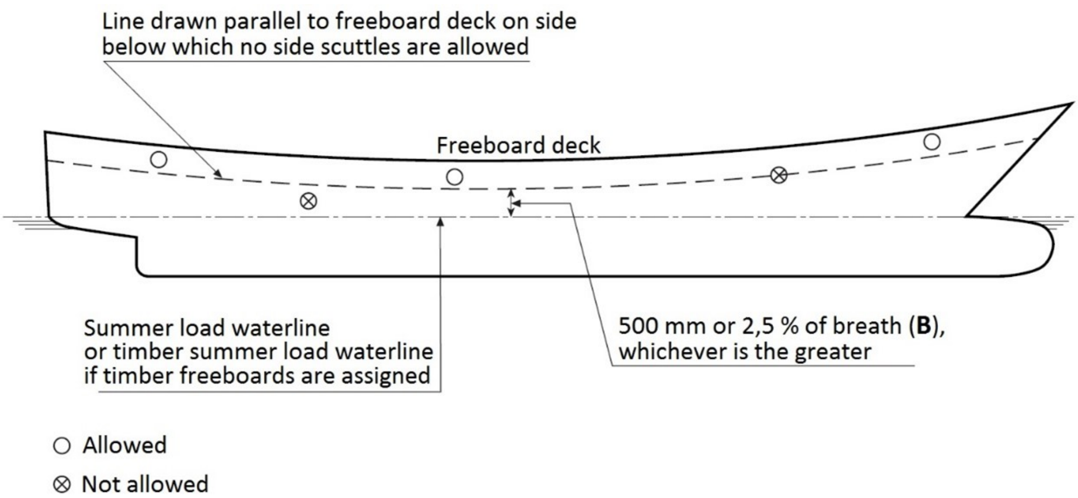


Figure 21.1: Arrangement of side scuttles

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))

2. Design Load

2.1 The design load shall be in accordance with Section 4 and Section 16.

2.2 In addition 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 (t_s) 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.

D. 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 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))

1.2.6 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.

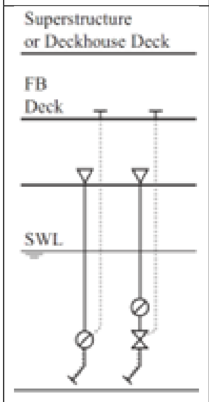
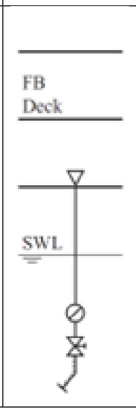
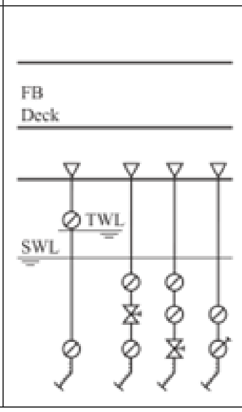
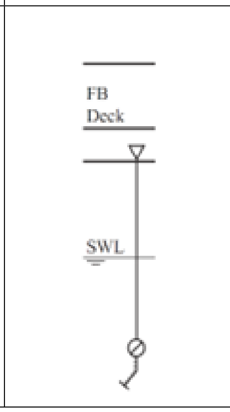
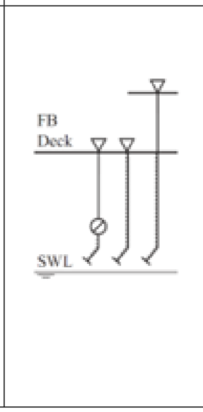
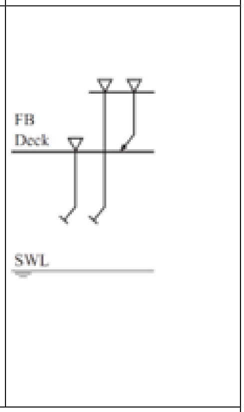
(ICLL Annex I, Ch. II, Reg. 22(7b))

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 D.1.2.1 where inboard end ≤ 0,01L above SWL	Discharges through machinery space	Alternatives (see D.1.2.1) where inboard end		outboard end > 450 mm below FB deck or ≤ 60 mm above SWL see D.1.2.1	otherwise see D.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 = $0,7 + 0,035 \cdot \ell$ [m^2] for $\ell \leq$ 20 m

= $0,07 \cdot \ell$ [m^2] for $\ell >$ 20 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 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	

2.8 The effectiveness of the freeing area in bulwarks required by 2.1 – 2.6 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 2.7 as if the hatchway coamings were continuous, then the minimum freeing port area calculated from 2.1 –2.6 is to be deemed sufficient.

— If the free flow area is equal to, or less than the area calculated from 2.1 – 2.6, the minimum freeing area in the bulwarks is to be determined from 2.7.

— If the free flow area is smaller than calculated from 2.7, but greater than calculated from 2.1 – 2.6, 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 – 2.6

F_2 = minimum freeing area calculated from 2.7

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))

2.9 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 2.9.2).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:

   $A_c = 0,004 \cdot l_w \cdot ((h_b) - 0,9/0,1)$ [m²] for bulwarks with $h_b < 0{,}9$ m

   $A_c = 0$ for bulwarks with $0{,}9 \le h_b \le 1{,}2$ m

   $A_c = 0,004 \cdot l_w \cdot ((h_b) - 1,2/0,1)$ [m²] 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 2.9.).a and 2.9.2).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))

2.10 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))

2.11 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))

2.12 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]

E. 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

(IACS UR S27.1.1)

5.2 Application

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)

5.3 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:

$$p = 0,5 \cdot \rho \cdot V^2 \cdot C_d \cdot C_s \cdot C_p \quad [kN/m^2]$$

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 $d \leq 0,5 \cdot d_1$
	=	$13,5\sqrt{2\left(1 - \frac{d}{d_1}\right)}$ m/sec for $0,5 \cdot d_1 \leq d \leq d_1$
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 · 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)

F. 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 E.5.

3. Machinery space- and emergency generator room ventilation

3.1 For special requirements for machinery space ventilation:

3.1.1 The ventilation systems for machinery spaces of category A shall be separated from the ventilation systems serving other spaces and shall be in general of the supply type. Other modes of operation may be applied upon special approval.

3.1.2 Machinery spaces of category A shall be adequately ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions including heavy weather, adequate supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery. Any other machinery space shall be adequately ventilated appropriate for the purpose of that machinery space.

3.1.3 In general, ventilators necessary to continuously supply the machinery space shall have coamings of sufficient height to comply with LLC 1966 as amended 1988, Regulation 19(3), without having to fit weathertight closing appliances (see also 3.3). However, where due to ship size and arrangement this is not practicable, lesser heights for machinery space coamings, fitted with weathertight closing appliances in accordance with LLC 1966 as amended 1988, Regulation 19(4), may be permitted by the Administration in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces. The machinery spaces are those defined in SOLAS Regulation II1/Reg.3.16.

3.1.4 The positions of air inlets and air outlets are to be such as to prevent short-circuiting of air.

3.1.5 In general the shipboard machinery, equipment and appliances in machinery spaces are to be designed for continuous operation at maximum engine room air temperature as required in the Rules for Machinery Installations (Pt.1, Vol.III) Sec.1, C.

3.1.6 For the determination of the ventilation capacity the heat radiation of the equipment in the space and the required combustion air are to be considered.

3.1.7 The capacity and arrangement of ventilation systems/ducts is to ensure that accumulation of oil vapour is avoided under normal conditions.

Note:

The capacity requirements mentioned in 3.1.5, 3.1.6 and 3.1.7 are in general deemed to be met by using the calculations as per ISO Standard 8861 in the latest version.

3.1.8 The number of ventilation inlets, ventilators and exhaust openings in funnels shall be kept to a minimum, consistent with the needs of ventilation and the proper and safe working of the ship.

3.1.9 Suitable arrangements shall be made to permit the release of smoke in the event of fire (see 3.4).

3.1.10 Further requirements for control of fans and fire closures are stipulated in 3.4 and 3.5. For application and design of fire closures see 3.6.

3.1.11 Air ducts close to electrical switchboards must be so installed and fitted with drains, where necessary, that condensed water cannot enter the electrical installation.

3.1.12 In case that a gas fire-extinguishing system is provided for the machinery space it is recommended, that one of the engine room supply fans should be of reversible type and supplied from the emergency source of power supply to enable extraction of fire extinguishing gases, should the need arise.

3.1.13 Power driven fire closures for engine rooms containing combustion engines shall not close automatically in case of loss of energy (fail safe type) unless an uninterrupted, adequate air supply to the engine room can be maintained. This requirement is deemed to be met if e.g. a sufficient number of fire closures at air inlets and/or air outlets are of manual operated type. For a pneumatically operated system for fail safe type fire closures, the air supply may be from one air receiver located outside the machinery space with separated piping from air receiver to the fire closures. For arrangement of air receiver the Rules for Machinery Installations (Pt.1, Vol.III) Sec.11.D.6.5 are to be used analogously.

3.2 Emergency generator rooms

3.2.1 The ventilation system serving the emergency generator room has to ensure a sufficient supply of combustion and cooling air for the equipment installed.

3.2.2 In general, ventilators necessary to immediately supply the emergency generator room must have coamings which comply with regulation 19(3) of ICLL 1966, without weathertight closing appliances, see also 3.2. However, where due to vessels size and arrangement this is not practicable, lesser heights for emergency generator room ventilator coamings may be accepted. In this case weathertight closing appliances in accordance with regulation 19(4) of ICLL 1966 in combination with other suitable arrangements have to be provided to ensure an uninterrupted, adequate supply of ventilation to these spaces 5.

3.2.3 Bulkheads between emergency generator room and open decks may have air intake openings without means of closure, unless a fixed gas firefighting system is fitted.

3.2.4 If the emergency generator starts automatically it is to be ensured that the fire closures are open. In case the fire closures do not open automatically, a warning plate is to be provided stating that they are to be kept open all the time.

3.3 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.

3.4 Release of smoke from machinery spaces.

3.4.1 The provisions of 3.4.2 to 3.4.4 shall apply to machinery spaces of category A, and where considered desirable to other machinery spaces.

3.4.2 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.

3.4.3 Means of control shall be provided for permitting the release of smoke and such controls shall be located outside the space concerned so that they will not be cut off in the event of fire in the space they serve.

3.4.4 The controls shall be easily accessible as well as prominently and permanently marked and shall indicate whether the shutoff is open or closed.

3.5 Means of control for machinery space ventilation arrangements.

3.5.1 Means of control shall be provided for opening and closure of skylights, closure of openings in funnels which normally allow for exhaust air ventilation and closure of ventilator dampers.

3.5.2 Means of control shall be provided for stopping fans. Controls provided for the power ventilation serving machinery spaces shall be grouped so as to be operable from two positions, one of which shall be outside such spaces. 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.

3.5.3 Means of control shall be provided for stopping forced and induced draught boiler fans.

3.6 Fire closures at main inlets and outlets.

3.6.1 The main inlets and outlets of all 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 whether the shut-off is open or closed.

3.6.2 Fire closures at ventilation inlets and outlets located at outside boundaries need not be of approved type.

3.6.3 Fire closures, which are not of approved type, are to comply with the following requirements:

- The thickness of steel fire closures is shown in the following Table 21.5.
- If measures to increase the strength are taken, the thickness may be reduced with agreement of BKI.
- The construction of approved closures shall comply with the tested ones.
- The means of control is to be capable of being locked in open and closed position.
- When shut, the fire closures shall have close contact with a steel strip throughout their circumference.
- All closures shall be easily accessible and capable of being operated easily and safely.
- Hinges and bearings of the fire closures are to be largely maintenance-free and easily accessible for inspections and repairs.
- The controls and the ”open” and ”closed” position of the fire closures are to be clearly and permanently marked.
- Power-driven controls and remote operated controls for fire closures must be provided with a second, independent power-operating system or manual control operable from a safe position outside the space to be protected or the closures are to be of fail safe type.

3.6.4 Fire closures of multi-blade design may be accepted provided they meet at least the following design criteria:

- The fire closure shall consist of not more than 5 single plates, whereas the clear height of each plate should be at least 20 % of the total clear height of the damper but not less than 200 mm.
- Each damper plate should have an overlap of at least 5 % of its height.
- A circumferential resting bar should be provided.
- Each damper plate should have a thickness depending on its cross section as specified in Table 21.5.
- The construction should be of robust design to avoid vibrations.

Prior to installation, drawings showing construction details of the multi blade fire closure have to be submitted for approval. The construction is to be tested to the satisfaction of a BKI Surveyor.

Special attention shall be paid to a regular service of the multi-blade fire closures.

3.6.5 The arrangement of two fire closures of multi blade design according to 3.6.4 in a common frame is acceptable, if the following requirements are fulfilled:

- The total free cross sectional area of the entire ventilation opening is at least 3 m^2
- The cross sectional area of each single blade is at least 0,5 m^2
- The two fire closures are to be separated from each other. For this purpose an intermediate frame is to be provided
- The closing mechanism of the two fire closures shall be independent from each other

3.6.6 Weather tight closures of a recognized standard are accepted as fire closures. In that case weathertight closures are to be permanently attached irrespective of the length of the ship.

3.6.7 BKI approved weather tight closures of multi-blade design, which are use rubber as sealing material, may be accepted as fire closures if the following requirements are fulfilled:

- The closure is located in a position, where in accordance with Load Line Convention weather tightness is required
- The closure consist of not more than 5 single blades
- The total clear height of each blade shall be at least 200 mm
- Each blade shall have a thickness depending on its cross section as specified in Table 21.5

Weather tight closures of multi-blade design, which use rubber as sealing material, shall not be fitted as fire closures for engine rooms and for positions where weather tightness is not required.

Table 21.5: Thickness of fire closures

Diameter of duct [mm]	Cross-section of duct [m^2]	Min. thickness of fire closures [mm]
Up to 200	Up to 0,03	4
Over 200 up to 400	Over 0,03 up to 0,13	5
Over 400 up to 600	Over 0,13 up to 0,28	6
Over 600 up to 800	Over 0,28 up to 0,50	7
Over 800	Over 0,50	8

G. 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, C.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.

H. 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.

Length of girders is to be proved according to Section 3, F., if required.

J. 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.

K. 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 21.6.

2.1.6 Where steel wire ropes according to Table 21.6 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

Table 21.6: 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

2.2 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 21.7

Table 21.7: 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.

L. 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.

M. 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.

N. 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 O. (in the form of guard rails, lifelines, gangways or underdeck passages, etc) is to be provided for the protection of the crew in getting to and from their quarters, the machinery spaces and any other spaces used in the essential operation of the ship.

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).

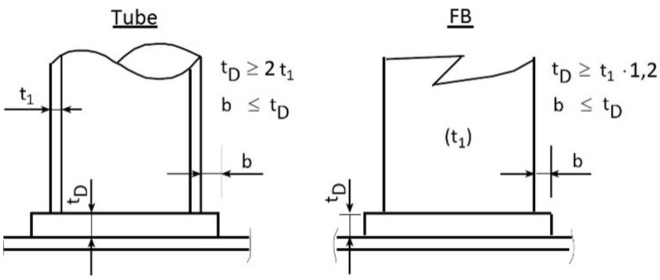


Figure 21.2: Plates below guard-rail stanchions

O. 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 centreline 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 N.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 N.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 N.8 and supported by stanchions spaced not more than 1,5 m apart;
- provided with a food-stop on each side;
- having openings, with ladders where appropriate, to and from the deck. Openings are not to be more than 40 m apart;
- having shelters set in way of the gangway at intervals not exceeding 45 m if the length of the exposed deck to be traversed exceeds 70 m. Every such shelter is to be capable of accommodating at least on person and be so constructed as to afford weather protection on the forward, port and starboard sides.

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.

P. Doors

1. All access openings in end bulkheads of closed superstructures are to be fitted with weather tight doors permanently attached to the bulkhead, having the same strength as the bulkhead. The doors are to be so arranged that they can be operated from both sides of the bulkhead. The coaming heights of the access opening above the deck are to be determined according to ICLL.

Weathertight doors in Load Line Position 1 and 2 according to ICLL are to be generally equivalent to the international standard ISO 6042.

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 weathertight 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.

Q. 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 P.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 P.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 F.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))

R. Shell Doors

1. General

1.1 Shell doors in the sides of ships below the freeboard deck shall be fitted with doors so designed as to ensure the same watertightness and structural integrity as the surrounding shell plating. Unless otherwise granted by the Administration, these openings shall open outwards. The number of such openings shall be the minimum compatible with the design and proper working of the ship.

1.2 Unless otherwise permitted by the Administration, the lower edge of openings referred to in 1.1 shall not be below a line drawn parallel to the freeboard deck at side, which is at its lowest point at least 230 mm above the upper edge of the uppermost load line.

1.3 Where it is permitted to arrange shell doors with their lower edge below the line specified in 1.2, additional features shall be fitted to maintain the watertight integrity.

1.4 The fitting of a second door of equivalent strength and watertightness is one acceptable arrangement. A leakage detection device shall be provided in the compartment between the two doors. Drainage of this compartment to the bilges, controlled by a readily accessible screw down valve, shall be arranged. The outer door shall open outwards.

1.5 Shell doors solely fitted for the embarkation of pilots shall open inboards.

2. Arrangement of securing and locking devices

2.1 Systems of operation

2.1.1 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 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.

2.1.2 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.

2.2 Indication shall be provided on the navigation bridge whether the door is closed and locked.

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Section 22 Structural Fire Protection

A. General

1. Application, Submission of Plans

1.1 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.

1.2 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.

1.3 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 [1)]. 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..

1.4 Documents to be Submitted

The following drawings and documents are to be submitted in 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
- Window plan
- Fire control plan (for information only)
- Report on alternative design and arrangements if applicable
- List of approved materials and equipment
- General Arrangement (for information only)

1.5 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)] Reference is made to the "Guidelines on Alternative Design and Arrangements for Fire Safety" adopted by IMO by MSC/Circ.1002

1.6 For regulations on fire alarm systems and on fire extinguishing arrangements, see Rules for Machinery Installations (Pt.1, Vol.III) Sec.12.

1.7 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. 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 22.1 as appropriate. Openings therein, if any, shall be suitably arranged and protected to prevent the spread of fire.

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 22.1.

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 22.1. 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 22.1 and 22.2.

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 22.1 and 22.2 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 22.1 and 22.2. The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row number in the tables.

Table 22.1: Fire integrity of decks separating adjacent spaces

Spaces		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Control stations	[1]	A-0[5]	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	9
Corridors	[2]		C	B-0	B-0 A-0[3]	B-0	A-60	A-0	A-0	A-0	9
Accommodation spaces	[3]			C[1,2]	B-0 A-0[3]	B-0	A-60	A-0	A-0	A-0	9
Stairways	[4]				B-0 A-0[3]	B-0 A-03	A-60	A-0	A-0	A-0	9
Service spaces (low risk)	[5]					C	A-60	A-0	A-0	A-0	9
Machinery spaces of category A	[6]						9	A-0	A-0[7]	A-60	9
Other machinery spaces	[7]							A-0[4]	A-0	A-0	9
Cargo spaces	[8]								9	A-0	9
Service spaces (high risk)	[9]									A-0[4]	9
Open decks	[10]										-

Notes to be applied to Tables 22.1 and 22.2, 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 in only required when the adjacent spaces are for a different purpose, e.g. in category [9]. A galley next to a galley does not require a bulkhead but a galley next to a paint room requires an ”A-0” bulkhead.

5 Bulkheads separating the wheelhouse, chartroom and radio room from each other may be ”B-0” rating.

6 ”A-0” rating may be used if no dangerous goods are intended to be carried or if such goods are stowed not less than 3,0 m horizontally from such bulkhead.

7 For cargo spaces in which dangerous goods are intended to be carried 4.2 applies.

8 Fire insulation need not be fitted if the machinery spaces in category [7], has little or no fire risk.

9 Where a 10 appears in the Tables, the division is required to be of steel or other equivalent material, but is not required to be of ”A” class standard.

Table 22.2: Fire integrity of decks separating adjacent spaces

Spaces below Spaces below		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Control stations	[1]	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0	9
Corridors	[2]	A-0	9	9	A-0	9	A-60	A-0	A-0	A-0	9
Accommodation spaces	[3]	A-60	A-0	9	A-0	9	A-60	A-0	A-0	A-0	9
Stairways	[4]	A-0	A-0	A-0	9	A-0	A-60	A-0	A-0	A-0	9
Service spaces (low risk)	[5]	A-15	A-0	A-0	A-0	9	A-60	A-0	A-0	A-0	9
Machinery spaces of category A	[6]	A-60	A-60	A-60	A-60	A-60	9	A-60[9]	A-30	A-60	9
Other machinery spaces	[7]	A-15	A-0	A-0	A-0	A-0	A-0	9	A-0	A-0	9
Cargo spaces	[8]	A-60	A-0	A-0	A-0	A-0	A-0	A-0	9	A-0	9
Service spaces (high risk)	[9]	A-60	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0[4]	9
Open decks	[9]	9	9	9	9	9	9	9	9	9	-

See notes under Table 22.1

[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).

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[2)].

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.

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:

[2)]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.

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[3)] 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 of at least 900 mm. When passing through bulkheads, this length shall be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, shall be provided with fire insulation. The insulation shall have at least the same fire integrity as the bulkhead or deck through which the duct passes.

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[2)].

.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).

[3)] 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.

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.

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[3)].

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[4)].

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[5)].

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[6)] 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.

[4)] 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.

[5)] 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.

[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.

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:

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[7)].

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.

[7)] 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.

11.7 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:

11.7.1 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 22.1 and 22.2 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

11.7.2 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.

11.7.3 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.

11.8 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.

11.9 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.

11.10 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.

11.11 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.

12.2.1 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].

12.2.2 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.

12.2.3 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.

12.2.4 The traditional wooden benches are permitted to be used in the sauna.

12.2.5 The sauna door shall open outwards by pushing.

12.2.6 Electrically heated ovens shall be provided with a timer.

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.

Section 23 Subdivisions and Stability

A. General

1. Application

All container ships may be assigned class only after it has been demonstrated that their intact stability is adequate for the service intended.

Adequate intact stability means compliance with standards laid down by the relevant Administration or with the requirements specified in this Section taking into account the ship's size and type. The level of intact stability for ships of all sizes in any case should not be less than that provided by the International Code on Intact Stability, 2008, chapter 2. In any case, the level of intact stability is not to be less than that provided by the BKI-Rules.

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

(IACS UR L2)

2. 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, E.

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.

3. References

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

IACS UR L2

ICLL containing all amendments up to 1st July 2010

SOLAS including all amendments up to 1st July 2012

4. Definitions

Draught (d)

Draught is the 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.

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 midpoint 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

In addition to the standard loading condition for intact stability calculation, as defined in Guidelines on Intact Stability (Pt.6, Vol.3) Sec.4, D.1.2, the stability manual for containerships must also include the following loading conditions:

- ship with a number of containers having a weight corresponding to the maximum permissible weight for each container at the summer load waterline when loaded with full stores and consumables
- same loading condition as above, but with 10% stores and consumables

The vertical location of the centre of gravity for each container is generally to be taken at one half of the container height. Different locations of the vertical centre of gravity may be accepted in specific cases, if documented.

Intact stability calculation refers to Guidelines on Intact Stability (Pt.6, Vol.3) Section 2.

2. Alternative criteria for container ships greater than 100 m in length

The alternative criteria intact stability calculation for container ships with length greater than 100 m refer to Guidelines on Intact Stability (Pt.6, Vol.3) Section 3, H

3. Onboard Stability Information

3.1 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)

3.2 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)

3.3 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)

3.4 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)

3.5 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)

3.6 When curves or tables of minimum operational metacentric height GM'or maximum allowable KG versus draught are not appropriate, 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)

3.7 The terms used in this Section are the same as those of SOLAS as amended.

C. Damage Stability

Damage stability calculation is required for container ships to comply with SOLAS Chapter II-1, Part B-1 to B-4. Container ships with proven damage stability will be assigned the symbol □.

D. Double Bottom

1. For all container ships 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:

$$h = \mathbf{B}/20$$

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)

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 in watertight bulkheads and internal decks

3.1 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)

3.2 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)

3.3 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)

3.4 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)

3.5 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)

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)

2. Such openings shall, except for cargo hatch covers, shall be fitted with indicators on the bridge.

(SOLAS II-1, 15-1.2)

3. 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)

4. 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)

G. Openings in the shell plating below the freeboard deck

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. 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)

5. 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)

6. 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)

7. 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)

8. 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)

9. 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)

10. 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)

11. 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)

12. The inboard opening of each ash-chute, rubbish-chute, etc., is to be fitted with an efficient cover.

(SOLAS II-1, 15.10.1)

13. 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[1)] 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.

[1)] Following the Res. MSC.245(83)

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Section 24 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.

C. Documents for Approval, Trials

1. In addition to the approval documents listed in Section 1, E 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 25, 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 25 Corrosion Protection

A. General

1. 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 Requirements with respect to the contractors executing the work and the quality control are subject to the conditions laid down in Section 1, H.1.1 and 1.2.

Note:

In addition, BKI also offers advisory services for general questions concerning corrosion and corrosion protection.

2. References

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 The coating used shall be approved by the manufacturer for application in cargo holds.

1.2 The coating manufacturer's instructions with regard to surface preparation as well as application conditions and processing shall be adhered to.

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.

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.

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Section 26 Functional Requirements on Load Cases for Strength Assessment of Container Ship by Finite Element Analysis

A. General

1. Application

This Section applies to container ships and ships dedicated primarily to carry their cargo in containers.

2. Reference

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

— IACS UR S34

3. Principles

The requirements in this Section are functional requirements on load cases to be considered on finite element analysis for the structural strength assessment (yielding and buckling).

The procedure for yielding and buckling assessment are to be in accordance with the BKI Rules. All in-plane stress components (i.e. bi-axial and shear stresses) induced by hull girder loads and local loads as specified in this Section are to be considered.

All aspects and principles not mentioned explicitly in this Section are to be applied according to the procedures of BKI.

4. Definitions

4.1 Global Analysis

A Global Analysis is a finite element analysis, using a full ship model, for assessing the structural strength of global hull girder structure, cross deck structures and hatch corner radii.

4.2 Cargo Hold Analysis

A Cargo Hold Analysis is a finite element analysis for assessing the structural strength of the cargo hold primary structural members (PSM) in the midship region.

4.3 Primary Structural Members (PSM)

Primary structural members are members of girder or stringer type which provide the overall structural integrity of the hull envelope and cargo hold boundaries, such as:

1) double bottom structure (bottom plate, inner bottom plate, girders, floors)

2) double side structure (shell plating, inner hull, stringers and web frames)

3) bulkhead structure

4) deck and cross deck structure

B. Analysis

1. Global Analysis

A Global Analysis is to be carried out for ships of length 290 m or above. Hull girder loads (including torsional effects) are to be considered in accordance with the procedures of BKI. The following methods may be used for Global Analysis:

Method 1 : Analysis where hull girder loads only (vertical bending moment, horizontal bending moment and torsional moment) are directly applied to the full ship finite element model

Method 2 : Analysis where direct loads transferred from direct load analysis are applied to the full ship finite element model

2. Cargo Hold Analysis

Cargo Hold Analysis is to be carried out for ships of length 150 m or above. Local loads such as sea pressure and container loads as well as hull girder loads are to be considered in accordance with the procedures of BKI.

C. Design Load

1. Load principles

1.1 Wave environment

The ship is to be considered sailing in the North Atlantic wave environment for yielding and buckling assessments. The corresponding vertical wave bending moments are to be in line with Section 5 and the other hull girder loads are to be taken in accordance with the BKI Rules. The corresponding local loads are to be taken in accordance with the BKI Rules.

1.2 Ship operating conditions

Seagoing conditions are to be considered. Harbour conditions and special conditions such as flooded conditions, tank testing conditions may be considered in accordance with the BKI Rules.

2. Load components

2.1 Global Analysis

The load components to be considered in Global Analysis are shown in Table 26.1

Table 26.1: Load components to be considered in Global Analysis

Method	Static Load	Dynamic Load
Method 1	Still water vertical bending moment Still water torsional moment	Wave-induced vertical bending moment Wave-induced horizontal bending moment Wave-induced torsional moment
Method 2	Static sea pressure Static container loads Static loads for ballast and fuel oil Self-weight of hull structure	Wave-induced sea pressure Dynamic loads for hull structure, containers, ballast and fuel oil

2.2 Cargo Hold Analysis

The load components to be considered in Cargo Hold Analysis are defined in Table 26.2

Table 26.2: Load components to be considered in Cargo Hold Analysis

	Static Load	Dynamic Load
Hull girder loads	Still water vertical bending moment	Wave-induced vertical bending moment
Local loads	Static sea pressure Static container loads Static loads for ballast and fuel oil[1)] Self-weight of hull structure	Wave-induced sea pressure Dynamic loads for hull structure, containers, ballast and fuel oil[1)]

[1)] For the minimum set of loading conditions specified in Table 26.3, all ballast and fuel oil tanks in way of the cargo hold model are to be empty. If additional loading conditions other than those given in Table 26.3 are considered, ballast and fuel oil loads may be taken into consideration at the discretion of BKI.

3. Loading conditions

3.1 Global Analysis

Loading conditions to be considered for the Global Analysis are to be in accordance with the Loading Manual and with the BKI Rules.

3.2 Cargo Hold Analysis

The minimum set of loading conditions is specified in Table 26.3. In addition, loading conditions from the Loading Manual are to be considered in the Cargo Hold Analysis where deemed necessary.

Table 26.3: Load components to be considered in Cargo Hold Analysis

Loading Condition	Draught	Container weight	Ballast and fuel oil tanks	Still water hull girder moment
Full loading condition	Scantling draught	Heavy cargo weight[1)] (40’ containers)	Empty	Permissible hogging
Full loading condition	Scantling draught	Light cargo weight[2)] (40’ containers)	Empty	Permissible hogging
Full loading condition	Reduced draught[3)]	Heavy cargo weight[1)] (20’ containers)	Empty	Permissible hogging (minimum hogging)
One bay empty condition[4)]	Scantling draught	Heavy cargo weight[1)] (20’ containers)	Empty	Permissible hogging

[1)] Heavy cargo weight of a container unit is to be calculated as the permissible stacking weight divided by the maximum number of tiers planned.

[2)] Light cargo weight corresponds to the expected cargo weight when light cargo is loaded in the considered holds.

- Light cargo weight of a container unit in hold is not to be taken more than 55% of its related heavy cargo weight (see (1) above).
- Light cargo weight of a container unit on deck is not to be taken more than 90% of its related heavy cargo weight (see (1) above) or 17 metric tons, whichever is the lesser.

[3)] Reduced draught corresponds to the expected draught amidships when heavy cargo is loaded in the considered holds while lighter cargo is loaded in other holds. Reduced draught is not to be taken more than 90% of scantling draught.

[4)] For one bay empty condition, if the cargo hold consists of two or more bays, then each bay is to be considered entirely empty in hold and on deck (other bays full) in turn as separate load cases

4. Wave conditions

4.1 Global Analysis

Wave conditions presumed to lead to the most severe load combinations due to vertical bending moment, horizontal bending moment and torsional moment are to be considered.

4.2 Cargo Hold Analysis

The following wave conditions are to be considered:

1) Head sea condition yielding the maximum hogging and sagging vertical bending moments.
2) Beam sea condition yielding the maximum roll motion. This condition may be disregarded for some loading conditions defined in Table 26.3 where deemed not necessary.

Section 27 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

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 the 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)

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 27.2)

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. 27.1.

(IACS UR S33.2.1)

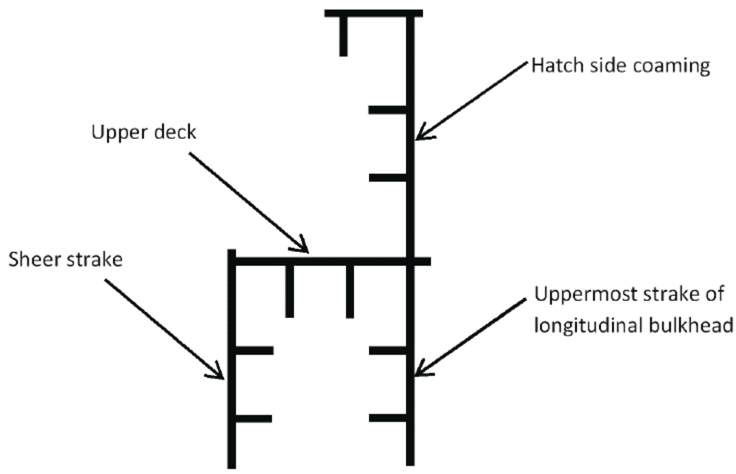


Figure 27.1: Upper Flange Longitudinal Structural Members

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 27.2)

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 27.2)

1. General

1.1 The brittle crack arrest steel method may be used when the measures No. 3, 4 and 5 of Table 27.2 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 the 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 steels 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.

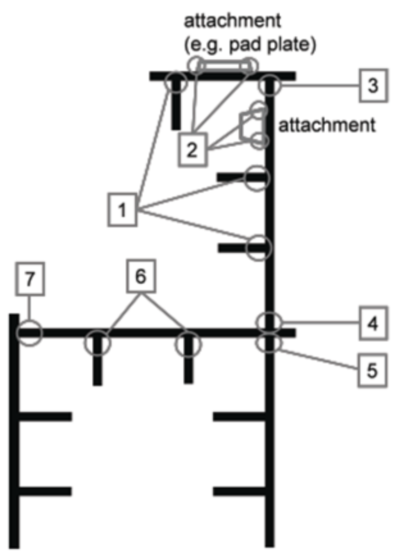


Figure 27.2: Other Weld Areas

*** "Other weld" includes the following (refer to Fig. 27.2):

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 detailed 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 27.1 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 27.1.

Table 27.1: 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 27.1 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 27.2 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 27.2, countermeasures are not necessary regardless of the thickness and yield strength of the upper deck plating.

(IACS UR S33.Annex 1)

Table 27.2: 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. 27.2) 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)

Annex A Certification of Hull Response Monitoring for Container Ships

A. General

1. Application

This certification applies to container ships where it is intended to provide a hull response monitoring system that monitors ship responses, such as motions and hull girder stresses, and warns the ship's personnel that these responses are approaching a level where corrective action is advisable.

2. Liability

This system is intended as an aid to the master's judgment and not as a substitute for it. Accordingly, any failure of the system does not detract from the master's absolute responsibility to take corrective action in operating the ship.

3. Plans and Information to be submitted

Depending on the requested class notation, the following plans and information are to be submitted for certification of the hull response monitoring system:

- general arrangement drawing showing, where applicable, locations of accelerometer(s), motion sensor(s), pressure transducer(s), strain gages, components of the shipboard routing assistance (SRA) system, and components of the shipboard wave sensor
- block diagram illustrating the operation of the system
- description of the functions and facilities of the system
- structural plans and properties of the hull section(s) in way of strain gages, including section inertia, position of the neutral axis, and the vertical distance from the neutral axis to the center of the strain gage element
- details of accuracy, range, and frequency response of accelerometer(s), pressure transducer(s), strain gages, ship response predictions, route planning, and wave heights and periods
- where applicable, procedures for installation, setup, calibration, and operational verification of accelerometer(s), pressure transducer(s), strain gages, SRA components, and wave sensor components
- description of the output display method
- description of the method and capability of the data recording system and facilities for examination of recorded data

- where applicable, details of the intrinsic safety arrangement of electrical equipment in hazardous areas
- description of the method of slam detection and the method of counting and recording fatigue stress ranges and cycles for the strain gages
- simulation procedure for testing the processing function of the system and results, including algorithms for slam detection and for stress range and cycle counting
- procedure for system testing and operational verification
- operating manual for the system and, where applicable, type approval certificates for the SRA system and the shipboard wave sensor

4. Alternatives

BKI will consider alternative arrangements that can be shown to be effective in meeting the overall standards of this certification.

B. System Types

1. General

In accordance with these requirements, a Hull Response Monitoring System is to display and/or record any one or a combination of various kinds of ship responses and/or wave data, such as ship motions, stresses, the occurrence of slams and green seas, and the continuous monitoring of the ship with the aim to recognize potentially dangerous situations.

2. HRM — Motion monitoring

2.1 Application

Where requested by the owner, the notation HRM will be assigned to ships having hull response monitoring systems for motion monitoring in compliance with 2.

Motion monitoring systems measure translational and/or rotational movements by means of motion monitoring devices, such as accelerometers, vertical reference gyroscopes, pitot or Doppler logs, wave height sensors, and servo inclinometers.

Motion monitoring systems are to be identified by their main function. This function will form the descriptive part of the notation awarded. Requirements for the most common types of systems are listed in C, for Ship Motion, Slam Warning, or Green Seas monitoring.

2.2 Ship motions

2.2.1 System requirements

The ship motion monitor is to warn the operating personnel that ship motions are approaching a level at which a specific problem condition is likely to occur. The specific problem being considered is to be clearly stated. Ship motion monitors are to indicate over time the possibility of the ship motions exceeding the selected warning levels.

2.2.2 Warning levels

The levels of motion that will cause the specific problem are to be submitted for information. The levels at which warnings are given to the ship's operating personnel are to reflect those levels and are also to be submitted for information.

2.3 Slam warning

2.3.1 System requirements

The slam warning monitor is to warn the ship's operating personnel in advance that the ship is in sea or operating conditions approaching those that could induce wave slams, possibly leading to either local or global hull girder structural damage. Slam warning monitors are to show the trend of slams over time in relation to the wave-induced slam impacts that exceed the selected warning level.

2.3.2 Warning levels

Structural damage warning levels on displays are to be set, taking into account the approved scantlings and their conditions of approval. Criteria selected to evaluate the approaching occurrence of slams that could cause structural damage are to be derived from computations, model tests, or full-scale trial results, and they are to be submitted for information. The method to select these criteria is to reflect the operating conditions of the ship being equipped.

2.3.3 Sensor types

Accelerometers measuring the vertical bow motions or pressure transducers measuring the ship's motions relative to the sea surface are to be used to warn against slams. Acceptable instruments to identify impacts include accelerometers and pressure transducers.

Using spectral analysis or other techniques, the acceleration signal of accelerometers indicates the decaying vibratory shape at the frequency of a two-node vibratory mode of the ship hull girder. The amplitude of the vibration is a measure of the severity of the impact.

Pressure transducers make it is possible to detect a pressure gage's emergence from the water surface. The reentry pressure is a measure of the impact's severity

2.4 Green seas warning

2.4.1 System requirements

The green seas warning monitor is to warn the operating personnel in advance that the ship is in sea or operating conditions approaching those where shipping of green seas could lead to damage of the ship or its cargo. Green seas warning monitors are to show the trend of green seas conditions over time in relation to the green seas conditions that exceed the selected warning levels.

2.4.2 Warning levels

Structural damage alarm levels and warning levels on displays are to be set, taking into account the approved scantlings and their conditions of approval. Criteria selected to evaluate the approaching occurrence of water on deck or bow acceleration that could cause damage to the ship's structure or to the cargo are to be derived from computations, model tests, or full-scale trial results, and they are to be submitted for information. The method to select these criteria is to reflect the operating conditions of the ship being equipped.

2.4.3 Sensor types

Monitoring the shipping of green water is to be accomplished by sensors that measure the amount of water coming on deck or the vertical motions at the ship's fore end.

3. HRS — Stress monitoring

3.1 Application

Where requested by the owner, the notation HRS will be assigned to ships having hull response monitoring systems for stress monitoring in compliance with 3. Stress monitoring systems are to be identified by their main function. This function will form the descriptive part of the notation awarded.

Stress monitoring usually involves fitting a number of strain gages to the hull structure.

3.2 Hull girder stress

3.2.1 System requirements

The hull girder stress monitor is to warn the ship's operating personnel that the hull girder stresses are approaching a level at which corrective action is advisable. Hull girder stress monitors are to indicate over time the possibility of the hull girder stresses exceeding the selected warning levels. Hull girder monitors are to show the still water bending moment and wave bending moment, how they vary with time, as well as their longitudinal position along the length of the ship.

A display for still water loads, obtained either from the loading computer or from measurements, is to be available in the wheel house. Information to be collected and presented is to ensure that firstly overloading, buckling, and collapse of the hull girder is prevented during cargo and ballasting operations and secondly that the strength of the hull girder is sufficient when the ship is at sea.

A display of wave loads is to be available to show the effects on wave-induced loads of the ship changing speed and/or wave heading and, thereby, indicating the possibility of damage within a short time span after making this change. In general, this time span is to be less than ten minutes.

3.2.2 Warning levels

BKI rule values for both static and dynamic load and stress components may be used to set the warning levels for stress monitoring. When installed as global hull girder response indicators, the warning levels should be set with reference to the approved scantlings and their conditions of approval. Warning levels are to be submitted for information along with the criteria used in determining settings.

Warning levels of hull girder stress caused by (static) still water loads are to reflect both "in harbor" and "at sea" load criteria as well as other appropriate criteria. Stresses caused by the still water loads are to be based on information from the loading manual or the loading computer.

Warning levels of hull girder stress caused by (dynamic) wave loads are to reflect limiting values that enable the master to avoid damage to the hull due to wave-induced loads. Where the monitor shows an increase in wave loads approaching the limiting values, timely corrective action can be taken by changing ship speed and/or wave heading. The monitor shall also show the effect of these changes on wave loads within a short time span after this change in speed and/or heading.

3.2.3 Sensors

Generally, hull girder stress measurements are obtained from a number of long-base strain gages distributed along the length of the ship and around its girth. Strain gages for hull girder monitors are to be located as close as possible to locations identified by the loading manual and loading computer for monitoring hull girder bending moments. Where the gages cannot be situated at these locations, the procedure for correcting these measurements is to be submitted for information and included in the operating manual. Where strain gages are located in areas subject to multiple load mechanisms, means are to be provided to separate out the different stress components. Compensation is to be made for hull girder stresses obtained from gages located in areas subject to shear lag.

A minimum of two strain gages at amidships is to be fitted, one port and one starboard on deck. However, it is preferable to fit four strain gages around a transverse section, namely, two strain gages on the upper deck and two strain gages at the inner bottom level or upper bilge, arranged symmetrically on a transverse section, near the end of the open deck section forward of the engine room. The longitudinal hull girder stresses at the bilge positions are to be derived from the strain gage measurements. More reliable stress monitoring can be obtained by fitting two additional strain gages on the upper deck amidships, arranged symmetrically about the longitudinal centreline.

Two strain gages are to be positioned on the upper deck, one gage about 25 percent and another gage about 75 percent of the ship's length from the aft perpendicular.

If it is intended to show the distribution on extremes of hull girder stresses, measured data need to be recorded and collected. Depending on ship size, BKI will advise on the exact data required. Generally, the data will furnish a frequency distribution of the dynamic stress component in 50 microstrain intervals.

3.3 Local stress

3.3.1 System requirements

The local stress monitor is to warn the ship's operating personnel that particular structural components are locally stressed to levels approaching the limits of their approval and that corrective action is advisable. Local stress monitors are to indicate over time the approaching possibility of local stresses exceeding the selected warning levels.

3.3.2 Warning levels

Warning levels of local stresses should be set taking into account the approved scantlings and their conditions of approval. Warning level settings are to be submitted for information along with the criteria used to determine these settings.

3.4 Fatigue

Fatigue monitors are to indicate over time the amount of usage of the initial fatigue strength relative to the approved scantlings and their conditions of approval. Miner's sum techniques, in conjunction with rainflow counting, are to be used to estimate fatigue life. Other schemes may also be accepted. For instance, the measured data may be used for crack growth calculations, based on a method submitted for information.

4. HRSRA — Shipboard routing assistance

4.1 General

In accordance with these requirements, a Shipboard Routing Assistance (SRA) system is to display and/or record various kinds of ship responses and/or wave data with the aim to recognize potentially dangerous situations to the ship and its cargo. The levels at which warnings are given to the ship's operating personnel are to be submitted for information.

4.2 Application

Where requested by the owner, the notation HRSRA will be assigned to ships having a shipboard routing assistance system for the continuous monitoring of the ship with the aim to recognize situations potentially dangerous to the ship and its cargo.

As container ships become larger and respond less directly to the seaway, it becomes more difficult for the ship officers to correctly judge the seas and to consistently make the right decisions for a safe operation of the vessel. Highly stacked containers on deck in front of the bridge further contribute to a distancing of the officers from the sea. A shipboard routing assistance (SRA) system combines performance monitoring of a ship at sea with information on the weather and the sea to supply active routing assistance to the navigating personnel. The objective of an SRA system is the prevention of dangerous conditions with cargo loss and possible structural damage to the ship when operating in bad weather.

An SRA system is to be identified by the extent of its recording capability, the time scale of its recording, and the survivability of its recordings. These functions will form the descriptive part of the notation awarded.

4.3 Concept

Basic functions of a typical SRA system are schematically shown in Fig.A.1 central processing unit collects information on the ship's loading condition, the ship's speed, the ship's scheduled route, and the seaway. This information is processed together with relevant hydrodynamic properties of the ship stored in a data bank to obtain the ship's response. This information is used as follows:

- for documentation in the ship's log
- to monitor the ship's behavior at sea
- to supply active routing assistance to the navigating personnel
- to warn the navigating personnel of situations potentially dangerous to ship and cargo
- to advise the navigating personnel of corrective action

An accurate mathematical model to compute the wave-induced response of the ship is a prerequisite for the system.

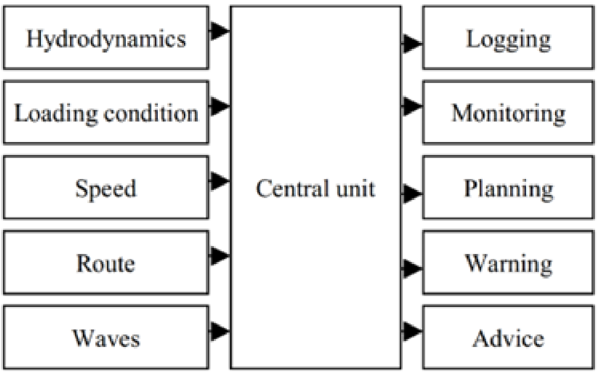


Figure A.1: Functional diagram of a typical SRA system

4.4 Central unit

The central unit comprises the core software of an SRA system, utilizing the hydrodynamic database together with other input variables by combining wave data with data on the ship's loading condition, speed, course, wave heading, and the planned route. It provides extensive prediction capabilities and superior analysis flexibilities compared to purely measurement based systems. Many kinds of responses can be analyzed, such as absolute and relative ship motions, hull girder loads and the resulting hull girder stresses, as well as accelerations of containers and the associated forces in container lashing systems.

Based on information available, the central unit calculates real time as well as future shipboard response. The decision making support to the bridge provided by an SRA system is based on this information. Thus, it is an effective feature to improve the operational safety of the ship. On the bridge, the system's graphical user interface displays the actual situation as well as effects of changing course and/or speed on the ship's behavior. Operational guidance based on the resulting predictions may be presented in the form of a polar diagram of wave heading angle versus ship speed, calculated for different sea states and loading conditions. Fig. A.2 shows a typical screen shot of actual and forecasted conditions and the corresponding ship behavior. The polar diagram identifies limiting wave heights for the ship to fulfill a limiting criterion, here for capsizing. The screen shot in Fig. A.3 shows a typical digital chart with weather information, marking the ship's track, its position, and its predicted response along this track.

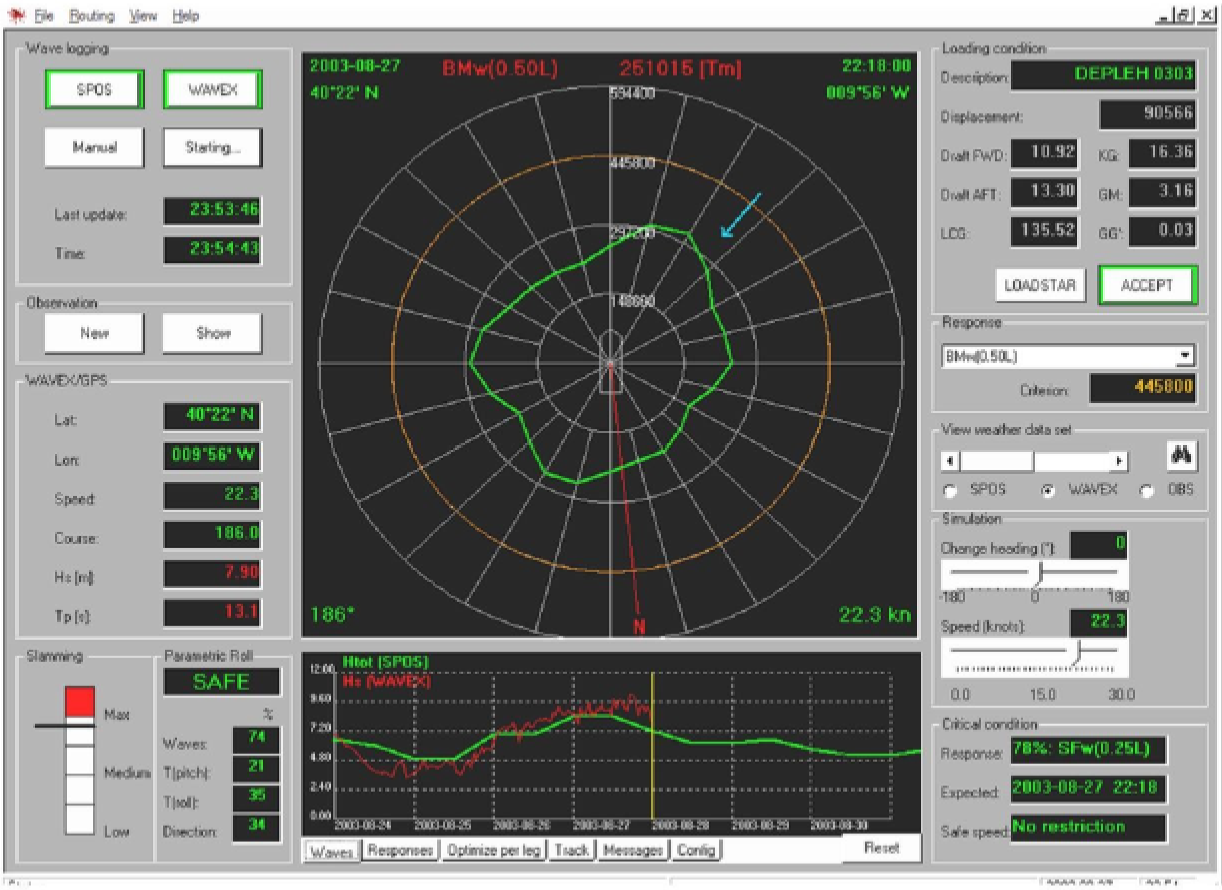


Figure A.2: Monitoring screen showing actual (polar diagram, above) and forecasted (below) conditions and the ship's predicted response

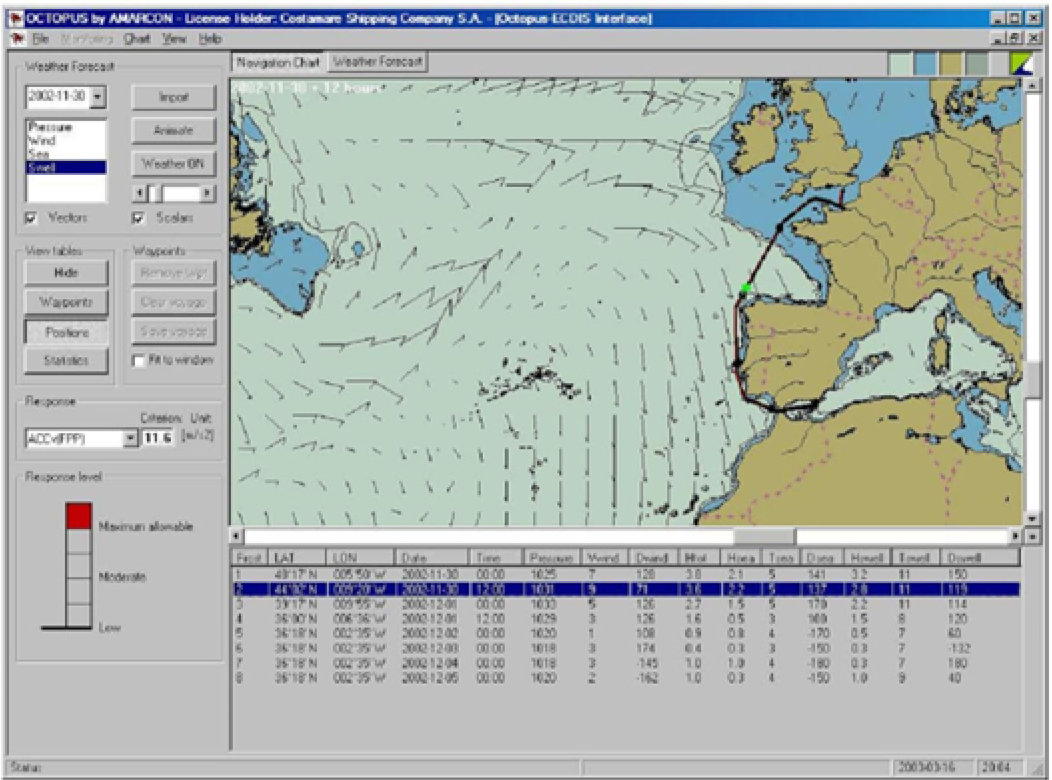


Figure A.3: Digital chart with weather information, marking the ship's track, its position, and its predicted response

4.5 Data base

4.5.1 Hydrodynamic data

The analysis of ship response requires pressure field predictions acting on the ship's hull. The pressure field is affected not only by the incoming waves, but also by the presence of the ship itself, causing diffracted wave pressures, and by the ship's motions, inducing radiated wave pressures. Three-dimensional boundary element methods are well suited to solve this problem. They are mostly formulated in the frequency domain and assume inviscid potential flow. The viscous nature of the flow is normally taken into account by introducing empirical damping coefficients. If a lower degree of accuracy is acceptable, classical strip theory methods are an economic and effective alternative to boundary element codes.

Three-dimensional methods are often disqualified for shipboard use because of their complexity and the required high computing power. Therefore, the central unit can be arranged to store pre-calculated diffraction and radiation potentials in a separate data base. Typically, such a data base contains potentials and their gradients for all boundary elements (panels) of the ship's hull, calculated for at least four drafts, five ship speeds, and seven wave headings. For each of these parameter combinations, covering theentire range of relevant operating conditions, these data are to be computed for at least 20 frequencies. In terms of the ratio wavelength over ship length, this range should extend from 0.2 to 5.0 to cover the period of maximum roll.

4.6 Loading condition

The SRA concept uses the actual, real-time loading condition to compute transfer functions of ship response. Using detailed information directly from the loading computer, the actual mass distribution and hydrostatic properties, including reductions of the metacentric height caused by free surface effects, can be determined.

4.6.1 Wave data

To yield ship responses, an SRA system imports the predicted sea states and processes them. Visually observed sea states may be specified and stored in an electronic data base, or environmental conditions along the planned route of the ship can be derived from forecasts supplied by a recognized meteorological weather service. Alternatively, monitoring of the seaway may be carried out by a wave sensing device that continuously measures the seaway surrounding the ship.

4.7 Ship response predictions

4.7.1 Linear predictions

An attested computer code should be used to predict the ship's response. Linearly computed ship response (in unit amplitude regular waves) should be validated against reliable measurements, such as model test data or closed form linear response predictions. Comparable data for similar ships may be useful. This linearly calculated ship response, normally presented as a function of wave frequency (transfer functions), depends on the actual loading condition and the ship's speed. Transfer function computed by the SRA system's central unit should be validated against comparable transfer functions obtained from desk studies.

A useful consequence of linear ship response predictions is that it allows treating the response of the ship in a seaway as a random process. Spectral techniques can then be used to analyze ship responses, yielding statistical measures of the responses in natural seaways, such as significant and maximum values. These values should be validated against full-scale data obtained from measurement campaigns conducted on board of existing container ships.

4.8 Nonliniear effects

Nonlinear effects, such as large amplitude roll motions and impact-related wave-induced slamming loads, may have to be accounted for to obtain accurate ship response predictions. Although linear theory can accurately calculate, for example, heave and pitch motions even in severe wave conditions, roll motions shall be treated nonlinearly because it is difficult to correctly model viscous damping effects. Nonlinear roll damping can be approximated by the inclusion of appropriately linearized damping coefficients when solving the equations of motion. The choice of roll damping coefficients can be validated by proper tuning on the basis of model test data or full scale measurements.

For container ships in severe seas, linear theory cannot always predict ship response reliably. Wave-induced impact-related load effects may be nonlinear even though ship motions are linear, especially for modern container ships with large bow flare and stern overhang. For practical applications, therefore, nonlinear corrections that influence the hull girder load behavior may need to be introduced into linear codes to provide accurate predictions.

4.8.1 Numerical simulations

Numerical simulations may be based on potential hydrodynamic formulations or on techniques that directly solve the Reynolds-averaged Navier-Stokes (RANS) equations. Such methods, mostly computed in the time domain, should be capable of calculating the hydrostatic and Froude-Krylov forces and moments over an instantaneously submerged ship hull. For large amplitude motion predictions, two-dimensional nonlinear strip methods may suffice to efficiently predict excessive motions in severe seas. Depending on the nature of the problem, some methods treat selected combinations of degrees of freedom nonlinearly in the time domain, while the remaining degrees of freedom are treated linearly. Use of RANS codes enables the inclusion of viscous effects on motions and loads and, by employing interface-capturing techniques of the volume-of-fluid (VOF) type, they compute complex free-surface shapes with breaking waves, sprays, and air trapping.

4.8.2 Parametric roll

Large modern container ships seem to be susceptible to what is known as parametric roll, a rare phenomenon that has only recently been investigated in depth. A finally balanced set of circumstances shall exist for this physical event to take place. Changing stability in a seaway excites parametric roll. Almost every ship experiences a decrease in transverse stability while on the wave crest and a corresponding increase in the wave trough. For such stability changes to generate parametric roll, not only shall the natural period of roll be equal to about twice the wave encounter period for head seas and equal to about the wave encounter period for following seas, but also the magnitude of parametric wave excitation is to be large enough to exceed a certain threshold.

Nonlinearities of the righting arm curve on the one hand and roll damping on the other determine the intensity of the parametric roll response. The basic nonlinearity of the phenomenon makes it difficult and leaves only limited ways to practically predict parametric roll in natural (irregular) seas. Application of nonlinear time-domain simulations seems to be the most promising and practical approach. It can be used to evaluate the risk of damage to a containership and its cargo inflicted by parametric roll. A nonlinear system, however, does not necessarily preserve probabilistic qualities of the stochastic input process, in this case the seaway. Several simulation runs are needed to obtain useful statistical measures of the stochastic process of this nonlinear system. This is not a practical procedure onboard. Therefore, criteria based on selected seaway parameters together with an approximate description of the seaway response should be built into the SRA system to indicate the possibility of dangerous parametric roll motions instead. Parametric roll occurs primarily if the following conditions are met:

- slender hull
- natural period of roll equal to about twice the wave encounter period for head seas and about equal the wave encounter period for following seas

— wave length in the order of ship length

— wave height exceeding a threshold level

— almost ahead or astern wave heading

— low roll damping

These criteria should be accounted for in the SRA system.

If the ship is found to be susceptible to parametric rolling, the navigating personnel on the bridge should be supplied with operational guidance indicating dangerous regimes for the representative loading conditions and sea states where parametric roll may represent danger. The operational guidance may be presented in the form of polar diagrams that indicate dangerous regimes of wave heading angle versus ship speed for each sea state and loading condition. Fig. A.4 shows a sample operational polar diagram for a container ship in long-crested sea state 8 conditions with a modal period of 16.4 s and a significant wave height of 11.5 m, where dangerous regimes are defined by roll angles exceeding 20°. The white areas in this figure indicate safe ship operation; the red areas are to be avoided.

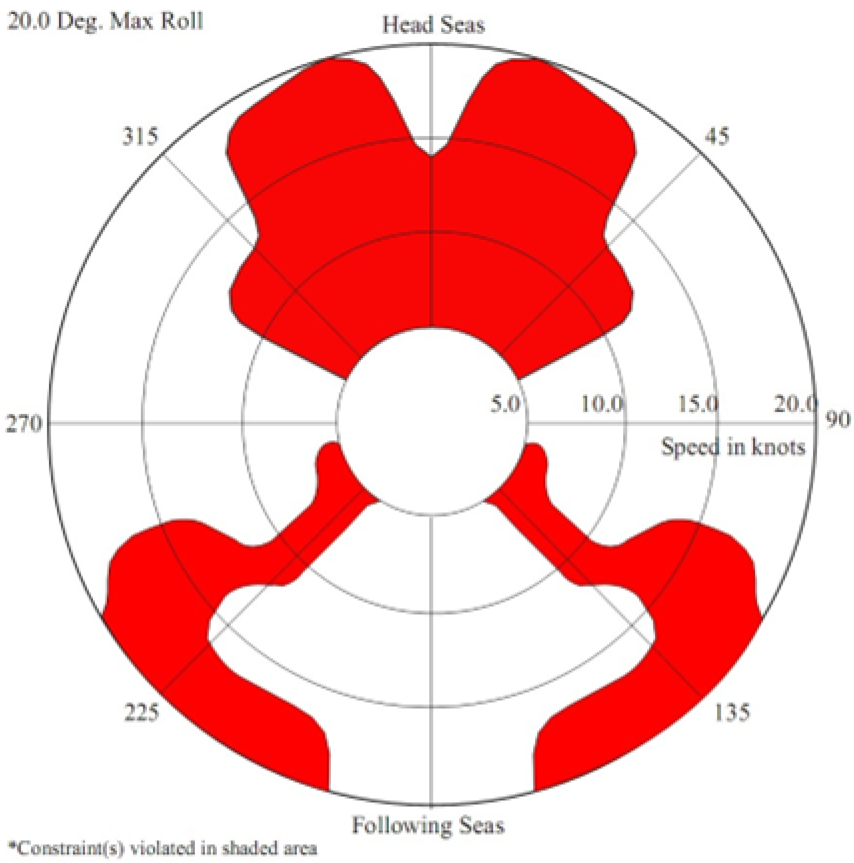


Figure A.4: Sample operational polar diagram

5. HRW — Shipboard wave sensor

5.1 General

In accordance with these requirements, a Shipboard Wave Sensor is to display and/or record wave data of the seaway surrounding the ship. The certification of the wave sensor device should comprise product description, range and limits of application, test conditions, and approval documents.

5.2 Application

Where requested by the owner, the notation HRW will be assigned to ships provided with a wave sensor for the continuous monitoring of the seaway surrounding the ship in compliance with 5.

5.3 Seaway monitoring

Monitoring of the seaway may be carried out by a wave sensing device, using the ship's nautical X-band radar antenna. An SRA system may import the monitored sea states and process them to yield ship responses. Other options may be used to monitor the seaway, such as Doppler radars or combined sensor systems.

6. HRD — Voyage data recordingl

6.1 Application

Where requested by the owner, the notation HRD will be assigned to ships having hull response monitoring systems for voyage data recording in compliance with 6. Voyage data recorders are to be identified by

the extent of their recording capability, the time scale of their recording, and the survivability of their recordings. These functions will form the descriptive part of the notation awarded.

6.2 Voyage data

6.2.1 System requirements

Approved systems generally monitor and record all bridge functions, fire and gas alarms, principal main engine and auxiliary engine operating parameters and alarms, environmental conditions, radar and hull monitor data, etc.

For large container ships (in excess of 200 m length), it is recommended that hull girder stress monitors be fitted in conjunction with voyage data recorders.

6.2.2 Recorded data

Recorded data are to be in a format that allows the original signal from the sensor to be reconstructed. This requirement can be waved for radar signals.

For the radar, the information from one complete sweep per minute is the minimum acceptable recording rate. Recorded data are to be kept for at least 24 hours before they are overwritten.

6.2.3 Power supply

Voyage data recorders are always to operate from an uninterruptible power supply with at least four hours backup. Loss of power from the power supply is to activate an audible and visual alarm in the wheel-house. The voyage data recorder is to shut down after its power supply fails and to restart on resumption of power without the need of intervention from the ship's operating personnel.

6.2.4 Survivability

The recordings are to be able to survive and be readable after exposure to a cellulose type fire for 30 minutes.

The recordings are to float free if the ship sinks, and an EPIRB is to be automatically activated.

C. System Requirements

1. General

In accordance with these requirements, hull response monitoring systems are to display and record data from the following components:

- devices such as accelerometers, vertical reference gyroscopes, pitot or Doppler logs, wave height sensors, and servo inclinometers measuring translational and/or rotational ship motions

- an accelerometer measuring the vertical acceleration at the bow and/or a pressure transducer measuring the pressure at the forward bottom position of the hull
- at least two strain gages providing measurements of the hull girder longitudinal stresses
- an SRA system consisting of components suitable for the continuous monitoring of the ship
- a shipboard wave sensor to display and/or record wave data of the seaway surrounding the ship

2. Sensors

There are no restrictions on the kind of sensor that can be used with a hull response monitoring system. Care is to be taken when selecting sensors to ensure that they are suitable for the marine environment. It is recommended to use sensors approved by a recognized Classification Society.

2.1 Accelerometers

The vertical acceleration at the bow is to be measured on the centerline, at the main deck level, in the forward 0,01**L** of the ship.

The acceleration is to be measured over the range ± 2,0 g, where g is the acceleration of gravity.

The accelerometer is to have a frequency response capable of measuring acceleration in the frequency range 0 to 5 Hz.

2.2 Pressure transducers

The position of the pressure transducer is to take account of the structural configuration of the ship and its hull form. The pressure at the bottom of the hull is to be measured on, or as near as possible to, the centerline, in the forward 0,01L of the ship.

The pressure is to be measured at least over the range 0 to 100 kPa with an accuracy of within ± 0,025 kPa.

The pressure transducer is to have a frequency response capable of measuring pressure in the frequency range 0 to 100 Hz.

2.3 Strain gages

The position of the strain gages is to take account of the structural configuration of the ship. The system is required to measure the hull girder longitudinal stress as close as practicable to the position(s) where it(they) is(are) expected to be most significant. If such stress cannot be measured at the appropriate location, it is to be adjusted by a method approved by BKI to represent the stress in that location.

Because container ships generally have large deck openings, four or more strain gages are fitted around a transverse section of the hull at a position where the longitudinal hull girder stress, caused by bending or torsional moments, is at its maximum. Generally, this is likely to be near the end of the open deck section forward of the engine room.

A minimum of four strain gages shall be fitted. If four strain gages are fitted, two strain gages are to be located on the upper deck and two strain gages at the inner bottom level or upper turn of the bilge, arranged symmetrically on a transverse section, near the end of the open deck section forward of the engine room. The longitudinal hull girder stresses are to be derived from the strain gage measurements.

If six strain gages are fitted, two additional strain gages are to be located on the upper deck amidships, arranged symmetrically about the longitudinal centerline.

Each strain gage is to measure the strain over a gage length of between 1.5 and 2.5 m, with an accuracy of at least five microstrains, and the strain is to be of such a type as to obviate the effects of local stress concentrations.

The linear range of each strain gage is to be in excess of the full range of the expected still water and dynamic stress variation.

Each strain gage is to have a frequency response capable of measuring strain in the frequency range 0 to 5 Hz.

2.4 SRA system

The SRA system is to be capable of displaying and/or recording various kinds of ship responses and/or wave data with the aim to recognize potentially dangerous situations to the ship and its cargo.

2.5 Wave sensor

The wave sensor shall be capable of continuous monitoring of the seaway surrounding the ship.

The wave sensor shall be type approved by a recognized Classifications Society.

3. Data sampling and system resolution

Data sampling rates employed are to be adequate for the intended frequency response of the sensors. In general, the data sampling rate is to be at least four times greater than the frequency response required.

The system is to have a resolution suitable for the accuracy required for the sensors. In general, the analogue to digital converter employed is to have a minimum resolution of 12 bits.

4. System displays

A visual display unit is to be positioned on the bridge to display the following data, where applicable:

- maximum, minimum, and mean values of bow vertical acceleration for each accelerometer
- maximum, minimum, and mean values of bow bottom pressure for each pressure transducer
- maximum, minimum, and mean values of the longitudinal hull girder stress for each strain gage
- maximum and minimum values of the wave-induced dynamic longitudinal hull girder stress for each strain gage
- the actual ship situation (marking the ship's track, its position, and its predicted response) as well as effects of changing course and/or speed on the ship's behavior, including operational guidancebased on the resulting predictions of the SRA system
- forecasted and actual weather information, comprising wave and wind conditions

Maximum and minimum values are to be updated at least once every minute; mean values, at least once every five minutes. A graphical display of the data is to be provided.

In addition to the display of the vertical acceleration or bottom pressure at the bow, the number of slam occurrences within one hour period, updated at least once every five minutes, is also to be displayed while at sea.

All data as well as the number of slams are also to be displayed, digitally and graphically, in a manner that enables the trends in the data to be seen over at least the previous four hours. The display is to be updated at least once every ten minutes.

Where a bow accelerometer is used to detect slams, the occurrence of a slam can be identified by the declining amplitude of vibratory bow acceleration in the two-node mode vibration frequency of the hull girder.

Where a bottom bow pressure transducer is used to detect slams, the occurrence of a significant slam can be identified by the emergence and re-entry of the bow section.

The purpose of displaying acceleration, pressure, and hull stress data is to enable visual comparison of values produced by the hull response monitoring system with independent user-selected criteria. User selected criteria are to be less in magnitude than the limit values provided by BKI. Audible and visual alarms are to be provided to indicate when the data exceed the independent user-selected criteria.

To facilitate the calibration of the hull response monitoring system, a numerical and/or visual display of the following data is to be provided:

— acceleration obtained from individual accelerometers or pressure transducers

— extension, strain, and stress obtained from individual strain gages

— inertia of the hull section, vertical distance from its neutral axis to the center of the strain gage rod, and effective length of each strain gage

— the ship's track, its position, and its predicted response as well as effects of changing course and/or speed on the ship's behavior

— operational guidance based on the resulting predictions of the SRA system

— forecasted and actual weather information, comprising wave and wind conditions

Text and graphics displayed on a visual display unit have to be read easily from the normal operator position under all operational lighting conditions.

It is recommended that an additional system display be provided in the cargo control area to assist the ship's personnel in monitoring hull stresses during ballasting and cargo operations.

5. Data recording and storage

A data recording system is to be provided. The data storage system is to use a removable permanent data storage medium capable of storing the required data for a continuous period of at least one round-trip. Facilities are to be available, either onboard or onshore, to enable the recorded data to be examined.

The system is to be capable of continuous recording of the following information, processed at intervals not greater than ten minutes:

— maximum, minimum, and mean values of acceleration, pressure, and stress

— maximum peak to trough values of acceleration, pressure, and stress

— average crossing period of acceleration, pressure, and stress

— time and date referenced to the universal time constant

— wave data, preferably energy density spectra of the seaway

— the ship's loading condition

— the ship's speed and position

The system is to be capable of counting and recording stress ranges and cycles for each strain gage. The processing function of this counting algorithm is to be tested, using a simulated signal containing a suitable spectrum of harmonic signals. The bin size(s) for stress ranges is(are) not to exceed 25 microstrains. The accumulated counts of stress cycles are to be recorded at intervals not exceeding 24 hours, with time and date referenced to the universal time constant.

6. System power supply

Following loss of power to the system, the operation of the system is to recover within five minutes after resumption of power with minimum operator intervention.

Computer software and data held in the data storage system are to be protected from corruption caused by loss of power.

7. Operating manual

An operating manual, written in English and in a language appropriate to the ship's operating personnel, is to be placed onboard. The operating manual is to include the following:

- instructions on operating the system
- instructions on how to interpret the resulting data
- instructions for maintenance, fault finding, and repair
- instructions for sensor setup, calibration, and verification
- list of spare parts

D. Commissioning

1. General

The procedure for operational verification of the hull response monitoring system, including sensors, data processing, display, alarm system, data recording system, and intrinsic safety of the equipment in hazardous areas, is to be submitted to BKI for approval, and an approved copy is to be kept onboard.

The procedure for installing, testing, and setting up and calibrating motion sensor(s), accelerometer(s), pressure transducer(s), and strain gages is to be submitted to BKI for approval, and an approved copy is to be kept onboard.

All sensing components are to be supplied with certificates of calibration from the manufacturer(s) or personnel authorized by the manufacturer(s). All such certificates are to be kept onboard for verification at each survey

2. Motion sensors

Motion sensor(s) are to be set to a value in accordance with trim and list of the ship under a known loading condition.

Satisfactory operation and linearity of the motion sensors are to be verified from the system display by simulating output at various angles of inclination of the sensor.

The operation of each motion sensor is to be checked within a three month period after setup, with a surveyor from BKI attending, to identify any signal drifting problems. This check is to be carried out after the ship completed at least one voyage at sea.

2.1 Accelerometers

Satisfactory operation and linearity of the accelerometer(s) are to be verified from the system display by simulating output at various angles of inclination of the sensor.

The operation of each accelerometer is to be checked within a three-month period after setup, with a surveyor from BKI attending, to identify any signal drifting problems. This check is to be carried out after the ship completed at least one voyage at sea.

2.2 Pressure Transducers

Satisfactory operation of the pressure transducer(s) is(are) to be verified by establishing that the pressure values displayed by the hull response monitoring system are at least compatible with the ship's draft at the appropriate transducer location.

The operation of each pressure transducer is to be checked within a three-month period after setup, with a surveyor from BKI attending, to identify any signal drifting problems. This check is to be carried out after the ship completed at least one seagoing voyage.

3. Strain gages

The measurement range of each strain gage is to cover the expected still water and dynamic stress variation. The linearity of each strain gage is to be verified from the system display using appropriate calibration equipment.

If possible, each strain gage is to be set up to a stress calculated for an agreed loading condition. This calculated stress is to be compatible with the output from the loading computer and calculations made using the loading manual.

The operation of each strain gage is to be verified by checking against an agreed loading condition, within a three-month period after setup, with a surveyor of BKI in attendance. This verification is to be carried out after the ship has completed at least one seagoing voyage. The setup and verification process is to be repeated if the difference between the hull girder vertical bending moment derived from the strain gages and the permissible (rule based) hull girder vertical bending moment is larger than ten percent.

Before setup, calibration, and measurement verification, the loading condition is to be verified by checking the ship's actual draft against the value calculated by the loading computer or the loading manual.

Before setup, calibration, and measurement verification of the strain gages are to be carried out, the ship is to be in an even and symmetrical loading condition in calm water and when the effects of temperature on the ship's structure are at a minimum, i.e., under the following conditions:

- in sheltered waters, preferably with a sea state not exceeding one
- if fetch is significant, wind force is not to exceed Beaufort twoe
- overcast whether or darkness

The surface temperature of the ship's structure where stress is measured is to be recorded.

4. System software

The processing functions of the hull response monitoring system software are to be tested using simulated signals. A spectrum of harmonic signals is to be used, covering the ranges of individual sensors. Output of the hull response monitoring system is to be compared with separate calculations based on the simulated signals. The proposed simulation test program is to be submitted to BKI for approval prior to the test.

5. General

5.1 SRA system

To obtain the class notation HRSRA, the following aspects should be validated:

- Linearly computed ship response, which is a basis of the SRA system's software, should be validated against reliable full-scale or model test measurements or closed form linear response predictions
- Transfer function computed by the SRA system's central unit should be validated against comparable transfer functions obtained from desk studies.
- If spectral techniques are used to analyze ship response, the resulting statistical measures of the responses in natural seaways, such as significant and maximum values, should be validated against full-scale data obtained from measurement campaigns conducted on board of existing container ship.
- The choice of roll damping coefficients should be validated by, for instance, proper tuning on the basis of model test data or full scale measurements.
- Nonlinear corrections should be validated against appropriate measurements

5.2 Shipboard wave sensor

To obtain the class notation HRW, the continuously monitored seaway surrounding the ship should be validated against measured wave data or against wave data forecasted by a recognized meteorological weather service.

E. Survey Requirements

1. General

After installation of a hull response monitoring system and at each annual survey, a survey is to verify satisfactory operation of the system, such as the following items:

- The number and location of motion sensor(s), accelerometer(s), pressure transducer(s), and straingages and the number of display locations of the system are in accordance with the approved specifications
- All welded attachments, hull penetrations, and supports to secure cabling and equipment are in asatisfactory condition
- The strain gages have been set up to cover an adequate linear range to span the full range of expected still water and dynamic stress variations
- Calibration certificates exist for the strain gages and, where applicable, for the motion sensor(s), accelerometer(s), and pressure transducer(s)
- The value of stress produced by the hull response monitoring system is compatible with the outputfrom the loading computer for a known loading condition
- The data recording facility complies with the outlined requirements
- An approved operating manual for the system, written in English and in a language appropriate forthe ship's crew, is onboard the ship
- The intrinsic arrangement of equipment in hazardous areas complies with relevant requirements

Two copies of the test schedule for the system, signed by the surveyor and the owner's representative, are to be provided on completion of the survey. The test schedule is to include the results of the setup, checking and calibration of the system sensors, and the ship's loading and environmental conditions. One copy of the test schedule is to be placed onboard the ship, and the other copy is to be submitted to BKI.

2. New Installations and modifications

Installation and operation of the hull response monitoring system are to be fully tested and verified in accordance with 1 and the approved system testing and operational verification procedure D.1.

Installation, setup, and testing of the system's sensors are to be in accordance with D.

Two copies of the equipment record detailing the components of the hull response monitoring system, including any additions and modifications, are to be provided on completion of the survey. One copy of the record is to be submitted to BKI, and the other copy is to be kept onboard the ship and is to be made available to the surveyor as required.

F. Guidance on Selection of Hull Response Monitoring System

1. Ship motions

In addition to the six degrees of freedom ship motions (surge, sway, heave, roll, pitch, and yaw), it may be of interest to monitor the effects of these motions on the hull girder, the local structure, or the cargo.

Ship motions themselves are seldom a problem for vessel integrity; however, they are often the reason for the master's reaction to deteriorating weather conditions. Heave, pitch, and roll are the principal motions which, if limited, will bring benefits.

Motion levels usually depend on frequency as well as magnitude. Deck containers can be lost or damaged in bad weather. The criteria should be set, taking into account the requirements of the Rules for Stowage and Lashing of Containers (Pt. 4, Vol. I). As the likelihood of excessive ship motions increases, timely action can be taken.

2. Slam warning

The most common effects of wave impacts are bottom slamming and bow flare slamming.

Slam warning levels depend on ship size, ship speed, and hull shape.

As wave-induced slam impacts shown on the monitor increase with deteriorating weather conditions, timely corrective action, such as changing ship speed, wave heading or increasing ballast, can be taken to prevent slams from reaching allowable limits.

3. Green seas warning

The shipping of green seas depends on weather conditions, ship speed, wave heading and hull shape, particularly at the ship's fore end.

As the monitor shows increasing on-deck green seas reaching limiting levels, timely corrective action can be taken to reduce the shipping of green seas.

4. Stress monitoring

Usually, stresses are deduced from strain measurements. Strain is commonly measured using short gage length resistance gages or long-base gages incorporating linear variable differential transformers or linear potentiometers. The use of other devices is not precluded if their fitness for purpose can be demonstrated.

The number, type, and location of these gages depend on the kind of system being fitted.

4.1 Hull girder stress

The principal hull girder design loads are a combination of vertical bending, horizontal bending, torsion, vertical shear, and horizontal shear. All these loads, except horizontal bending, can be considered to comprise a static part, caused by the distribution of weight and buoyancy in still water, and a dynamic part, caused principally by waves.

The static (still water) loads are obtained from the loading computer or the loading manual and, generally, account for about 40 to 50 percent of the total loads, with the dynamic (wave) loads accounting for the rest. Calculated still water loads are relatively more accurate than calculated wave loads. Conversely, measured wave loads may generally be more accurate than measured still water loads, mainly because of the compilation of diurnal thermal effects.

4.1.1 Still water loads

Still water loads may be monitored to prevent buckling and collapse of the hull girder caused by overloading during cargo and ballast operations. This is to ensure that adequate strength for wave loading remains in the hull girder when the ship puts to sea. As a check between calculated and actual still water bending moments, an interface with the loading computer can warn the ship's operating personnel of a departure from the loading plan. It should be verified whether this departure is caused by diurnal effects. Still water loads should be displayed in the cargo control area. Still water hull girder stress levels should reflect ”in harbor” and ”at sea” criteria as well as other criteria that may be appropriate.

4.1.2 Wave loads

Wave loads may be monitored to enable the master to avoid damage to the hull girder caused by waves. If the monitor shows that increasing wave loads approach limit values, timely corrective action can be taken, such as changing the ship's speed and/or heading. The monitor shall also show the effects of these changes on the wave loads within a short time span after the corrective action.

4.1.3 Fatigue monitor

The fatigue monitor shows the ship operator how much of the design fatigue life has been used up. There are a number of different loading mechanisms that cause fatigue damage in ships. Fatigue has to be monitored at locations that provide data typical for each mechanism and combination of mechanisms.

Information regarding the fatigue life is valuable for planning of surveys and dockings as it indicates where to look for possible fatigue cracks. Upon request, BKI will advise on the interpretation of recorded data. To obtain information on possible fatigue damage monitoring should be carried out regarding:

- Side shell longitudinals subject to combined wave pressure and hull girder loading
- Welded connections such as of hull outfitting equipment in way of the upper part of the hull girderplating and longitudinals
- Hatch corners subject to combined hull girder loads particularly torsional moments

5. Voyage data recording

Voyage data are usually gathered for specific ship management purposes or to enable finding the causes of accidents and other incidents.

6. Derivation of output

Output data comprises high and low frequency components of wave-induced signals. To be able to separate these signals, it is necessary to know the frequency of the vibration modes of the hull girder, which modes can be computed with sufficient accuracy to define the necessary filters.

7. Sensors

Motion sensors should be fitted at positions where they will not be affected by vibrations. In this context, for example, it may be worth considering the mode shapes of the hull girder. Motion monitoring devices and accelerometers should be mounted on structurally hard foundations that are subject to minimal structural vibrations.

System redundancy should be considered when designing the system, and it should be simple to replace gages. This is especially important when fitting resistance type strain gages at inaccessible locations. Reliability and longevity should be considered when selecting gages to measure local loads. Taking along spare parts should be considered.

8. Displays

Non-technical personnel should find the system easy to use and easy to understand. It is recommended that the ship's operating personnel be familiar with the technical terminology on the displays and the language in the supporting documentation.

The rate at which the displayed data is updated should be carefully considered. Data displayed for too long a time between updates are of reduced usefulness to the ship's operating personnel, whereas data displayed for too short a time between updates are less valuable and prone to improper use. Continued statistical analyses can reduce some of the problems.

9. Recording

Recordings should be sent for analysis on a regular basis. The recording period should account for the ability of the system to display system failures to enable ratification of system failure by the ship's operating personnel. If the recording period is too long, problems with the system may not be detected for a long time.

Recordings may be accomplished by alternative solutions, such as remote login.

Manual input may be the most effective method to record some of the data.

10. Training

Although not required to obtain class notation, it is strongly recommended that the ship's operating personnel be formally trained in the use of the system.

Annex B Global Strength Analysis of Container Ships

I. Basic Principles

A. General

1. These Annex specify the procedure for strength assessment of container ship structures by means of Finite Element (FE) Analysis. Application of this advanced analysis method, amending the standard Rule scope, allows verification of complex structures under a more refined approach, thus enabling further optimisation of structural design and material utilisation.

2. A container ship is defined as a ship intended for the carriage of containers and equipped with the appropriate facilities.

3. The structural analysis is to be carried out on the basis of permissible stresses in accordance with Section 5.

4. Computer programs used for finite element analysis have to be recognised. As recognised software is considered all finite element programs that can show results to the satisfaction of BKI.

5. Required fatigue strength assessment is to be based on the Guidelines for Analysis Techniques Strength (Pt.1, Vol.6).

B. Strength Analysis

1. In general, strength analysis comprises the following steps:

- determination of the objective, type and extent of the analysis
- structural modelling and specification of boundary conditions
- determination of load cases and load application
- solving of the equation system
- evaluation and assessment of the results

2. Regarding structural modelling, boundary conditions and loading, certain simplifications are possible or necessary, depending on the objective of the analysis and the type of structure.

3. In ship structures the deformations and stresses can usually be subdivided into the following categories, depending on the structural conditions:

- global deformations and stresses of the hull girder and the primary structural members
- local deformations and stresses of the primary and secondary structural members
- locally increased stresses at structural details and discontinuities

4. Global deformations and stresses

4.1 The structural response of the hull girder and the primary structural members under normal, shear, bending and torsional loads results in global (i. e. large-area) deformations and stresses.

4.2 The primary structural members, in this sense, are the floors, bottom girders, side and deck transverses, stringers, longitudinal and transverse deck strips, deck girders and comparable components, each including the effective part of the plating and stiffeners.

4.3 The resulting stresses are nominal stresses, i. e. stresses which would also result from integral quantities of the sectional forces and moments and of the cross-sectional properties. Global nominal stresses generally include the effective breadths, but not locally increased stresses.

5. Local deformations and stresses

5.1 In secondary structural members local loads can give rise to additional local deformations and stresses

5.2 The secondary structural members include all frames, stiffeners, longitudinals, beams and the plating with their bending, shear and torsional stiffness as well as the associated tripping and supporting brackets.

5.3 Effective plate breadth shall be taken into account

5.4 The resulting stresses are nominal stresses which are superimposed on the global stresses.

6. Locally increased stresses

6.1 Locally increased stresses at structural details and discontinuities have to be assessed especially in respect of fatigue strength. Here a distinction is made between three types of stresses.

- maximum stress in the notch root
- structural or hot spot stress, defined alternatively for welded joints
- special parameters for assessing the stress at crack tips

6.2 The maximum stress in the notch root, e. g. of the rounded edges of cut-outs, can already exceed the elastic limit of the material for realistic load assumptions in typical structural details of shipbuilding. Instead of the nonlinear notch stress ς and strain ε, the notch stress ς_k can be determined and assessed for normal cases under the assumption of linear-elastic material behaviour. In the case of very sharp notches, the local supporting effect of the material can be considered with a correspondingly enlarged notch radius.

6.3 In complex welded structures, only the stress increase as a result of the structural geometry is generally considered in the analysis, whilst that caused by the weld toe is considered during the assessment. This leads to the structural or hot spot stress σs at welds, and this is determined under the assumption of elastic material behaviour

6.4 Apart from a direct calculation of the locally increased stresses, it is possible to use catalogued stress concentration factors or detail categories. When using concentration factors and detail categories, the associated nominal stresses have to be determined with sufficient accuracy in accordance with their definition. Moreover, the ranges of application and validity for the catalogued data are to be observed.

6.5 Fatigue strength requirements are given in Section 20 of these rules. Assessment procedures are specified in Guidelines for Analysis Techniques Strength (Pt.1, Vol.6).

C. Structural Modelling

1. Type of structural model

1.1 Global model of hull

A global model of the hull girder is normally used for the global strength analysis of the entire hull girder and its primary structural components. For 3D modelling of all the primary structural components, the loads can be applied realistically, and the structural behaviour of complex ship structures, including the interactions between the individual components, can be taken into account, see II. Global strength analysis. A Global Strength Analysis is to be carried out for ships of length 290 m or above.

1.2 Partial model of hull

Partial models of the hull girder are used for the analyses of global and local stresses of the respective part and its primary structural components, e.g. midship cargo hold area. Like 3D global models, Cargo hold analyses are generally used to analyze the complex, three-dimensional strength behavior of the primary structural components. Cargo Hold Analysis is to be carried out for ships of length 150 m or above.

1.3 Local models

Local models are used for the strength analysis of secondary or special components as well as structural details. The main focus of the investigations is usually on the analysis of the local structural behaviour and/or the locally increased stresses at structural details and discontinuities

2. Elements used for structural modelling

2.1 Selecting the type of element used primarily depends on the objective of the analysis. The characteristics of the selected element type have to be able to reflect with sufficient accuracy the stiffness of the structure and the stresses to be analyzed.

2.2 Usually, the following types of elements are used for strength calculations of ship structures:

- truss elements (1D elements with only axial stiffness)
- beam elements (1D elements with axial, shear, bending and torsional stiffness)
- plane stress elements (2D elements with membrane stiffness in the plane, but without bending stiffness about the axes lying in the plane)
- plate and shell elements (2D elements with membrane, bending and torsional stiffness)
- solid elements (3D elements)
- boundary and spring elements.

When using different element types, attention shall be paid to the compatibility of the displacement functions as well as the transferability of the boundary loads and stresses, particularly for the coupling of elements with and without bending stiffness at the nodes

3. Checks of the model

Geometry of the modelled structure, chosen elements and associated material characteristics as well as applied boundary conditions have to be checked systematically for errors.

D. Loads and Loading Conditions

1. General notes

1.1 The relevant loads for the strength analyses of ship structures can generally be classified into the following types:

- static (stillwater) loads from the deadweight of the ship and cargo and from the hydrostatic pressure caused by the buoyancy and tank contents
- wave-induced loads, i.e. dynamic pressure, loads from accelerated masses and tank contents, as well as internal and external hydrodynamic impact forces
- other variable loads from the ship's operation, e.g. from the action of the engines or the rudder, and also wind loads and ice loads
- loads due to container handling or special cargo types.
- loads in case of accidents, e.g. collision, grounding or flooding of compartments

1.2 The selection and generation of the load cases to be analysed shall be done in such a way that, with respect to the sum of the forces and moments, either fully balanced load cases are created or clearly defined, realistic sectional forces and/or deformations are obtained at the model boundaries or supports.

1.3 Since several of the load components mentioned are of a stochastic nature, and because the selection and determination of the relevant load cases might be very complex, there are simplified procedures which can be used for practical cases. Moreover, there are special procedures which refer particularly to wave-induced loads, but can also be applied to other stochastic load effects.

1.4 Loading conditions

1.4.1 Global Strength Analysis

Loading conditions to be considered for the Global Analysis are to be in accordance with II.D.3.

1.4.2 Cargo Hold Analysis

The minimum set of loading conditions is specified in Table 26.3. In addition, loading conditions from the Loading Manual are to be considered in the Cargo Hold Analysis where deemed necessary.

2. Simplified procedures

2.1 Under this approach selected (deterministic) load cases are considered that are decisive for the strength of the structural areas under analysis. In general, these load cases consist of unfavourable, but physically meaningful, combinations of diverse load effects. For assessments of the fatigue strength, those load cases are to be selected that generate both maximum and minimum stresses at the critical points.

2.2 Load cases represent unfavourable loading conditions combined with the following unfavourable wave situations:

- wave from astern and ahead (with respect to the vertical hull girder bending and loads on the forebody)
- oblique waves from astern and wave from ahead when the ship is upright (relevant for container ships which react sensitively to horizontal bending moments and torsional moments in the hull girder)
- oblique waves from astern and wave from ahead when the ship is rolling (insofar as this is relevant for the ship structure or component under consideration).

2.3 Application of the load components and load combination factors are specified in Section 5 of these rules.

2.4 With respect to the loading conditions, conditions with uniform and non-uniform cargo distribution at maximum draught should generally be considered. Furthermore, the relevant loading conditions with single holds or tanks loaded to the maximum or empty, as well as ballast conditions, have to be included in the computations.

2.5 With regard to the situation of waves from astern and/or ahead, the load cases ”ship on wave crest” and ”ship in wave trough” have to be analysed, whereby the position of the crest or trough is to be varied. The external pressure shall correspond to the phase relations between ship and wave. Moreover, vertical and longitudinal acceleration components shall be applied that have an unfavourable effect on the masses of the ship and the cargo or tank contents.

2.6 The situations with oblique wave from astern or ahead, when the ship is upright, has to be chosen so that the maximum torsional or horizontal bending moments are applied at various positions of the hull girder, whilst the vertical bending moment exhibits values that are generally reduced in relation to the peak value. Furthermore, the relevant vertically and longitudinally oriented acceleration components that have an unfavourable effect on the masses of the ship and the cargo or tank contents shall be applied

2.7 The situations for rolling of the ship are to be selected so that the maximum transverse accelerations actually occur. The vertical and horizontal acceleration components that have an unfavourable effect on the masses of the ship and the cargo or tank contents shall be applied.

3. Special procedures

3.1 As an alternative to the simplified procedure with selected (deterministic) load cases, there are also special procedures which are especially suited for consideration of the wave-induced ship motions and loads.

For specified irregular waves, there are two possibilities for calculating the motions and loads:

- computation in the frequency domain and assessment with the aid of the spectral method
- computation in the time domain by simulation

The natural seaways are usually characterized by energy spectra. Here, the use of the Pierson-Moskowitz spectrum is recommended. The results shall be assessed statistically, whilst considering the frequency of occurrence of the seaways, cargo distributions, ship’s courses and speeds.

3.2 For computations in the frequency domain, the first step is to determine the structural response to harmonic elementary waves, in the form of transfer functions which apply for each case of a particular cargo distribution, ship speed and heading relative to the wave direction. Here a sufficient number of wave frequencies shall be taken in order to consider the resonance peaks of the structural response with sufficient accuracy. For a specified natural seaway, the spectrum of the structural response is obtained from the transfer function and the wave spectrum.

3.3 For computations in the time domain, the loading process shall be generated in a suitable manner from the characteristic data of the wave spectrum. The time domain for analysis of the structural response shall be selected to be large enough, so that the subsequent statistical evaluation can be performed with sufficient accuracy with respect to the expected values.

3.4 The structural response for a natural seaway is to be determined for a representative selection of waves, container distributions, ship’s headings and speeds, and these shall be selected with reference to their frequency of occurrence and the structural response to be assessed. For the waves, the long-term statistics of the North Atlantic should be used in general. If the examination is not to be performed in detail, a uniform distribution for the ship courses and 2/3 of the maximum speed can be assumed. For the loading conditions see 2.4. In the statistical assessment of the structural response, the probability level specified in these rules is to be used as the basis.

4. Modelling the loads

4.1 The loads have to be modelled realistically. Distributed loads shall be converted to the equivalent nodal forces. If necessary, the modelling of the structure has to be adapted to the modelling of the loads.

4.2 If the boundary deformations derived from coarse models of large structural areas are applied to local models, the correspondingly interpolated values shall be specified for the intermediate nodes. In addition, the loads acting within the local structural area are to be applied, insofar as they are relevant.

5. Load input check

5.1 The input data on the loads shall be checked thoroughly for errors. As is the case for the structural geometry, here the effectiveness of the check can be increased considerably with the aid of suitable checking programs and visualization of the data.

5.2 It is particularly important to check the sums of the forces and moments. For balanced load cases, it is to be ensured that the residual forces and moments are negligible

5.3 The checks performed have to be documented.

E. Calculation and Evaluation of the Results

1. Plausibility of the results

1.1 Before and during the evaluation, the results shall be examined for plausibility. This involves, in particular, the visual presentation and checking of the deformations to see whether their magnitudes lie within the expected range and whether their distributions are meaningful with respect to the loads and boundary conditions or supports.

1.2 Furthermore, it should be checked whether the forces and moments at the supports lie within the expected order of magnitude or can be neglected, as appropriate for the modelling used.

1.3 For local models with specified boundary deformations from the models of large structural areas, it is necessary to check whether the stresses near the boundaries correspond for the two models.

2. Deformations

2.1 The deformations of the structure should generally be plotted so that other persons can perform a plausibility check of the results. Here it has to be observed that in a three-dimensional representation the direction of the deformation is not clearly defined.

2.2 A further evaluation of the deformations is generally performed with a view to special questions for certain structures, e.g. for deformations of the foundations of propulsion plants or supports of hatch covers.

3. Stresses

3.1 Stresses have to be checked with respect to the permissible values, as defined in Section 5. The corresponding stress category is to be observed, see B.3. $\sim$ B.6. If necessary, stress components that are missing because of the selected models and element types shall be superimposed.

3.2 For the stress evaluation simplifications in the model in relation to the real structure have to be included in the assessment.

3.3 In models with relatively coarse meshes, the reduced effective breadth has to be considered, if applicable. Furthermore, local stress increases at existing structural details and discontinuities shall be included in the assessment, if their effect is not considered separately.

3.4 To improve the clarity, it is recommended that the assessment be carried out with the aid of utilisation factors, which are obtained from the relationship between the existing and the permissible stress. Result tables should be set up and sorted according to the utilisation factors.

3.5 For analyses that are nonlinear with respect to materials, the local strain shall generally also be determined and assessed in addition to the local elastic plastic stress.

4. Buckling strength

The safety with respect to buckling failure is to be determined by considering all calculated stress components in the member area under assessment, on the basis of the criteria given in this rules. In the buckling analysis of stiffeners, the effective breadth of the associated plating has to be taken into account.

5. Fatigue strength

5.1 Fatigue strength aspects shall generally be taken into account in the assessment of ship structures, owing to the cyclic stresses that are usually present. In strength analyses for specified load cases, a simplified assessment can be performed if the load cases according to D.2. are chosen such that the maximum stress ranges are approximately attained in the components under consideration. Calculation of fatigue strength is then to be carried out on the basis of Section 20.

5.2 Container ship structural members to be assessed for fatigue strength have to be selected according to the structural arrangement characteristics of the individual ship. In general fatigue strength calculations have to be carried out for hatch corners, side shell longitudinals, large openings and cut-outs in members subjected to cyclic loads and to the welded joints of these members.

5.3 In the assessment of the stresses with regard to fatigue strength, the stress type has to be considered, i.e. whether nominal stresses or locally increased notch or structural stresses are calculated with the chosen model.

5.4 For the assessment, it is recommended that utilisation factors are applied; these are obtained from the ratio of the maximum actual stress range to the permissible stress range for an equivalent stress spectrum of the same shape and number of load cycles, see also the Guidelines for Analysis Techniques Strength (Pt.1, Vol.6)

6. Presentation of the results

6.1 The results obtained and the conclusions made on the basis of these results shall be clearly and completely documented.

6.2 The documentation can take the form of plots and lists. Lists are necessary for the case that a graphical presentation of results is not sufficiently accurate. Extensive lists shall be sorted, for example, according to utilisation factor.

II. Global Strength Analysis

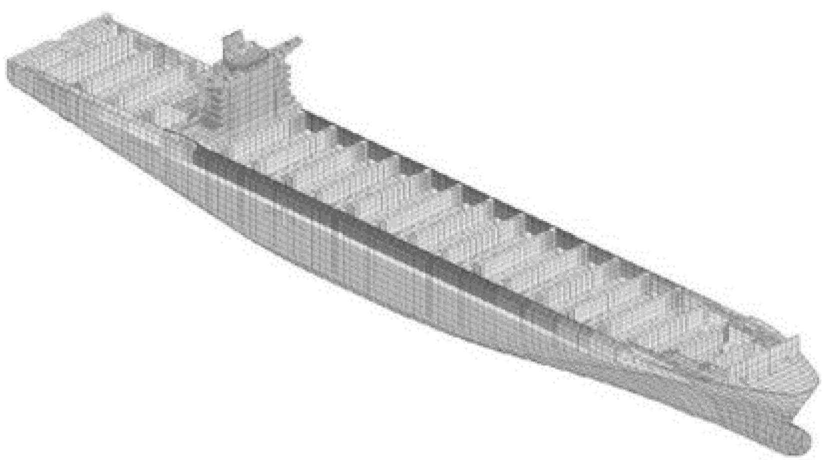


Figure B.1: Global FE model of a container ship

A. General

1. The objective of the global strength analysis is to obtain a reliable description of the overall hullgirder stiffness and to calculate and assess the global stresses and deformations of all primary hull members for specified load cases resulting from realistic loading conditions and the wave-induced forces and moments.

2. Generally, the purpose of the global analysis is not to judge on local stresses due to stiffener- or plate bending, whereas the focus is at realistic stiffness and deformation characteristic of the hull girder particularly under consideration of the torsional moments.

3. The finite element analysis of the entire ship shall verify the structural adequacy of the longitudinal and transverse primary structure. Particularly the scantlings of members which are influenced mainly by the torsional moment i.e. the side shell longitudinals, radii of the hatch corners as well face plates and horizontal girders of the transverse bulkheads shall be checked by a global analysis

4. Stresses in all primary members will be assessed with respect to yield strength and buckling. Hatch corners and side shell longitudinals are subject to fatigue strength analysis

5. The applied tools for the finite element calculations shall be based on recognised software. As recognised software is considered all finite element programs that can show results to the satisfaction of BKI.

B. Structural Idealization

1. Model size, coordinate system and units

1.1 The global FE model is to represent the entire ship including the deckhouse. Due to the asymmetric loading in seaway half models cannot be accepted.

1.2 A right-handed cartesian coordinate system according Fig. B.9 should be used with

— X measured in the longitudinal direction, positive forward from the aft perpendicular

— Y measured in the transverse direction, positive from the centreline to port

— Z measured in the vertical direction, positive upwards from the baseline

1.3 Units and material properties may be used in Table B.1 and Table B.2:

Table B.1: Units

Length	**m**
Mass	t
Force	kN

Table B.2: Material properties

	Young's Modulus [kN/m^2]	**Poisson Value**	**Shear Modulus [kN/m^2]**	**Density [t/m^3]**
Steel	$2{,}06 \cdot 10^8$	0,30	$0{,}792 \cdot 10^8$	7,80
Aluminium	$0{,}69 \cdot 10^8$	0,33	$0{,}259 \cdot 10^8$	2,75

1.4 The minimum yield stress R_{eH} has to be related to the material defined as indicated in Table B.3. Consequently for every used steel a separate data set for the material has to be defined regardless the fact of same Young's Modulus. Elements have to refer to this material data set as the materials are defined in the structural drawings. Later used evaluation routines refer to these material data sets when permissible stresses and buckling strength will be checked.

Table B.3: Minimum yield stresses for steel

	1	**2**	**3**	**4**	**5**
R_{eH} [N/mm^2]	235	315	355	390	460

2. Element types

2.1 The global strength calculation will deliver the global stress state resulting from hull girder bending and torsion. Local effects like bending of stiffened plates under water pressure will not be analysed with the global model. The membrane stress state will be the dominating result.

2.2 All primary structural members, i.e shell, inner skin, girders, web frames, horizontal stringers and vertical girders of transverse bulkheads, are to be idealized preferably by 4-node plane stress or shell elements.

2.3 Secondary stiffening members may be idealized by 2-node truss or beam elements. High transverse and longitudinal girders can either be idealized by use of beam elements or by use of plane stress elements (PSE) for the webs and truss elements for the flanges. In case the FE-model shall be used for a subsequent vibration analysis beam elements are to be preferred. For beam elements the effective breadth has to be carefully evaluated when defining the bending stiffness. For the axial stiffness, however, only the sectional area of the profile shall be considered.

2.4 The characteristics of the selected element type shall reflect the stiffness of the structure with sufficient accuracy. When carrying out a strength analysis, adequate knowledge of the characteristics of the elements used is a prerequisite

2.5 When using different element types, attention shall be paid to the compatibility of the displacement functions as well as the transferability of the boundary loads and stresses, particularly for the coupling of elements with and without bending stiffness at the nodes.

2.6 In the coarse meshes used for global analyses it is beneficial that the plane stress or shell element's shape functions include "incompatible modes" which offer improved bending behaviour of the modelled member, as illustrated in Fig. B.2. This type of element is required for the modelling of web plates with a single element over the full web height, in order to calculate the bending stress distribution correctly. Disadvantage of the incompatible mode is that the element edges could be diverged and reproduce a lower stiffness. But in combination with the used coarse mesh these elements reproduce the stiffness of the hull girder in a realistic way.

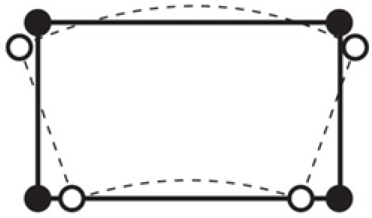


Figure B.2: Improved bending of web modelled with one element over height

2.7 Triangular elements with a linear shape function shall be avoided where possible. These 3-node elements can only represent constant strain or stress. They have no in-plane bending characteristic and are therefore too stiff in areas of significant stress gradients. As well 4-node elements with inner angles below 45° or above 135° between the edges shall be avoided.

2.8 The element edge aspect ratio shall generally not exceed the value 3. This aspect ratio may be exceeded in areas of low-stress gradients or where a constant stress distribution over the element width can be expected.

2.9 Elements should be preferably oriented according to Fig. B.3 In case the specification regarding the ij-direction and the ij-edge cannot be followed, at least the orientation of the normal vector has to be according to Table B.4 and Fig. B.3. This convention facilitates load application and the idealization of corrugated walls as well as the evaluation of the element stresses.

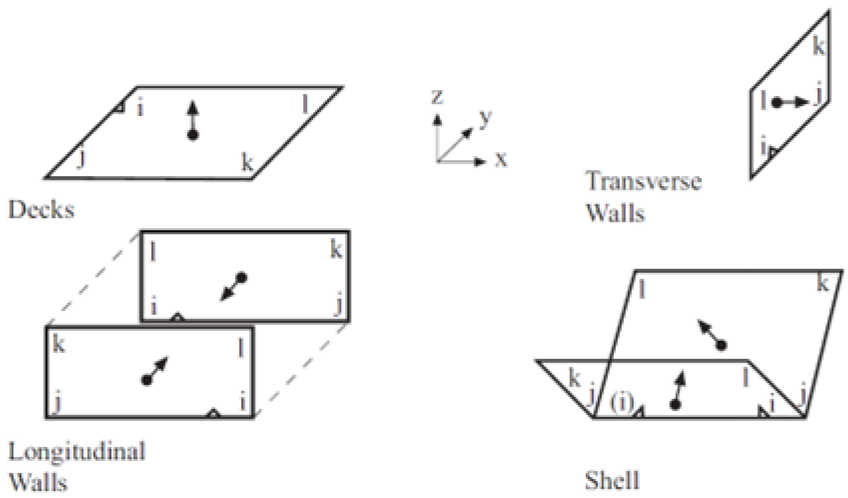


Figure B.3: Element orientation and normal vector

Table B.4: Element orientation

	ij-Direction	**ij-Edge**	**Normal vector direction to**
Decks	Transverse	After	Top
Longitudinal walls	Longitudinal	Bottom	Inside
CL-walls	Longitudinal	Bottom	PS
Transverse-walls	Transverse	Bottom	Fore
Shell	Longitudinal	Inwards/Bottom	Inwards

3. Modelling the structure

3.1 Mesh size shall be determined according to proper stiffness representation and load distribution. The distance between the longitudinal girders and transverse floors is taken as the standard length of the elements. If the spacing of primary members deviates much from normal, the mesh arrangement described above shall be re-considered to provide a proper meshing of the global FE-model. Typical meshes used for global strength analysis are shown in Fig. B.5 for the foreship and Fig. B.6 for the midship section.

3.2 The FE-model is to be based on the gross scantlings of the hull structures. For buckling evaluation the corrosion addition will be deducted.

3.3 Due to the complexity of the ship structure, simplifications are generally necessary in modelling. These simplifications are permissible, provided that the results are only impaired to a negligible extent.

3.4 Small secondary components or details that only affect the stiffness to a lesser extent can be neglected in the modelling. Examples are brackets at frames, sniped short buckling stiffeners and small cutouts.

3.5 Man holes or cut-outs of significant size shall always be considered to calculate realistic shear stresses. The reduction in stiffness can be considered by a corresponding reduction in the element thickness. Even larger openings which correspond to the element size such as pilot doors are to be considered by deleting the appropriate elements

Plate thickness reduction in way of cut-outs:

1) Web plates with several adjacent cut-outs, e.g. floor plates, longitudinal bottom girder:

$$t_{red}(y) = \frac{H - h}{H} t_0$$

$$t_{red}(x) = \frac{L - \ell}{L} t_0$$

$$t_{red} = \min\left(t_{red}(x), t_{red}(y)\right)$$

For t_0, L, ℓ, H, h see Fig. B.4

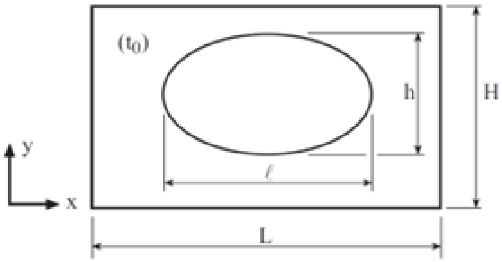


Figure B.4: Cut-out

2) Larger areas with cutouts and walls with doors and windows e.g. wash bulkheads:

$$t_{red} = \frac{1}{1 + 0,0025 \cdot p^2} t_0$$

p = cut-out area in %

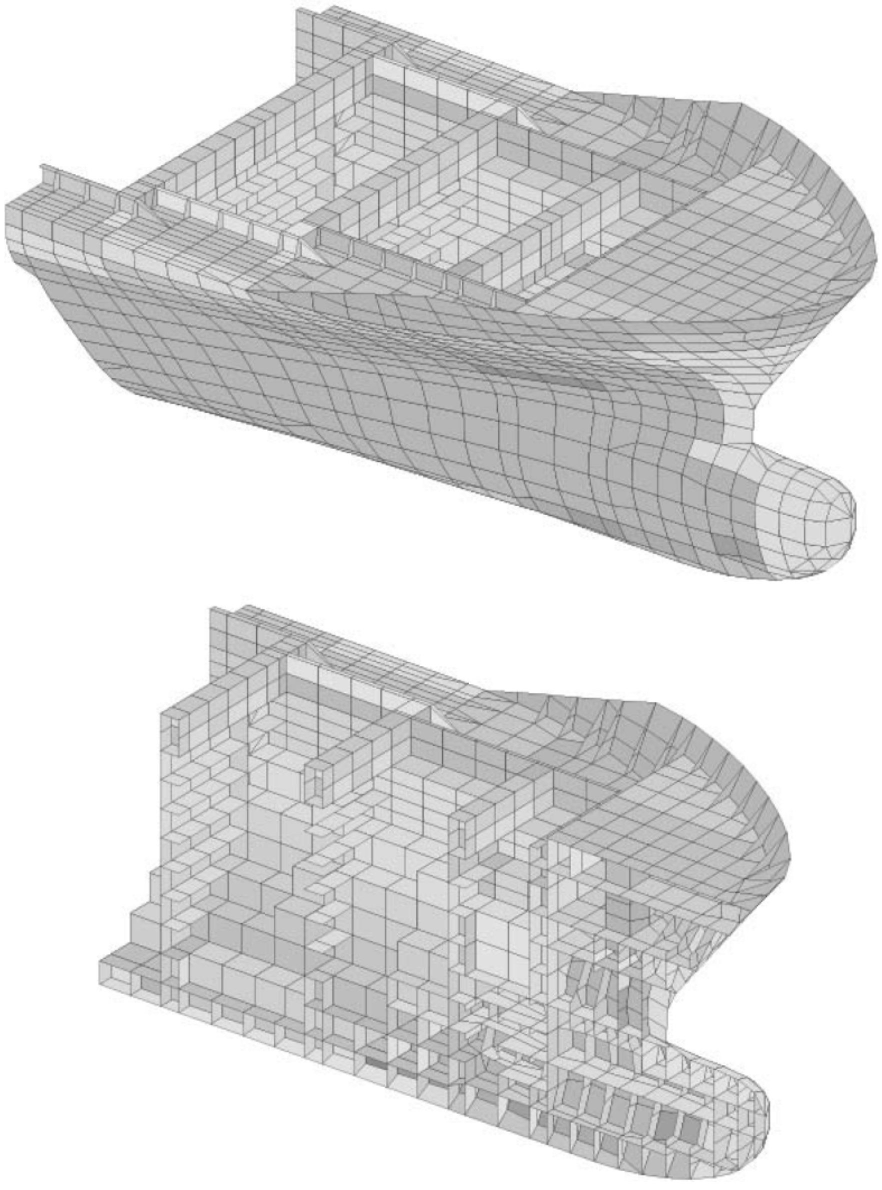


Figure B.5: Typical foreship mesh used for global FEA

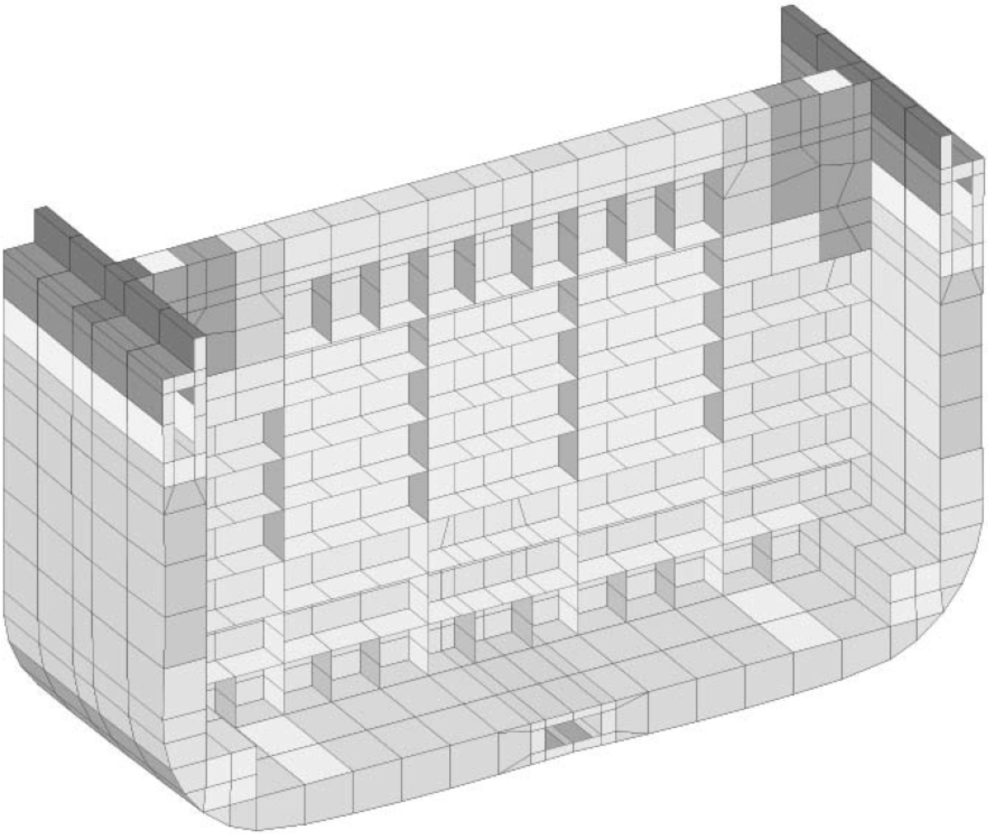


Figure B.6: Typical midship mesh used for global FEA

3.6 Steps in the plate thickness or scantlings of profiles, insofar as they are not positioned on the element boundaries, shall be taken into account through correspondingly adapted element data or characteristics to obtain an equivalent stiffness

3.7 The plane elements shall generally be positioned in the mid-plane of the corresponding components. For thin-walled structures, the elements can also be arranged at moulded lines, as an approximation

3.8 Plane 2D elements in inclined or curved surfaces shall be positioned at the geometrical center of the modelled area if possible, in order that the global stiffness behaviour can be reflected as correctly as possible.

3.9 Translatory singularities in PSE structures can be avoided by arranging so-called singularity trusses as indicated in Fig. B.7.

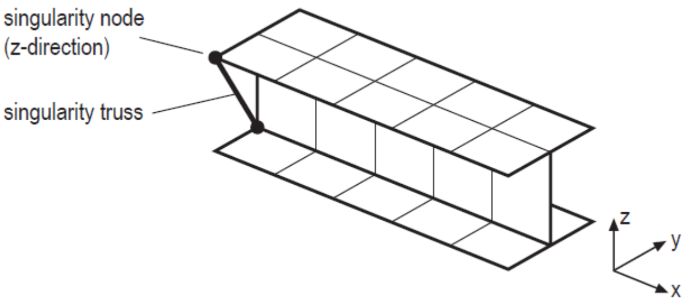


Figure B.7: Singularity trusses

3.10 For coarse meshes stiffeners have to be assembled to trusses or beams by summarising relevant cross-section data. They have to be arranged at the edges of the plane stress or shell elements. Fig. B.8 shows an example of a part of a deck structure with an adjacent longitudinal wall with longitudinal stiffeners. In this case, the stiffeners at the longitudinal wall and stiffeners at the deck have to be idealized by two truss elements at the intersection of the longitudinal wall and the deck. Each of the truss elements has to be assigned to different element groups: One truss to the group of the elements representing the deck structure the other truss to the element group representing the longitudinal wall. In the example of Fig. B.8 at the intersection of the deck and wall the deck stiffeners are assembled to one truss representing 2 x 1,5 × FB 100·8 and the wall stiffeners to an additional truss representing 1,5 × FB 200·10.

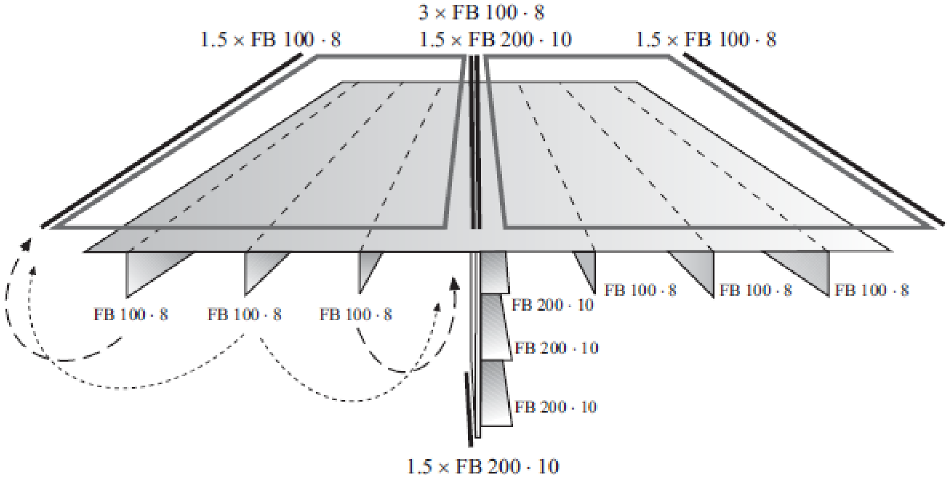


Figure B.8: Example of plate and stiffener assemblies

C. Boundary Conditions

To eliminate rigid body motion of entire global finite element models 6 supports or boundary elements(springs with high stiffness) have to be arranged. As ship and cargo weight are in equilibrium with buoyancy and wave loads these boundary elements get no loads. This has to be checked. A typical arrangement is indicated in Table B.5 and Fig. B.9 Care shall be taken to place pairs of boundary elements on a single plane to avoid unrealistic deformation plots, e.g. three z-constraints on the bottom level.

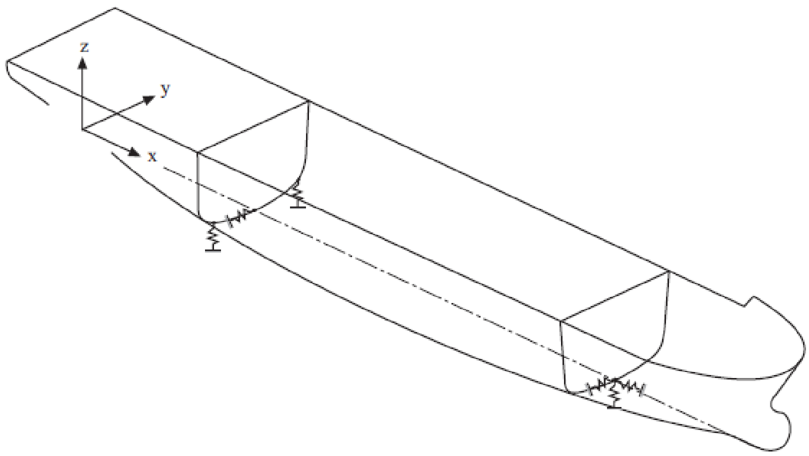


Figure B.9: Support of the global model

Table B.5: Global Support

	Location	Direction
Engine Room Front Bulkhead	SB	Z
	CL	Y
	PS	Z
Collision Bulkhead	CL	X
	CL	Y
	CL	Z

D. Design Loads

1. General

A direct wave load analysis shall be carried out to calculate hull girder forces and moments which in turn have to be in compliance with the rule requirements.

The global FE-model needs to include the masses, because the inertia forces counteract the external seapressures. All force components obtained from the direct wave load analysis are to be in a state of equilibrium.

2. Mass model

The hydrodynamic analysis needs a correct mass distribution to generate correct motions and forces. The mass models applied in the global FE analysis and the wave load analysis need to be complete and represent the considered loading conditions.

The lightship weight components such as hull structure, machinery and equipment, outfitting, etc. are the same for every considered loading condition. Likewise consumables, effects and stores will vary little if at all.

The other weight groups such as containers and ballast water shall be defined according to each loading condition.

2.1 Light ship weight

The weight of the hull structure is obtained by applying a material density to the FE-elements. It is common practice to use an increased value to account for structural components not included in the model, such as brackets. To match a specified centre of gravity position for the hull structure weight, different material densities can be used for the individual element groups

The remainder of the lightship weight (such as machinery, hatch covers, and outfitting) and consumables will be represented by a distribution of nodal masses in relevant regions according to their locations and centres of gravity.

The mass of each weight group will be adjusted in order to achieve the correct mass distribution and the position of the centre of gravity. The use of negative nodal masses is not acceptable. The whole mass model shall be in compliance with the considered lightship weight distribution.

2.2 Water ballast and tank contents

The liquid mass in tanks will be represented by distribution of nodal masses to the surrounding structure. It is not necessary to include the local pressure distribution of the tanks in the global FE-analysis.

2.3 Container loads

The inertia forces of the containers have to be transferred to the appropriate nodes in the hull structure. Load transfer can be carried out in two different ways:

2.3.1 If the forces are transferred to ship interface nodes prior to a Finite-Element calculation, no explicit auxiliary model to account for the containers is required for the finite-element calculation itself.

2.3.2 If auxiliary systems are used for load application and load transfer, they shall not influence the stiffness of the FE model. This shall be checked by test calculation without loads on the auxiliary systems. Deformations of the hull have to result into stresses and strains within the auxiliary systems equal to zero. On-deck containers can be modelled by using plane stress, shell or solid elements, which may be connected directly or via the hatch covers to the hull structure by either truss elements. The containers or the hatch covers have to be supported on the coaming by use of a vertically oriented truss element. At the location of the transverse and longitudinal stoppers the structure of the hatch covers will be supported either in transverse direction only or in transverse and longitudinal direction, respectively. The centre of gravity for the on-deck containers has to be correctly represented to get realistic heeling moments. If the containers in the holds are modelled by an auxiliary system, again special attention shall be paid to the vertical and horizontal force transfer to the appropriate nodes in the hull structure in order not to influence the stiffness of the ship.

3. Loading conditions

In general 2 loading conditions are investigated:

3.1 Max SWBM

Maximum displacement at scantling draught with maximum permissible vertical hogging still water bending moment (Max SWBM) shall be considered. If possible with respect to stability, a homogenous weight distribution in all bays with a high stack load for the containers on the deck shall be used for this loading condition. The maximum used charge for water ballast, fuel etc. is limited to around 30 % of the total cargo weight. With the exception of the hold of the midship area, where 40’ containers are to be loaded, the use of 20’ or 40’ containers is optional. A relatively low GM (metacentric height) for the vessel’s size will be achieved with this loading condition.

3.2 Min SWBM

Maximum displacement at scantling draught with minimum possible vertical hogging/ maximum sagging still water bending moment (Min SWBM) shall be considered. For the hold containers all bays shall be used. The deck containers are to be arranged in the midship area as it is necessary to achieve the Min SWBM. For hold and deck containers a relatively high uniform weight shall be used. The maximum use charge for water ballast, fuel etc. is limited to 20 % of the total cargo weight. The use of 20’ or 40’ containers in the hold and on the deck is optional. A relatively high GM (metacentric height) for the vessel’s size will be achieved with this loading condition.

3.3 One bay empty

This condition is optional for investigation depending on the scope of analysis agreed between yard and ship owner.

Similar as the Max SWBM condition but one 40’ bay in a hold of the midship area is to be empty

4. Wave load analysis

The ship motions and the pressure distribution on the shell have to be calculated for different wave lengths, heights and heading angles. The design wave approach is based on the following assumptions:

— For every loading condition the hydrodynamic pressure and ship motions are calculated for different heading angles by a linear analysis. Application of the so-called strip theory is sufficient. In this approach pressure distribution is determined by linear analysis up to the still water line only.

— For different sea states the hydrodynamic pressure is then adjusted to the real wave contour by a non-linear correction. These non-linear load effects due to the characteristic hull form of containerships, i.e. pronounced bow and stern flare are significant. The load magnitude including non-linear effects differs considerably from the linear response

— Since the ship motions are based on the results of the linear analysis, the imbalances of forces due to the non-linear correction of pressures have to be compensated by adjustment of the ship accelerations. Inertia forces of the ship and hydrodynamic pressure shall be in equilibrium.

— In a ”simulation in regular waves”, numerous wave situations are systematically analysed with varying wave lengths, wave crest positions and headings in a first step, taking the hull shape fully into account. With these load cases the vertical and horizontal wave bending and the torsional moments according to Section 5 are to be covered.

— Consideration of pressure and acceleration loads caused by free (resonant) rolling is also necessary. Here the additional torsional moment due to inertia forces from the containers during rolling may play an important part. The maximum rolling angle is to be determined on the basis of a refined ship motion analysis including rolling in a realistic way or on design values given in this Section

— For every loading condition around 20 load cases are finally selected for the finite element analysis. Selection of these load cases generally results in envelope curves of bending and torsional moment over the ship length, approximating the curves found in the systematic variation of wave situations and considering also other design load parameters such as acceleration and rolling.

The applied tools for the calculation of wave loads shall be based on recognized software. All wave load programs that can show results to the satisfaction of BKI will be considered recognized software.

The wave load analysis shall be carried out for a ship's speed corresponding to 2/3 of the service speed. Additionally, non-linear effects have to be included in the wave load analysis.

4.1 Design wave amplitude

The length and height of the design wave have to be chosen with respect to the vertical design bending moment of Section 5.

As a first step, the most sensitive wave length for the vertical wave bending moment has to be found for the wave crest condition (hogging) and the wave trough condition (sagging). The most sensitive wave configuration (length and crest position) is defined as the condition where the vertical bending moment according to the Rule is achieved with a wave height as small as possible. This wave configuration is the so-called design wave.

For head and following seas a variation of the wave length from 0,8 to 1,2 L_w/L_{pp} is to be considered. During this variation process and during the systematic ”simulation in regular waves”, the relevant wave amplitude A depends on the considered wave length.

$$\frac{A_i}{\sqrt[3]{L_{w,i}/L_{pp}}} = \frac{A_j}{\sqrt[3]{L_{w,j}/L_{pp}}}$$

To compare the relevant amplitudes from different wave lengths, they shall be scaled on the wave length.

$$L_w/L_{pp} = 1$$

For each wave length, a full period is considered. Therefore, 50 equidistant positions of the wave crest along the ship length are recommended.

4.2 Reference wave amplitude

The reference wave amplitude is the corresponding amplitude of the design wave scaled on the wave length $L_w/L_{pp} = 1$.

$$W_{red} = \frac{A_{sagg}}{A_{hogg}}$$

For positions of the wave crest between amidships (hogging condition) and the ship ends (sagging condition) following formula has proved to be useful to adjust the dynamic wave amplitude A_{dyn}.

$$A_{dyn} = A_{x/L_{PP}=0.5} \cdot (1 - (1 - W_{red})) \cdot \cos^2(\pi \cdot x/L_{pp}))$$

For beam sea (60° – 120°) the sagging reduction of the amplitude shall be neglected.

4.3 Simulation in regular waves

For ships with a high deck opening ratio, situations in oblique waves and by free rolling have been found to be decisive for several structural components

4.3.1 Additional roll angle

Conventional wave load analysis cannot simulate the roll motion adequately. To solve this problem, BKI requires the method of additional roll angle to simulate realistic distribution of the torsional moment over the ship length.

In order to avoid severe load combinations, which are unlikely to occur, the additional roll angle shall be applied under the assumption that maximum wave amplitude A and extreme roll angle φ do not act simultaneously

$$\sqrt{\frac{A}{A_{\varphi=0}} + \frac{\varphi}{\varphi_{max}}} = 1$$

This interaction formula assumes statistical independence between wave amplitude and additional roll angle.

Generally two combinations of additional roll angle and wave amplitude have to be considered.

$$\varphi = 0,5 \cdot \varphi_{max} \quad \Rightarrow A = 0,866 \cdot A_{max} \quad \text{and}$$

$$A = 0,50 \cdot A_{max} \quad \Rightarrow \varphi = 0,866 \cdot \varphi_{max} \quad \text{or}$$

$$A = 0,25 \cdot A_{max} \quad \Rightarrow \varphi = 0,97 \cdot \varphi_{max} \approx \varphi_{max}$$

The maximum roll angle φ_{max} in degrees for a probability level of $Q = 10^{-6}$ can be derived by:

$$\varphi_{max} = \frac{2160}{\mathbf{B} + 60} \cdot f(GM_0)$$

$$f(GM_0) = 1 - \exp\left(\frac{-GM_{dyn}}{GM_{min}}\right)$$

$$GM_{dyn} = GM + 0.01 \cdot \mathbf{B}$$

$$GM_{min} = \frac{\mathbf{B}^2}{(8 \cdot \mathbf{L}_{pp})}$$

GM_0 = metacentric height of the actual loading condition.

φ_{max} is not to be less than $17,5°$, reflecting the increased sensitivity in beam wind loads at low metacentric heights.

4.3.2 Variation of the wave parameters

In the "simulation in regular waves", a large number of wave situations is systematically analysed with different wave lengths, wave heading angles, additional roll angles and wave crest positions. Each additional roll angle, positive (starboard side immersed) and negative (port side immersed), shall be combined with 6 wave heading angles. The necessary wave length depends on the wave heading angle. Table B.6 shows the relevant combinations of the wave parameters, which have be to analysed for each loading condition. Head and following seas correspond to 180 and 0 degrees respectively. Due to the symmetry of the ship geometry, it is sufficient to consider wave directions from one side. The heading angles 30, 60, 120 and 150 degrees correspond to waves from starboard.

For each combination of additional roll angle and heading angle a full wave period is considered. Also here 50 equidistant positions of the wave crest over the entire ship length are recommended. The resulting wave amplitude is to be based on the design wave amplitude and the corrections for the additional roll angle, the wave length and the wave crest position. In total, 9500 situations of the vessel in regular waves are to be analysed.

Table B.6: Variation of the wave parameters

additional roll angle φ	$0°$			$\pm 50\% \varphi_{max}$			$\pm 87\% \varphi_{max}$ or $\pm \varphi_{max}$		
wave Amplitude A	100%			87%			50% or 25%		
wave heading angle φ	0, 180	30, 150	60, 120	0, 180	30, 150	60, 120	0, 180	30, 150	60, 120
$\frac{\text{wave length}}{\text{ship length}}$									
0,35			2 × 50			4 × 50			4 × 50
0,40			2 × 50			4 × 50			4 × 50
0,45			2 × 50			4 × 50		4 × 50	4 × 50
0,50		2 × 50	2 × 50		4 × 50	4 × 50		4 × 50	4 × 50
0,55		2 × 50	2 × 50		4 × 50	4 × 50		4 × 50	4 × 50
0,60		2 × 50	2 × 50		4 × 50	4 × 50		4 × 50	4 × 50
0,65		2 × 50	2 × 50		4 × 50	4 × 50		4 × 50	4 × 50
0,70		2 × 50			4 × 50			4 × 50	
0,80	2 × 50	2 × 50		4 × 50	4 × 50		4 × 50	4 × 50	
0,90	2 × 50	2 × 50		4 × 50	4 × 50		4 × 50	4 × 50	
1,00	2 × 50			4 × 50			4 × 50		
1,10	2 × 50			4 × 50			4 × 50		
1,20	2 × 50			4 × 50			4 × 50		
analysed wave situations	500	700	700	1000	1400	1400	1000	1400	1400

4.4 Load case selection

The relevant load cases for FE analysis are to be selected by evaluation of sectional forces and moments along the ship's length for all analysed wave situations. In these load cases the vertical and horizontal wave bending and the torsional moments have to match the design values defined in Section 5.

Additionally critical combinations of the sectional forces and moments have to be considered, such thatthe largest stress values and stress ranges for fatigue are obtained. Table B.8 shows the moment's distribution of the dominant sea conditions.

Table B.7 shows the ratio of the maximum considered moments to the design values.

For the torsional moments the zero-crossing point is also of prime importance. In upright conditions or conditions with 50 % additional roll angle the torsional moment has a zero-crossing about at 0,5 x/**L**.

In conditions of free rolling (with either 0,87 φ_{max} or φ_{max}) the point of zero-crossing depends on the loading condition. For the Max SWBM it is positioned about at 0,3 x/**L** and for the Min SWBM at 0,7 x/**L**.

The applied bending and torsional moments shall approximately represent the envelope curves according to the BKI Rules. Therefore it is necessary to select several load cases of the dominant sea conditions.

For each loading condition about 20 load cases are finally selected for the finite element analysis.

Note:

f_Q is a function of the design lifetime. For a design lifetime of n > 20 years, f_Q may be determined by the following formula for a straight-line spectrum of seaway-induced stress ranges:

$$f_Q = -0,125 \cdot \log\left(\frac{2 \cdot 10^{-5}}{n}\right)$$

Table B.7: Moment factors

	Still Water Static Moment		Wave-Induced Dynamic Moment		
	Vertical	Torsion	Vertical	Horizontal	Torsion
Head and follow sea	1	1	0,75*	0	0
Head and follow sea	1	1	0,50	0,75*	0,75*
Free rolling	1	1	0,25	0,75*	0,75*

*f_{Qmin} = 0,75 for n = 20 years
f_Q = probability factor according to Table 4.2

Table B.8: Load case selection

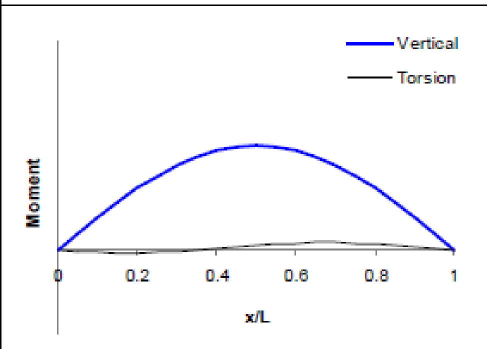
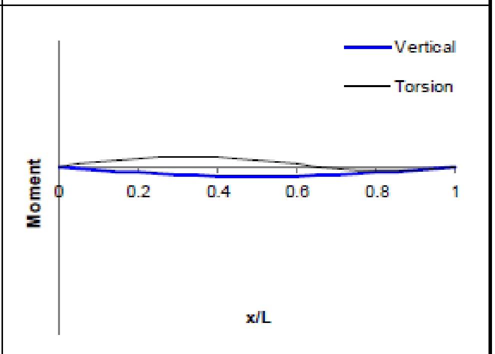
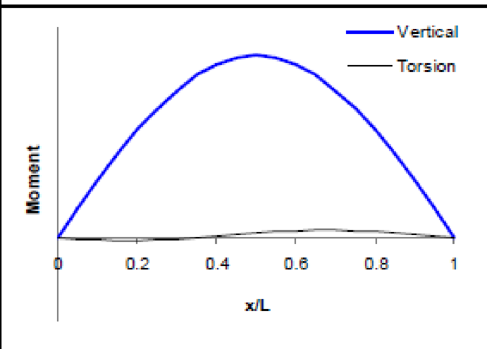
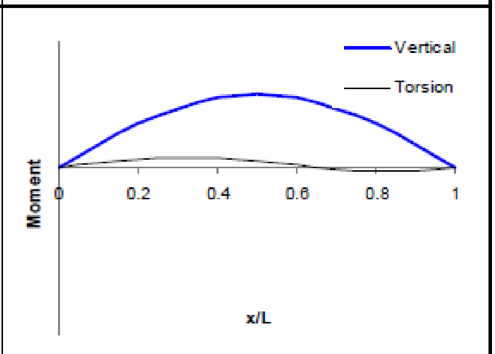
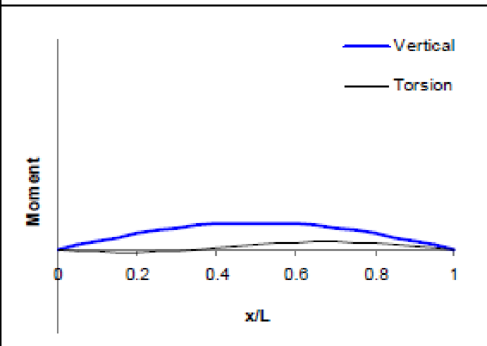
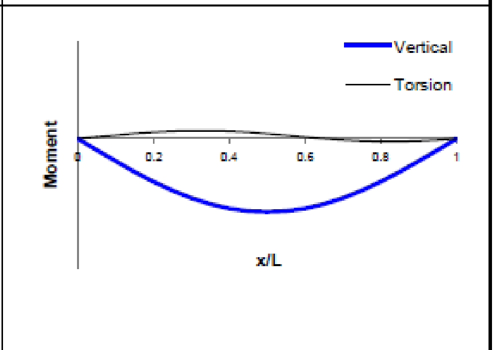
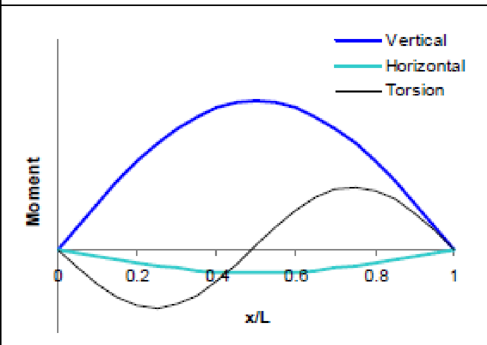
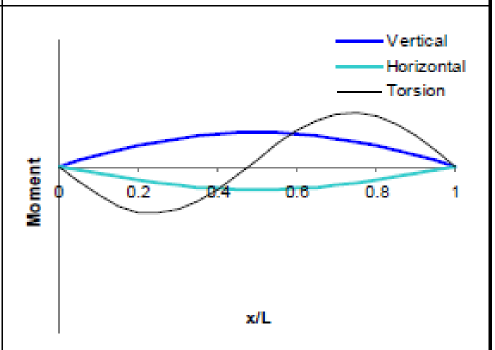
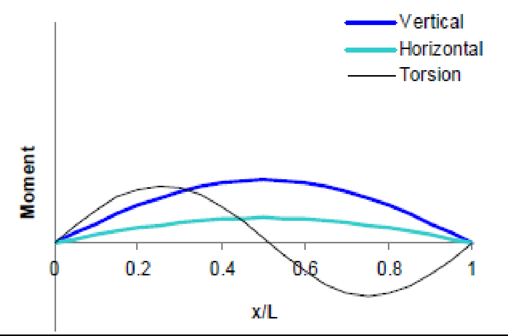
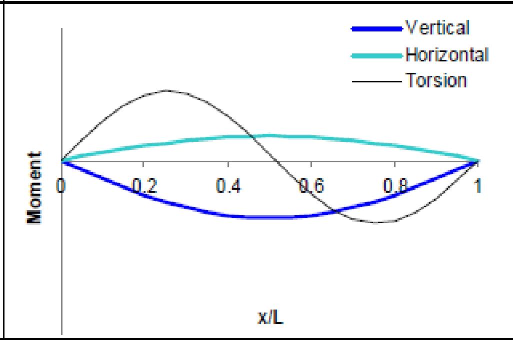
	Max Stillwater Bending Moment	Min Stillwater Bending Moment
Stillwater		
Max Hogging		
Max Sagging		
Oblique sea in wave crest		

Table B.8 Load case selection *(continued)*

<table>
<tr><th></th><th>Max Stillwater Bending Moment</th><th>Min Stillwater Bending Moment</th></tr>
<tr><td>Oblique sea in wave trough</td><td>
</td><td>
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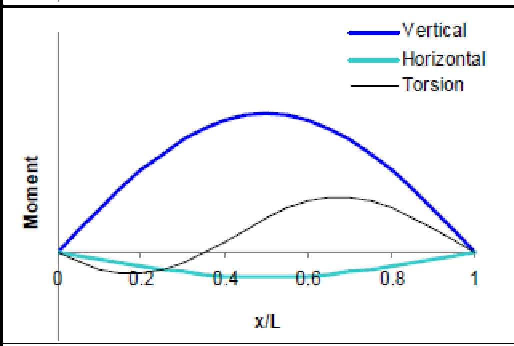
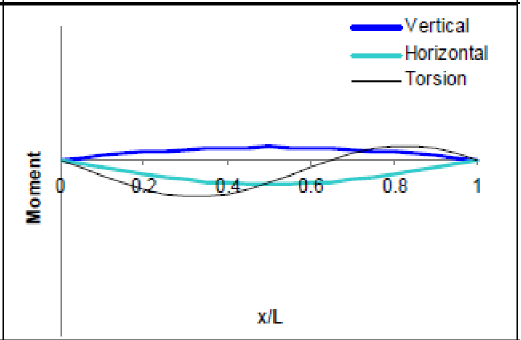
<tr><td>Free rolling in wave crest</td><td>
</td><td>
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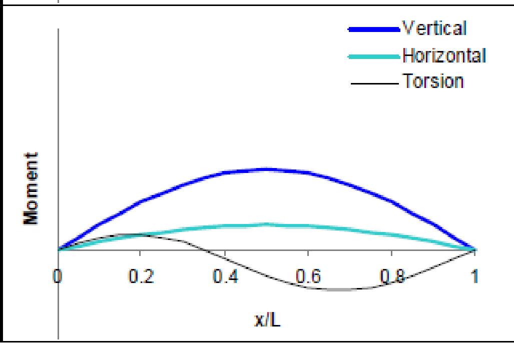
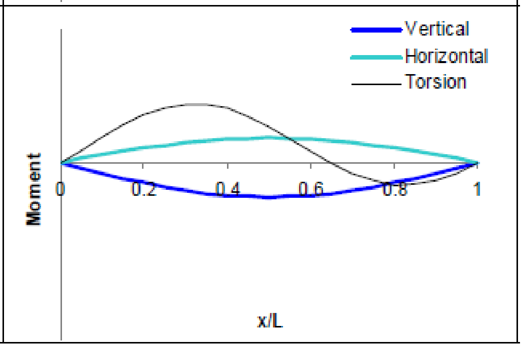
<tr><td>Free rolling in wave trough</td><td>
</td><td>
</td></tr>
</table>

5. Loads on bow and stern structures

Consideration of slamming loads is crucial for container ships with excessive bow flare and stern overhang. Since direct calculation of slamming loads is extensive and time-consuming, BKI require the generation of load cases from rule-based slamming pressures pe. The concept used to obtain balanced load cases comprises the following steps:

- Consider static loads that represent the loading condition Max SWBM. No hydrostatic loads are applied to elements where slamming pressures are at least as large as the static pressure.
- Pressures pe on shell elements are computed from these rules, Section 4, B.2.2 orB.2.3 for bow area and stern areas, respectively.
- Pressures pe on bow and stern areas are applied in a way that in combination with hydrostatic and weight loads, the resulting vertical bending moment (incl. stillwater loads) does not exceed the rule wave sagging bending moment (without stillwater loads). This restriction is imposed between 10% and 90% of the ship's length. For typical vertical bending moment distributions, see Fig. B.10.
- For this purpose, bow and stern areas are divided into several vertical areas. Load cases are generated by adding slamming loads, area by area, until the required vertical bending moment is reached. If necessary, the slamming pressure on the last added area is scaled by a factor less than one, so that the resulting vertical bending moment does not exceed the rule bending moment.
- In this way, several load cases are generated until at each z-position above the ballast waterline the pressure pe is applied.

Each slamming load case results from the combination of pressures pe, hydrostatic loads, and weight loads. These loads are balanced by adjusting the acceleration factors for the weight loads.

This procedure represents the slamming condition for global strength analyses in a simple but realistic way and enables dimensioning of fore and aft ship areas. The evaluation is limited to permissible stresses and buckling strength only. The fatigue criteria are ignored for slamming load cases.

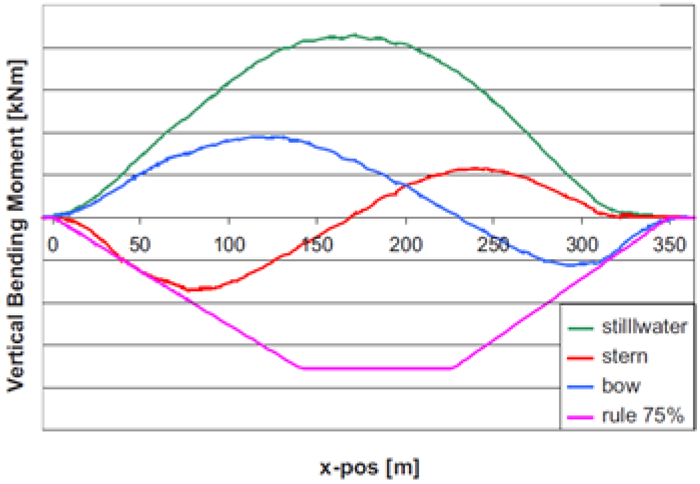


Figure B.10: Vertical bending moments without and with slamming loads

E. Model Check

The FE-model shall be checked systematically with respect of the following possible errors:

— fixed nodes

— nodes without stiffness

— intermediate nodes on element edges, not connected to the element.

— trusses or beams crossing shells

— double shell elements

— extreme element shape (element edge aspect ratio and warped elements)

Additionally, verification of the correct material and geometrical description of all elements is required. Also the moments of inertia, section moduli and neutral axes of the complete cross sections shall be checked.

For each load case, the sum of forces and the reaction forces of the boundary elements shall be negligibly small.

To check the boundary conditions and detect weak areas as well as singular sub-systems, a test calculation run is to be performed. The model should be loaded with a unit force to all nodes for each coordinate direction. This will result in 3 load cases – one for each direction. The calculation results have to be checked with respect to maximum deformations in all directions. This test helps to find areas of improper connections between adjacent elements or gaps between elements.

All checks performed shall be documented. For instance all thickness plots of all web frames, longitudinal girder sections, decks and the bottom and side shell.

F. Evaluation

1. Permissible stresses

The following limits are applicable for the nominal stresses:

— normal stress 175/k [N/mm^2]
— shear stress 110/k [N/mm^2]
— equivalent stress 190/k [N/mm^2]

Where k is the material factor according to Table B.9

Table B.9: Material factor k

k	R_{eH} [N/mm^2]
1,0	235
0,78	315
0,72	355
0,66	390
0,62	460

2. Buckling strength

The buckling strength is checked for compliance with Section 3, F, with a safety factor of S = 1,1

3. Fatigue of hatch corners

The global analysis already allows for the consideration of fatigue aspects. In such a simplified fatigue analysis, the shape of the stress spectrum, the number of load cycles and other fatigue parameters are assumed on the basis of Section 20.

3.1 Local Model

It is required to carry out a fine mesh analysis for every hatch corner by means of a local model. This model shall extend two web spaces aft and forward of the considered hatch corner in the longitudinal direction, and one container height above and below.

The results are sensitive to the mesh arrangement in way of the hatch corner area. Therefore, it is required that an arc equal to a quarter of a circle be divided at least into 10 elements

To evaluate the edge stresses of the hatch corner it is useful to arrange truss elements along the fr edge with a zero cross-sectional area.

Secondary stiffeners may be represented by truss elements as in the global model.

3.2 Load Application

A maximum stress range is to be derived within each loading condition.

The deflections obtained from the global analysis will be applied to the relevant nodes of the local model as forced deformations.

If the size of the local model is greater than in the description above, local loads like container loads and sea pressures shall be applied on the local model if they are relevant.

4. Fatigue of longitudinal stiffeners

The global uniaxial stress and the corresponding local lateral pressure for the longitudinal stiffeners in the side shell can be evaluated by the global strength analysis. With these data, the fatigue strength for the connection between the longitundinal stiffeners and the web frames shall be assessed. For each loading condition the maximum and minimum stress has to be determined. Port side and starboard side are to be combined to determine the maximum stress range, because wave directions were considered from only one side in the load case selection. The total stress is the sum of the global stress (equivalent to the FE-stress) and the local stress due to stiffener bending. The local stress shall be calculated on the basis of Section 9, B. In addition to the outside pressure based on the wave load analysis, the static pressure due to a full wing tank shall also be considered. Finally, the minimum required detail categories should be calculated on the basis of Section 20.

Note:

Other significant fluctuating stresses in the longitudinals due to deflections of supporting transverses as well as additional stresses due to the application of non-symmetrical sections have to be considered.

G. Documentation

1. Structure of report

The global strength analysis has to be documented by a report. In general the report shall be structured as follows:

- Scope of investigation
  - General
  - Description of the strength investigations
- Ship specifications
  - Main ship data
  - Container arrangement
- Finite element model
  - Considered drawings
  - Characteristics of the FE-model
- Loading conditions
- Load cases
  - Global loads resulting from the seaway
  - Slamming loads on bow and stern
- Results
  - Global deformation
  - Hatch cover deflections
  - Permissible stresses
  - Proof of buckling strength
  - Proof of hatch corner stresses
  - Stress plots
  - Fatigue results of longitudinal stiffeners
- Summary

2. Content of report

In addition to the textual component, the report shall also provide the following information in the form of figures and tables:

2.1 Drawings and basic information

A general arrangement plan together with a list of relevant drawings including dates and versions shall be provided as well as frame table and a list of element groups

2.2 3-D views of the FE-model

It is recommended that overview 3-D plots of the FE model be included. Colour plots of plate thickness and/or material yield strength provide added clarity.

2.3 2-D views of the FE-model

2.3.1 All relevant structural members have to be documented by plots.

The plots shall contain the following information:

— plate thickness [mm] (plane stress or shell elements)

— cross sectional area [cm^2] (trusses)

— cross section number (beams).

The cross-sectional properties of beams have to be summarised in a separate table.

2.3.2 Using an element "shrink" option, truss and plane stress elements can be separated. Depending on the mesh fineness it might be necessary to present 2 figures, showing plate thicknesses and truss sectional areas respectively.

2.3.3 Standard scales used in drawings shall be chosen.

2.3.4 The dimensions proposed for documentation may differ from those recommended for the preferred units. This could be caused by an internal data conversion. The units have to be indicated on plots that have common geometric dimensions

2.4 Mass distribution

The mass distribution of the lightship weight and the analysed loading conditions have to be documented. The weight and centre of gravity of each weight group shall be listed in tables. In addition for each bay the number of containers is to be listed. Additionally, the in-hold and on-deck containers shall be separated.

2.5 Summary of load cases

The selected load cases for the FE-analysis have to be documented. The wave parameters considered and the maximum sectional forces and moments will be listed in a table.

2.6 Envelope curves of all load cases

The bending and torsional moments shall meet the design values to be documented by envelope curves.

2.7 Documentation of the load cases

For each selected load case, the distribution of the sectional forces and moments over the ship length shall be documented.

2.8 Global deformation

In order to obtain an impression of the global deformation behaviour, overall deformation for every selected load case is to be documented in 3-D and 2-D views.

2.9 Hatch cover deflection

One important result of the global strength analysis is the determination of the deformed hatch diagonal dimension and the determination of the hatch cover movements relative to the hatch coaming and relative to the adjacent hatch covers.

2.10 Fatigue of hatch corners

The fatigue results regarding hatch corners have to be summarised in tables.

2.11 Fatigue of longitudinal stiffeners

The fatigue results regarding longitudinal stiffeners have to be summarised in tables.

2.12 Stress plots

The maximum stress of all load cases for each element shall be documented.

2.13 Buckling results

Buckling analysis for plate fields shall be documented.

2.14 Changes of the ship design

Proposed structural modifications, if necessary, shall be included in the report

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