IACS

INTERNATIONAL ASSOCIATION
OF CLASSIFICATION SOCIETIES

IACS COMMON STRUCTURAL RULES FOR BULK CARRIERS

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Draft for Comments

Common Structural Rules for Bulk Carriers

Foreword

In recent years expectations and demands to improve the structural safety of ships by maritime industry groups such as the IMO, maritime Administrations, shipowners and shipbuilders have increased greatly, and the role and responsibility of Classification Societies have become ever larger.
As part of its response to these increased expectations and demands, IACS decided to develop IACS Common Structural Rules for both bulk carriers and oil tankers, and established two project teams in 2003.
One of the project teams is the Joint Bulker Project (JBP) comprising the following seven IACS members:

- BV: Bureau Veritas
- CCS: China Classification Society
- ClassNK: Nippon Kaiji Kyokai
- GL: Germanischer Lloyd
- KR: Korean Register of Shipping
- RINA: Registro Italiane Navale
- RS: Russian Register of Shipping

which embarked on the project of developing Common Structural Rules for both single and double side skin bulk carriers.
The team concentrated all its resources in order to achieve this task by the IACS adoption in December 2004. The unique feature of the new Rules is their incorporation of both state-of-the-art technology and the experiences of the seven Classification Societies. The JBP is aiming to develop user-friendly rules with high transparency.
At this stage of the development, preliminary comments from the Industry have been received through External Review Panels. Some of them have already been incorporated for the issuance of this first draft of the Rules.
Feedback information and comments from individual Members' technical committees, External Review Panel and other sources will be further considered to improve the Common Structural Rules.

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Chapter 1 - General principles

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Section 1 - APPLICATION

1. General

1.1 Structural requirements

1.1.1
These Rules apply to the hull structures of single side skin and double side skin bulk carriers, as defined in SOLAS Chapter XII, with unrestricted worldwide navigation, having length L of 90 m or above.

1.1.2
The present Rules contains the requirements for determination of the minimum hull scantlings, applicable to all types of bulk carriers having the following characteristics:

- $L < 500$ m
- $L / B > 5$
- $B / D < 2,5$
- $C_B \geq 0,6$

1.1.3
The Rule requirements apply to hull structures made of steel. The requirements apply also to steel ships in which parts of the hull, such as superstructures or small hatch covers, are built in aluminium alloys.

1.1.4
Ships whose hull materials are different than those given in [1.1.3] and ships with novel features or unusual hull design are to be individually considered by the Society, on the basis of the principles and criteria adopted in the present Rules.

1.1.5
The strength of ships constructed and maintained according to the Rules is sufficient for the draught corresponding to the assigned freeboard. The scantling draught considered when applying the present Rules is to be not less than that corresponding to the assigned freeboard.

1.1.6
Where scantlings are obtained from direct calculation procedures which are different from those specified in Chapter 7.

1.2 Limits of application to lifting appliances

1.2.1
The fixed parts of lifting appliances, considered as an integral part of the hull, are the structures permanently connected by welding to the ship's hull (for instance crane pedestals, masts, king posts, derrick heel seatings, etc., excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any dismountable parts). The shrouds of masts embedded in the ship's structure are considered as fixed parts.

1.2.2
The fixed parts of lifting appliances and their connections to the ship's structure are covered by the Society's Rules for lifting appliances, even when the certification (especially the issuance of the Cargo Gear Register) of lifting appliances is not required.

1.3 Limits of application to welding procedures

1.3.1
The requirements of the present Rules apply also for the preparation, execution and inspection of welded connections in hull structures.

They are to be complemented by the general requirements relevant to fabrication by welding and qualification of welding procedures given by the Society.

2. Rule application

2.1 Ship parts

2.1.1 General
For the purpose of application of the present Rules, the ship is considered as divided into the following three parts:

- fore part
- central part
- aft part.

2.1.2 Fore part
The fore part includes the structures located forward of the collision bulkhead, i.e.:

- the fore peak structures
- the stems.

In addition, it includes:

- the reinforcements of the flat bottom forward area
- the reinforcements of the bow flare area.

2.1.3 Central part
The central part includes the structures located between the collision bulkhead and the after peak bulkhead.

Where the flat bottom forward area or the bow flare area extend aft of the collision bulkhead, they are considered as belonging to the fore part.

2.1.4 Aft part
The aft part includes the structures located aft of the after peak bulkhead.

2.2 Rules applicable to various ship parts

2.2.1
The various Chapters and Sections are to be applied for the scantling of ship parts according to Tab 1.

Table 1 : Chapters and Sections applicable for the scantling of ship parts

Part	Applicable Chapters and Sections	
	General	Specific
Fore part	Chapter 1 Chapter 2 Chapter 3 Chapter 4 Chapter 5 Chapter 9 (1), excluding: • Ch 9, Sec 1 • Ch 9, Sec 2 Chapter 11	Ch 9, Sec 1
Central part		Chapter 6 Chapter 7 Chapter 8
Aft part		Ch 9, Sec 2
(1) See also [2.3].		

2.3 Rules applicable to other ship items

2.3.1

The various Chapters and Sections are to be applied for the scantling of other ship items according to Tab 2.

Table 2 : Chapters and Sections applicable for the scantling of other items

Item	Applicable Chapter and Section
Machinery space	Ch 9, Sec 3
Superstructures and deckhouses	Ch 9, Sec 4
Hatch covers	Ch 9, Sec 5
Hull and superstructure openings	Ch 9, Sec 6
Rudders	Ch 10, Sec 1
Bulwarks and guard rails	Ch 10, Sec 2
Equipment	Ch 10, Sec 3

3. Classification Notations

3.1 Additional service feature

3.1.1

The following requirements apply to ships, as defined in [1.1.1], having length L of 150 m or above.

3.1.2

Bulk Carriers are to be assigned one of the following additional service features:

a) **BC-A**: for bulk carriers designed to carry dry bulk cargoes of cargo density 1,0 t/m^3 and above with specified holds empty at maximum draught in addition to **BC-B** conditions.
b) **BC-B**: for bulk carriers designed to carry dry bulk cargoes of cargo density of 1,0 t/m^3 and above with all cargo holds loaded in addition to **BC-C** conditions.
c) **BC-C**: for bulk carriers designed to carry dry bulk cargoes of cargo density less than 1,0 t/m^3.

3.1.3

The following additional service feature are to be provided giving further detailed description of limitations to be observed during operation as a consequence of the design loading condition applied during the design in the following cases:

- **{maximum cargo density (in t/m^3)}** for notations **BC-A** and **BC-B** if the maximum cargo density is less than 3,0 t/m^3.
- **{no MP}** for all notations when the ship has not been designed for loading and unloading in multiple ports in accordance with the conditions specified in Ch 4, Sec 7, [3.3].
- **{allowed combination of specified empty holds}** for notation **BC-A**.

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Section 2 - VERIFICATION OF COMPLIANCE

1. General

1.1 New buildings

1.1.1

For new buildings, the plans and documents submitted for approval, as indicated in [2], are to comply with the applicable requirements in Ch 1 to Ch 11 of the present Rules, taking account of the relevant criteria, as the additional service feature assigned to the ship or the ship length.

1.2 Ships in service

1.2.1

For ships in service, the requirements in Ch 12 of the present Rules are to be complied with.

2. Documentation to be submitted

2.1 Ships surveyed by the Society during the construction

2.1.1 Plans and documents to be submitted for approval

The plans and documents to be submitted to the Society for approval are listed in Tab 1.

Structural plans are to show details of connections of the various parts and, in general, are to specify the materials used, including their manufacturing processes, welded procedures and heat treatments. See also Ch 11, Sec 1, [1.4].

2.1.2 Plans and documents to be submitted for information

In addition to those in [2.1.1], the following plans and documents are to be submitted to the Society for information:

- general arrangement
- capacity plan, indicating the volume and position of the centre of gravity of all compartments and tanks
- lines plan
- hydrostatic curves
- lightweight distribution.

In addition, when direct calculation analyses are carried out by the Designer according to the rule requirements, they are to be submitted to the Society (see [3]).

2.2 Ships for which the Society acts on behalf of the relevant Administration

2.2.1 Plans and documents to be submitted for approval

The plans required by the National Regulations concerned are to be submitted to the Society for approval, in addition to those in [2.1]. Such plans may include:

- arrangement of lifesaving appliances and relevant embarking and launching devices (davits and winches)

- arrangement of compasses
- arrangement of navigation lights
- order transmission
- loading and unloading arrangement to be included in the ILO Register
- forced ventilation in cargo spaces intended for the carriage of vehicles, dangerous goods in bulk or packaged form, etc.
- lashing of tank vehicles intended for the carriage of dangerous liquids
- cargo securing manual, where required.

Table 1: Plans and documents to be submitted for approval

Plan or document	Containing also information on
Midship section Transverse sections Shell expansion Decks and profiles Double bottom Pillar arrangements Framing plan Deep tank and ballast tank bulkheads, wash bulkheads	Class characteristics Main dimensions Minimum ballast draught Frame spacing Contractual service speed Density of cargoes Design loads on decks and double bottom Steel grades Corrosion protection Openings in decks and shell and relevant compensations Boundaries of flat areas in bottom and sides Details of structural reinforcements and/or discontinuities Bilge keel with details of connections to hull structures
Watertight subdivision bulkheads Watertight tunnels	Openings and their closing appliances, if any
Fore part structure	
Aft part structure	
Machinery space structures Foundations of propulsion machinery and boilers	Type, power and r.p.m. of propulsion machinery Mass and centre of gravity of machinery and boilers
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)
Hatch covers	Design loads on hatch covers Sealing and securing arrangements, type and position of locking bolts Distance of hatch covers from the summer load waterline and from the fore end
Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures	
Bulwarks and freeing ports	Arrangement and dimensions of bulwarks and freeing ports on the freeboard deck and superstructure deck
Windows and side scuttles, arrangements and details	
Scuppers and sanitary discharges	
Rudder and rudder horn **(1)**	Maximum ahead service speed
Sternframe or sternpost, sterntube Propeller shaft boss and brackets **(1)**	
Plan of watertight doors and scheme of relevant manoeuvring devices	Manoeuvring devices Electrical diagrams of power control and position indication circuits

Plan or document	Containing also information on
Plan of outer doors and hatchways	
Derricks and cargo gear Cargo lift structures	Design loads (forces and moments) Connections to the hull structures
Sea chests, stabiliser recesses, etc.	
Hawse pipes	
Plan of manholes	
Plan of access to and escape from spaces	
Plan of ventilation	Use of spaces and location and height of air vent outlets of various compartments
Plan of tank testing	Testing procedures for the various compartments Height of pipes for testing
Loading manual and loading instruments	Loading conditions as defined in Ch 4, Sec 7 (see also Ch 4, Sec 8)
Equipment number calculation	Geometrical elements for calculation List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes
(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted. For azimuth propulsion systems, see Ch 10, Sec 1, [11].	

3. Computer programs

3.1 General

3.1.1

In order to increase the flexibility in the structural design direct calculations with computer programs are acceptable. See Ch 7. The aim of such analyses is to assess the structure comply with the rule requirements. Directt calculations may also be used in order to optimise a design.

3.2 General programs

3.2.1

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

3.2.2

Direct calculations may be used in the following fields

- global strength
- longitudinal strength
- beams and grillages
- detailed strength

3.2.3

For such calculation the computer model, the boundary condition and load cases are to be agreed upon with the Society.

The calculation documents are to be submitted including input and output. During the examination it may prove necessary that the Society performs independent comparative calculations.

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Section 3 – FUNCTIONAL REQUIREMENTS

1. General

1.1 Application

This section defines the set of requirements relevant to the functions of the ship structures to be complied with and verified during design and construction, to meet the following safety objectives.

1.2 Design Life

The ship are to remain safe and environmental friendly, if properly operated and maintained, for her expected design life, which, unless otherwise specifically stated, is assumed to be equal to 25 years. The actual ship life may be longer or shorter than the design life, depending on the actual conditions and maintenance of the ship verified at periodic surveys, taking into account aging effects, in particular fatigue, coating deterioration, corrosion, wear and tear.

1.3 Environmental Conditions

Ships are to be designed in accordance with foreseeable North Atlantic environmental conditions and relevant long-term sea state scatter diagram.

1.4 Structural Safety

The ship is to be designed and constructed, and subsequently operated and maintained, to minimise the risk for the safety of life at sea, pollution of the marine environment or total loss of the vessel due to structural collapse and consequent flooding, loss of watertight integrity or sinking.

1.5 Structural Accessibility

The ship is to be designed and constructed to provide adequate means of access to all internal structures to enable overall and close-up inspections and thickness measurements.

1.6 Quality of construction

Ships is to be built in accordance with controlled quality production standards, with due care to the health and safety of personnel, and by using original materials, capable of maintaining their physical and mechanical properties during the expected design life.

2. Functional Requirements

The functional requirements relevant to the ship structure are to include the following:

2.1 Structural strength

2.1.1

Ships are to be designed to withstand, in the intact condition, the environmental conditions during the design life, for the appropriate loading conditions. Structural strength is to be verified against buckling and yielding. Ultimate strength calculations include ultimate hull girder capacity and ultimate strength of plates and stiffeners.

2.1.2

Ships are to be designed to have sufficient reserve strength to withstand the wave and internal loads in damaged conditions that are reasonably foreseeable, e.g. collision, grounding or flooding scenarios. Residual strength calculations are to take into account the ultimate reserve capacity of the hull girder, considering permanent deformation and post-buckling behaviour.

2.1.3

Ships are to be designed to have sufficient fatigue life for reprentative structural details.

2.2 Coating

Coating, where required, is to be selected as a function of the intended use of the compartment, materials and application of other corrosion prevention systems, e.g. cathodic protection or other alternative means. The protective coating systems, applied and maintained in accordance with manufacturer's specifications concerning steel preparation, coating selection, application and maintenance, is to comply with the SOLAS requirements, the flag administration requirements and the Owner specifications. The coating conditions is to be assessed at periodic surveys.

2.3 Corrosion addition

The corrosion addition to be added to the net scantling required by structural strength calculations is to be adequate for the expected design life. The corrosion addition is to be assigned in accordance with the use and exposure of each internal and external structure to corrosive agents, such as water, cargo or corrosive atmosphere, in addition to the corrosion prevention systems, e.g. coating, cathodic protection or by alternative means. The actual corrosion condition, depending on the actual conditions and maintenance of the ship is to be assessed at periodic surveys.

2.4 Means of access

Ship structures subject to overall and close-up inspection and thickness measurements are to be provided with means capable of ensuring safe access to the structures. The means of access are to be described in a Ship Structure Access Manual.

2.5 Construction quality procedures

Specifications for material manufacturing, assembling, joining and welding procedures, steel surface preparation and coating are to be included in the ship construction quality procedures.

3. International Regulations

Ships are designed, constructed and operated in a complex regulatory framework prescribed internationally by IMO and implemented by flag states or by classification societies on their behalf. Statutory requirements set the standard for statutory aspects of ships such as life saving, subdivisions, stability, fire protection, etc.

These requirements influence the operational and cargo carrying arrangements of the ship and therefore may affect its structural design.

The main applicable international instruments with their latest consolidated edition are to be observed with regard to the strength of bulk carriers having a length greater than or equal to 90 meters are

- **International Convention for Safety of Life at Sea (SOLAS)**
- **International Convention on Load Lines**

4. National Regulations

Applicable national flag state regulations are to be observed.

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

5. SEQSEQSEQWorkmanship

5.1 Requirements to be complied with by the manufacturer

The manufacturing plant is to be provided with suitable equipment and facilities to enable proper handling of the materials, manufacturing processes, structural components, etc.

The manufacturing plant is to have at its disposal sufficiently qualified personnel. The Society is to be advised of the names and areas of responsibility of all supervisory and control personnel.

5.2 Quality control

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.

Upon inspection and corrections by the manufacturing plant, the structural components are to be shown to the surveyor of the Society for inspection, in suitable sections, normally in unpainted condition and enabling proper access for inspection.

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.

6. Structural details

6.1 Details in manufacturing documents

All significant details concerning quality and functional ability of the component concerned are to 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 is to be used (works or national standard etc.) it is to be harmonized with the Society. For weld joint details, see Ch 11, Sec 1.

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, the Society 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.

6.2 Cut-outs, plate edges

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 draglines, etc. are not to be welded out, but are to be smoothly ground. All edges are to be broken or in cases of highly stressed parts, be rounded off.

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 above This also applies to cutting drag lines, etc., in particular to the upper edge of shear strake and analogously to weld joints, changes in sectional areas or similar discontinuities.

6.3 Cold forming

For cold forming (bending, flanging, beading) of plates the minimum average bending radius is to be not less than 3 t (t = gross plate thickness).

In order to prevent cracking, flame cutting flash or sheering burrs are to 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.

6.4 Assembly, alignment

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 are to be corrected before further assembly.

Girders, beams, stiffeners, frames, etc. that are interrupted by bulkheads, decks, etc. are to 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.

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

Chapter 1 – General principles

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Section 4 – SYMBOLS AND DEFINITIONS

1. Units

1.1

1.1.1

Unless otherwise specified, the units used in the present Rules are those defined in Tab 1.

Table 1: Units

Designation	Usual symbol	Units
Angles	θ, Φ	deg
Acceleration	a	m/s^2
Angular acceleration	α	rad/s^2
Hull girder inertia	I	m^4
Hull girder section modulus	Z	m^3
Hull girder area	A	m^2
Density	ρ	t/m^3
Mass	M	t
Concentrated loads	P	kN
Linearly distributed loads	q	kN/m
Surface distributed loads (pressures)	p	kN/m^2
Temperature	t_0	°C
Thickness	t	mm
Span of ordinary stiffeners and primary supporting members		m
Spacing of ordinary stiffeners and primary supporting members	s	m
Bending moment	M	kN.m
Ship's dimensions	See [2]	m
Shear force	Q	kN
Ship's speed	V	knot
Stresses	σ, τ	N/mm^2
Section modulus of ordinary stiffeners and primary supporting members	w	cm^3
Inertia of ordinary stiffeners and primary supporting members	I	cm^4
Sectional area of ordinary stiffeners and primary supporting members	A	cm^2
Sectional moment of inertia of ordinary stiffeners and primary supporting members	I	cm^6

2. Symbols

2.1 Ship's main data

2.1.1

L : Rule length, in m, defined in [3.1]

L_{LL} : Freeboard length, in m, defined in [3.2]

L_{BP} : Length between perpendiculars, in m, is the length of the ship measured between perpendiculars taken at the extremities of the deepest subdivision load line, i.e. of the waterline which corresponds to the greatest draught permitted by the subdivision requirements which are applicable

FP_{LL} : forward freeboard perpendicular. The forward freeboard perpendicular is to be taken at the forward end the length L_{LL} and is to coincide with the foreside of the stem on the waterline on which the length L_{LL} is measured.

AP_{LL} : after freeboard perpendicular. The after freeboard perpendicular is to be taken at the after end the length L_{LL}.

B : Moulded breadth, in m, defined in [3.4]

D : Depth, in m, defined in [3.5]

T : Moulded draught, in m, defined in [3.6]

T_S : Scantling draught, in m

T_B : Minimum ballast draught at midship, in m, in normal ballast condition, as defined in Ch 4, Sec 7, [2.2.1]

T_{LC} : Midship draught, in m, in the considered loading condition

Δ. : Moulded displacement, in tonnes, at draught T, in sea water (density $\rho = 1,025$ t/m^3)

C_B : Total block coefficient

$$C_B = \frac{\Delta}{1{,}025 LBT}$$

V : Maximum ahead service speed, in knots,

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system.

2.2 Materials

2.2.1

E : Young's modulus, in N/mm^2, to be taken equal to:

$E = 2{,}06.10^5$ N/mm^2 for steels in general

$E = 1{,}95.10^5$ N/mm^2 for stainless steels

$E = 7{,}0.10^4$ N/mm^2 for aluminium alloys

R_{eH} : Minimum yield stress, in N/mm^2, of the material

k : Material factor, defined in Ch 3, Sec 1, [2.2]

ν : Poisson's ratio. Unless otherwise specified, a value of 0,3 is to be taken into account,

R_Y : Nominal yield stress, in N/mm^2, of the material, to be taken equal to 235/k N/mm^2, unless otherwise specified.

2.3 Loads

2.3.1

g : Gravity acceleration, taken equal to 9,81 m/s^2

ρ : Sea water density, taken equal to 1,025 t/m^3

ρ_L : Density, in t/m^3, of the liquid carried

ρ_C : Density, in t/m^3, of the dry bulk cargo carried

C : Wave parameter, taken equal to:

$C = 10{,}75 - \left(\frac{300 - L}{100}\right)^{1,5}$ for $90 \le L < 300$m

$C = 10{,}75$ for $300 \le L \le 350$m

$C = 10{,}75 - \left(\frac{L - 350}{150}\right)^{1,5}$ for $L > 350$m

H : Height, in m, of a tank, to be taken as the vertical distance from the bottom to the top of the tank, excluding any small hatchways

Z_{TOP} : Vertical distance, in m, of the highest point of the tank from the baseline. For ballast holds, Z_{TOP} is the vertical distance, in m, of the top of the hatch coaming from the baseline

l_C : Length, in m, of the compartment

M_{SW} : Design still water bending moment, in kN.m, at the hull transverse section considered:

- $M_{SW} = M_{SW,H}$ in hogging conditions
- $M_{SW} = M_{SW,S}$ in sagging conditions

M_{WV} : Vertical wave bending moment, in kN.m, at the hull transverse section considered:

- $M_{WV} = M_{WV,H}$ in hogging conditions
- $M_{WV} = M_{WV,S}$ in sagging conditions

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered,

Q_{SW} : Design still water shear force, in kN, at the hull transverse section considered

Q_{WV} : Vertical wave shear force, in kN, at the hull transverse section considered

p_S : Still water pressure, in kN/m^2

p_W : Wave pressure or dynamic pressures, in kN/m^2

p_{SF}, p_{WF} : Still water and wave pressure, in kN/m^2, in flooding conditions

σ_X : Hull girder normal stress, in N/mm^2

a_X, a_Y, a_Z : Accelerations, in m/s^2, along X, Y and Z directions, respectively

T_R : Roll period, in s

θ : Single angle roll amplitude, in deg

T_P : Pitch period, in s

Φ : Single pitch amplitude, in deg

k_r : Roll radius of gyration, in m

GM : Metacentric height, in m

λ : Wave length, in m

2.4 Scantlings

2.4.1 Hull girder scantlings

I_Y : Moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis

I_Z : Moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis

S : First moment, in m^3, of the hull transverse section

Z_{AB},Z_{AD} : Section moduli, in m^3, at bottom and deck, respectively

N : Vertical distance, in m, from the base line to the horizontal neutral axis of the hull transverse section

2.4.2 Local scantlings

s : Spacing, in m, of ordinary stiffeners or primary supporting members, as the case may be

: Span, in m, of an ordinary stiffener or a primary supporting member, as the case may be

$_b$: Length, in m, of brackets

t_C : Corrosion addition, in mm

h_w : Web height, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

t_w : Net web thickness, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

b_f : Face plate width, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

t_f : Net face plate thickness, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

t_p : Net thickness, in mm, of the plating attached to an ordinary stiffener or a primary supporting member, as the case may be

b_P : Width, in m, of the plating attached to the stiffeners or the primary supporting member, for the yielding check,

A_S : Net sectional area, in cm^2, of the stiffener or the primary supporting member, with attached plating of width s

A_{Sh} : Net shear sectional area, in cm^2, of the stiffener or the primary supporting member

I : Net moment of inertia, in cm^4, of an ordinary stiffener or a primary supporting member, as the case may be, without attached plating, around its neutral axis parallel to the plating

I_p : Net polar moment of inertia, in cm^4, of an ordinary stiffener or a primary supporting member, as the case may be, about its connection to plating

I_w : Net sectional moment of inertia, in cm^6, of an ordinary stiffener or a primary supporting member, as the case may be, about its connection to plating

I_S : Net moment of inertia, in cm^4, of the stiffener or the primary supporting member, with attached shell plating of width s, about its neutral axis parallel to the plating

w : Net section modulus, in cm^3, of an ordinary stiffener or a primary supporting member, as the case may be, with attached plating of width b_p

3. Definitions

3.1 Rule length

3.1.1

The rule length L is the distance, in m, measured on the summer load waterline, from the forward side of the stem to the after side of the rudder post, or to the centre of the rudder stock where there is no rudder post. L is to be not less than 96% and need not exceed 97% of the extreme length on the summer load waterline.

3.1.2

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 summer load waterline.

3.1.3

In ships with unusual stem or stern arrangements, the rule length L is considered on a case by case basis.

3.2 Freeboard length

3.2.1

The freeboard length L_{LL} is the distance, in m, on the waterline at 85% of the least moulded depth from the top of the keel, measured from the forward side of the stem to the centre of the rudder stock. L_{LL} is to be not less than 96% of the extreme length on the same waterline.

3.2.2

Where the stem contour is concave above the water-line at 85% of the least moulded depth, both the forward end of the extreme length and the forward side of the stem are to be taken at the vertical projection to that waterline of the aftermost point of the stem contour (above that waterline).

3.2.3

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

3.3 Ends of rule length L and midship

3.3.1 Fore end

The fore end (FE) of the rule length L, see Fig 1, is the perpendicular to the summer load waterline at the forward side of the stem.

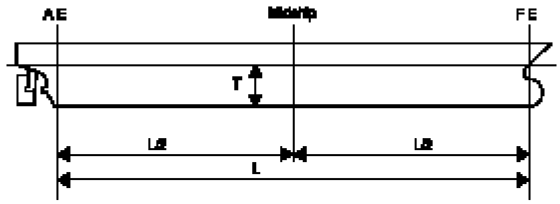


Figure 1: Ends and midship

The aft end (AE) of the rule length L, see Fig 1, is the perpendicular to the waterline at a distance L aft of the fore end.

3.3.2 Midship

The midship is the perpendicular to the waterline at a distance 0,5L aft of the fore end.

3.3.3 Midship part

The midship part of a ship is the part extending 0,4 L amidships, unless otherwise specified.

3.4 Moulded breadth

3.4.1

The moulded breadth B is the greatest moulded breadth, in m, measured amidships below the weather deck.

3.5 Depth

3.5.1

The depth D is the distance, in m, measured vertically on the midship transverse section, from the moulded base line to the top of the deck beam at side on the upper-most continuous deck.

3.6 Moulded draught

3.6.1

The moulded draught T is the distance, in m, measured vertically on the midship transverse section, from the moulded base line to the summer load line.

3.7 Lightweight

3.7.1

The lightweight is the displacement, in t, without cargo, fuel, lubricating oil, ballast water, fresh water and feed water, consumable stores and passengers and crew and their effects, but including liquids in piping.

3.8 Deadweight

3.8.1

The deadweight is the difference, in t, between the displacement, at the summer draught in sea water of density $\rho = 1{,}025$ t/m^3, and the lightweight.

3.9 Freeboard deck

3.9.1

The freeboard deck is defined in Regulation 3 of the 1966 International Convention on Load Lines.

3.10 Bulkhead deck

3.10.1

The bulkhead deck is the uppermost deck to which the transverse watertight bulkheads, except both peak bulkheads, extend and are made effective.

3.11 Strength deck

3.11.1

The strength deck at a part of ship's length is the uppermost continuous deck at that part to which the shell plates extend.

3.12 Superstructure

3.12.1 General

A superstructure is a decked structure connected to the free-board 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.

3.12.2 Enclosed and open superstructure

A superstructure may be:

- enclosed, where:
- it is enclosed by front, side and aft bulkheads complying with the requirements of Ch 9, Sec 4
- all front, side and aft openings are fitted with efficient weathertight means of closing
- open, where it is not enclosed.

3.13 Raised quarterdeck

3.13.1

A raised quarterdeck is a partial superstructure of reduced height as defined in [3.14].

3.14 Deckhouse

3.14.1

A deckhouse is a decked structure other than a superstructure, located on the freeboard deck or above.

3.15 Trunk

3.15.1

A trunk is a decked structure similar to a deckhouse, but not provided with a lower deck.

3.16 Standard height of superstructure

3.16.1

Ref. ILLC, Reg. 33

The standard height of superstructure is defined in Tab 2.

Table 2: Standard height of superstructure

Freeboard length L_{LL}, in m	Standard height h_S, in m	
	Raised quarter deck	All other superstructures
$90 < L_{LL} < 125$	$0,3 + 0,012L_{LL}$	$1,05 + 0,01L_{LL}$
$L_{LL} \geq 125$	1,80	2,30

3.17 Type A and Type B ships

3.17.1 Type A ship

Ref. ILLC, Reg. 27

A Type A ship is one which:

is designed to carry only liquid cargoes in bulk;

has a high integrity of the exposed deck with only small access openings to cargo compartments, closed by watertight gasketed covers of steel or equivalent material; and

has low permeability of loaded cargo compartments.

A Type A ship is to be assigned a freeboard following the requirements reported in the International Load Line Convention 1966, as amended.

3.17.2 Type B ship

Ref. ILLC, Reg. 27

All ships which do not come within the provisions regarding Type A ships stated in [3.15.1] are to be considered as Type B ships.

A Type B ship is to be assigned a freeboard following the requirements reported in the International Load Line Convention 1966, as amended.

3.17.3 Type B-60 ship

Ref. ILLC, Reg. 27

A Type B-60 ship is any Type B ship of over 100 metres in length which, according to applicable requirements of in the International Load Line Convention 1966, as amended, is assigned with a value of tabular freeboard which can be reduced up to 60 per cent of the difference between the "B" and "A" tabular values for the appropriate ship lengths.

3.17.4 Type B-100 ship

Ref. ILLC 1966, Reg. 27

A Type B-60 ship is any Type B ship of over 100 metres in length which, according to applicable requirements of in the International Load Line Convention 1966, as amended, is assigned with a value of tabular freeboard which can be reduced up to 100 per cent of the difference between the "B" and "A" tabular values for the appropriate ship lengths.

3.18 Positions 1 and 2

3.18.1 Position 1

Ref. ILLC, Reg. 13 and IMO Res. MSC.143(77)
Position 1 includes:

exposed freeboard and raised quarter decks,

exposed superstructure decks situated forward of 0,25 LLL from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel.

3.18.2 Position 2

Ref. ILLC, Reg. 13 and IMO Res. MSC.143(77)
Position 2 includes:

exposed superstructure decks situated aft of 0,25 L from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel and located at least one standard height of superstructure above the freeboard deck,

exposed superstructure decks situated forward of 0,25 L from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel and located at least two standard heights of superstructure above the freeboard deck.

4. Reference co-ordinate system

4.1

4.1.1

The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand co-ordinate system (see Fig 2):

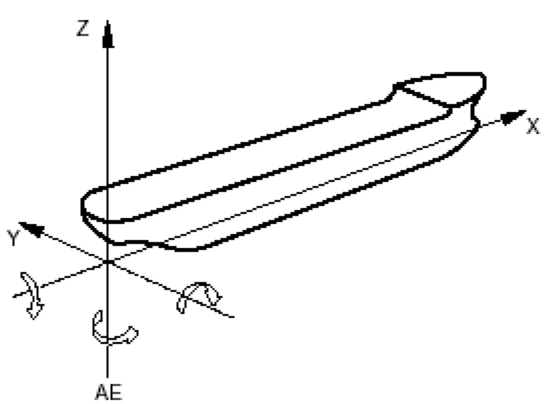
Origin: at the intersection among the longitudinal plane of symmetry of ship, the aft end of L and the baseline

X axis: longitudinal axis, positive forwards

Y axis: transverse axis, positive towards portside

Z axis: vertical axis, positive upwards.

Figure 2 : Reference co-ordinate system



4.1.2

Positive rotations are oriented in anti-clockwise direction about the X, Y and Z axes.

Chapter 2 – General arrangement design

Welcome JBP

Section 1 - SUBDIVISION ARRANGEMENT

1. Number and arrangement of transverse watertight bulkheads

1.1 Number of watertight bulkheads

1.1.1 General

All ships, in addition to complying with the requirements of [1.1.2], are to have at least the following transverse watertight bulkheads:

- one collision bulkhead
- one after peak bulkhead
- two bulkheads forming the boundaries of the machinery space in ships with machinery amidships, and a bulkhead forward of the machinery space in ships with machinery aft. In the case of ships with an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulkheads. Application for classification is to be made in writing, using the request for classification form, by the Owner, his representative or the builder. This form is signed by the party applying for classification and a representative of the Society.

1.1.2 Additional bulkheads

For ships not required to comply with subdivision regulations, transverse bulkheads adequately spaced and in general not less in number than indicated in Tab 1 are to be fitted.

Table 1: Number of bulkheads

Length (m)	Number of bulkheads for ships with aft machinery **1)**	Numbers of bulkheads for other ships
$90 \le L < 105$	4	5
$105 \le L < 120$	5	6
$120 \le L < 145$	6	7
$145 \le L < 165$	7	8
$165 \le L < 190$	8	9
$L \ge 190$	To be defined on a case by case basis	
1) After peak bulkhead and aft machinery bulkhead are the same.		

2. Collision bulkhead

2.1 Arrangement of collision bulkhead

2.1.1

Ref. SOLAS Ch. II-1, Part B, Reg. 11

A collision bulkhead is to be fitted which is to be watertight up to the freeboard deck. This bulkhead is to be located at a distance from the forward perpendicular FP_{LL} of not less than 5 per cent of the length L_{LL} of the ship or 10 m, whichever is the less, and not more than 8 per cent of L_{LL} .

2.1.2

Ref. SOLAS Ch. II-1, Part B, Reg. 11

Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g. a bulbous bow, the distances, in metres, stipulated in [2.1.1] are to be measured from a point either:

- *at the mid-length of such extension, or*
- *at a distance 1,5 per cent of the length L_{LL} of the ship forward of the forward perpendicular, or*
- *at a distance 3 metres forward of the forward perpendicular*

2.1.3

Ref. SOLAS Ch. II-1, Part B, Reg. 11

The bulkhead may have steps or recesses provided they are within the limits prescribed in [2.1.1] or [2.1.2].

No door, manhole, ventilation duct or any other opening is to be fitted in this bulkhead.

2.1.4

The Society may, on a case by case basis, accept a distance from the collision bulkhead to the forward perpendicular FP_{LL} greater than the maximum specified in [2.1.1] and [2.1.2], provided that subdivision and stability calculations show that, when the ship is in upright condition on full load summer waterline, flooding of the space forward of the collision bulkhead will not result in any part of the free-board deck becoming submerged, or in any unacceptable loss of stability.

2.1.5

Ref. SOLAS Ch. II-1, Part B, Reg. 11

Where a long forward superstructure is fitted, the collision bulkhead is to be extended weathertight to the next deck above the freeboard deck. The extension need not be fitted directly above the bulkhead below provided it is located within the limits prescribed in [2.1.1] or [2.1.2] with the exemption permitted by [2.1.6] and the part of the deck which forms the step is made effectively weathertight.

2.1.6

Ref. SOLAS Ch. II-1 Part B, Reg. 11

Where bow doors are fitted and a sloping loading ramp forms part of the extension of the collision bulkhead above the freeboard deck, the part of the ramp which is more than 2,3 m above the freeboard deck may extend for-ward of the limit specified in [2.1.1] or [2.1.2] The ramp is to be weathertight over its complete length.

2.1.7

Ref. SOLAS Ch. II-1, Part B, Reg. 11

The number of openings in the extension of the collision bulkhead above the freeboard deck is to be restricted to the minimum compatible with the design and normal operation of the ship. All such openings are to be capable of being closed weathertight.

3. After peak, machinery space bulkheads and stern tubes

3.1

3.1.1 General

Ref. SOLAS Ch. II-1, Part B, Reg. 11

An after peak bulkhead, and bulkheads dividing the machinery space from the cargo spaces forward and aft, are also to be fitted and made watertight up to the freeboard deck. The after peak bulkhead may, however, be stepped below the bulkhead deck, provided the degree of safety of the ship as regards subdivision is not thereby diminished.

3.1.2 Sterntubes

Ref. SOLAS Ch. II-1, Part B, Reg. 11

Sterntubes are to be enclosed in a watertight space (or spaces) of moderate volume. Other measures to minimise the danger of water penetrating into the ship in case of damage to sterntube arrangements may be taken at the discretion of the Society.

4. Number and arrangement of tank bulkheads

4.1 Bulkheads in compartments intended for the carriage of liquid cargoes

4.1.1

The number and location of transverse and longitudinal watertight bulkheads in compartments intended for the carriage of liquid cargoes are to comply with the subdivision requirements to which the ship is subject.

5. Height of transverse watertight bulkheads

5.1

5.1.1

Transverse watertight bulkheads other than the collision bulkhead and the after peak bulkhead are to extend watertight up to the freeboard deck. In exceptional cases at the request of the Owner, the Society may allow transverse watertight bulkheads to terminate at a deck below that from which freeboard is measured, provided that this deck is at an adequate distance above the full load waterline.

5.1.2

Where it is not practicable to arrange a watertight bulkhead in one plane, a stepped bulkhead may be fitted. In this case, the part of the deck which forms the step is to be watertight and equivalent in strength to the bulkhead.

6. Openings in the watertight bulkheads below the freeboard deck

6.1 General

6.1.1

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9 and IMO Res. A.684(17) - Part B

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 Society may permit relaxation 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.

6.1.2

No door, manhole ventilation duct or any other opening is permitted in the collision bulkhead below the subdivision deck.

6.1.3

Lead or other heat sensitive materials may not be used in systems which penetrate watertight subdivision bulkheads, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkheads.

6.1.4

Valves not forming part of a piping system are not permitted in watertight subdivision bulkheads.

6.1.5

The requirements relevant to the degree of tightness, as well as the operating systems, for doors or other closing appliances complying with the provisions in [6.2] and [6.3] are specified in Tab 2.

6.2 Openings in the watertight bulkheads below the freeboard deck

6.2.1 Openings used while at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9

Doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors 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 minimise the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. The possibility of opening and closing the door by hand at the door itself from both sides is to be assured.

6.2.2 Openings normally closed at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9

Access doors and access hatch covers normally closed at sea, intended to ensure the watertight integrity of internal openings, are to be provided with means of indication locally and on the bridge showing whether these doors or hatch covers are open or closed. A notice is to be affixed to each such door or hatch cover to the effect that it is not to be left open. The use of such doors and hatch covers is to be authorised by the officer of the watch.

6.2.3 Doors or ramps in large cargo spaces

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9

Watertight doors or ramps of satisfactory construction may be fitted to internally subdivide large cargo spaces, provided that the Society is satisfied that such doors or ramps are essential. These doors or ramps may be hinged, rolling or sliding doors or ramps, but are not to be remotely con-trolled.

Such doors are to be closed before the voyage commences and are to be kept closed during navigation. Should any of the doors or ramps be accessible during the voyage, they are to be fitted with a device which prevents unauthorised opening.

The word “satisfactory” means that scantlings and sealing requirements for such doors or ramps are to be sufficient to withstand the maximum head of the water at the flooded waterline.

6.2.4 Openings permanently kept closed at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9

Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of internal openings are to be provided with a notice which is to be affixed to each such closing appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

Table 2: Doors

			Sliding type			Hinged type			Rolling type (cargo between deck spaces)
			Remote operation indication on the bridge	Indicator on the bridge	Local operation only	Remote operation indication on the bridge	Indicator on the bridge	Local operation only	
Watertight	Below the freeboard deck	Open at sea	X						
		Normally closed **(2)**		X			X **(3)**		
		Remain closed **(2)**			X **(4) (5)**			X **(4) (5)**	X **(4) (5)**
Weathertight / watertight **(1)**	Above the freeboard deck	Open at sea	X						
		Normally closed **(2)**		X			X		
		Remain closed **(2)**						X **(4) (5)**	

(1) Watertight doors are required when they are located below the waterline at the equilibrium of the final stage of flooding; other-wise a weathertight door is accepted.
(2) Notice to be affixed on both sides of the door: "to be kept closed at sea".
(3) Type A ships of 150 m and upwards, and Type B ships with a reduced freeboard may have a hinged watertight door between the engine room and the steering gear space, provided that the sill of this door is above the summer load waterline.
(4) The door is to be closed before the voyage commences.
(5) If the door is accessible during the voyage, a device which prevents unauthorised opening is to be fitted.

6.3 Openings in the bulkheads above the freeboard deck

6.3.1 General

The openings in flooding boundaries located below the waterline at the equilibrium of the final stage of flooding are to be watertight. The openings immersed within the range of the positive righting lever curve are only to be weathertight.

6.3.2 Doors used while at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9

The doors used while at sea are to be sliding doors 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 minimise the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. It should be possible to open and close the door by hand at the door itself from both sides.

6.3.3 Doors normally closed at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9

The doors normally closed at sea are to be provided with means of indication locally and on the bridge showing whether these doors are open or closed. A notice is to be affixed to each door to the effect that it is not to be left open.

6.3.4 Openings kept permanently closed at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9

The doors kept closed at sea are to be hinged doors. Such doors and the other closing appliances which are kept closed at sea are to be provided with a notice affixed to each closing appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

Chapter 2 – General arrangement design

Welcome JBP

Section 2 - COMPARTMENT ARRANGEMENT

1. Definitions

1.1 Cofferdam

1.1.1

A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. As a rule, a cofferdam is to be properly ventilated and of sufficient size to allow for inspection.

1.2 Machinery spaces of category A

1.2.1

Ref. SOLAS Ch. II-2, Part A, Reg. 3.31

Machinery spaces of category A are those spaces or trunks to such spaces which contain:

- *internal combustion machinery used for main propulsion; or*
- *internal combustion machinery used for purposes other than propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or*
- *any oil fired boiler or fuel oil unit.*

2. Cofferdams

2.1 Cofferdam arrangement

2.1.1

Cofferdams are to be provided between compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and those intended for fresh water (drinking water, water for propelling machinery and boilers) as well as tanks intended for the carriage of liquid foam for fire extinguishing.

2.1.2

Cofferdams separating fuel oil tanks from lubricating oil tanks and the latter from those intended for the carriage of liquid foam for fire extinguishing or fresh water or boiler feed water may not be required when deemed impracticable or unreasonable by the Society in relation to the characteristics and dimensions of the spaces containing such tanks, provided that:

- the thickness of common boundary plates of adjacent tanks is increased, with respect to the thickness obtained according to Ch 6, Sec 1, by 2 mm in the case of tanks carrying fresh water or boiler feed water, and by 1 mm in all other cases
- the sum of the throats of the weld fillets at the edges of these plates is not less than the thickness of the plates themselves
- the structural test is carried out with a head increased by 1 m with respect to Ch 11, Sec 2.

2.1.3

Spaces intended for the carriage of flammable liquids are to be separated from accommodation and service spaces by means of a cofferdam. Where accommodation and service spaces are arranged immediately above such spaces, the cofferdam may be omitted only where the deck is not provided with access openings and is coated with a layer of material recognized as suitable by the Society.

The cofferdam may also be omitted where such spaces are adjacent to a passageway, subject to the conditions stated in [2.1.2] for fuel oil or lubricating oil tanks.

2.1.4

Cofferdams are only required between fuel oil double bottoms and tanks immediately above where the inner bottom plating is subjected to the head of fuel oil contained therein, as in the case of a double bottom with its top raised at the sides.

Where a corner to corner situation occurs, tanks are not be considered to be adjacent.

Adjacent tanks not separated by cofferdams are to have adequate dimensions to ensure easy inspection.

3. Double bottoms

3.1 General

3.1.1

Ref. SOLAS Ch. II-1, Part B, Reg. 12-1

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.

3.1.2

Ref. SOLAS Ch. II-1, Part B, Reg. 12-1

Where a double bottom is required to be fitted, its depth is to satisfy the provisions of Ch 3, Sec 6, [4.2] and the inner bottom is to be continued out to the ship side in such a manner as to protect the bottom to the turn of the bilge.

3.1.3

Ref. SOLAS Ch. II-1, Part B, Reg. 12-1

Small wells constructed in the double bottom, in connection with the drainage arrangements of holds, are not to extend in depth more than necessary. A well extending to the outer bottom, may, however, be permitted at the after end of the shaft tunnel of the ship. Other wells may be permitted by the Society if it is satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with [3.1].

3.1.4

Ref. SOLAS Ch. II-1, Part B, Reg. 12-1

A double bottom need not be fitted in way of water-tight compartments used exclusively for the carriage of liquids, provided the safety of the ship in the event of bottom damage is not, in the opinion of the Society, thereby impaired.

4. Compartment forward of the collision bulkhead

4.1 General

4.1.1

The fore peak and other compartments located forward of the collision bulkhead may not be arranged for the carriage of fuel oil or other flammable products.

5. Minimum bow height

5.1 General

5.1.1

Ref. ICLL Reg. 39.1 and IMO Res. MSC.143(77)

In all ships which are subject to the provisions of the International Convention on Load Line in force, the bow height F_b, defined as the vertical distance at the forward perpendicular between the waterline corresponding to the assigned summer freeboard and the designed trim and the top of the exposed deck at side, is to be not less than:

$$F_b = (6075(L_{LL}/100) - 1875(L_{LL}/100)^2 + 200(L_{LL}/100)^3) \times (2,08 + 0,609C_b - 1,603C_{wf} - 0,0129(L/T_1))$$

where:

F_b : *calculated minimum bow height, in mm*

T_1 : *draught at 85% of the depth for freeboard D_1, in m*

D_1 : *depth for freeboard, is the moulded depth amidship plus the freeboard deck thickness at side. The depth for freeboard in a ship having a rounded gunwale with a radius greater than 4% of the breadth (B) or having topsides of unusual form is the depth for freeboard of a ship having a midship section with vertical topsides and with the same round of beam and area of topside section equal to that provided by the actual midship section.*

C_{wf} : *waterplane area coefficient forward of $L_{LL}/2$:*

$$C_{wf} = \frac{A_{wf}}{\frac{L_{LL}}{2} B}$$

A_{wf} : *waterplane area forward of $L_{LL}/2$ at draught T_1, in m^2.*

For ships to which timber freeboards are assigned, the summer freeboard (and not the timber summer freeboard) is to be assumed when applying the formula above.

5.1.2

Where the bow height required in paragraph [5.1.1] is obtained by sheer, the sheer is to extend for at least 15% of the length of the ship measured from the forward perpendicular. Where it is obtained by fitting a superstructure, such superstructure is to extend from the stem to a point at least 0.07L abaft the forward perpendicular, and is to be enclosed as defined Ch 9, Sec 4.

5.1.3

Ships which, to suit exceptional operational requirements, cannot meet the requirements in [5.1.1] and [5.1.2] will be considered by the Society on a case by case basis.

5.1.4

The sheer of the forecastle deck may be taken into account, even if the length of the forecastle is less than 0.15L, but greater than 0.07L, provided that the forecastle height is not less than one half of standard height of superstructure between 0.07L and the forward perpendicular.

5.1.5

Where the forecastle height is less than one half of the standard height of superstructure, the credited bow height may be determined as follows:

a) *Where the freeboard deck has sheer extending from abaft 0.15L, by a parabolic curve having its origin at 0.15L abaft the forward perpendicular at a height equal to the midship depth of the ship, extended through the point of intersection of forecastle bulkhead and deck, and up to a point at the forward perpendicular not higher than the level of the forecastle deck (as illustrated in Fig 1). However, if the value of the height denoted h_t in Fig 1 is smaller than the value of the height denoted h_b then h_t may be replaced by h_b in the available bow height, where:*

$$ht = Z_b \left(\frac{0,15L}{x_b} \right)^2 - Z_t$$

Z_b : *As defined in Fig 1*

Z_t : *As defined in Fig 1*

hf : *Half standard height of superstructure*

b) *Where the freeboard deck has sheer extending for less than 0.15L or has no sheer, by a line from the forecastle deck at side at 0.07L extended parallel to the base line to the forward perpendicular (as illustrated in Fig 2).*

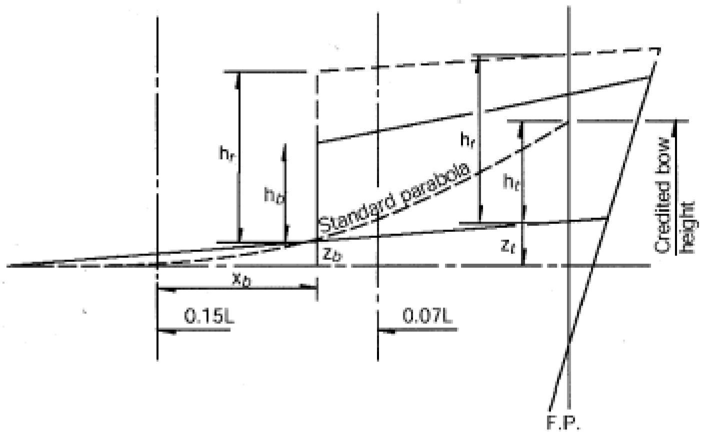


Figure 1 : Credited bow height where the freeboard deck has sheer extending from abaft 0.15L

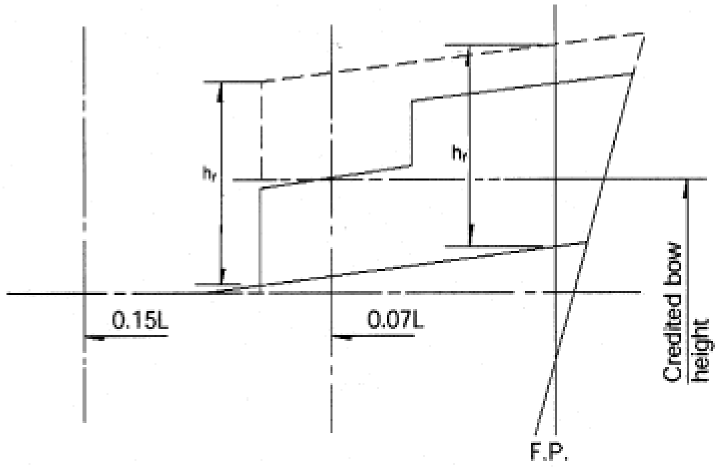


Figure 2 : Credited bow height where the freeboard deck has sheer extending for less than 0.15L

6. Shaft tunnels

6.1 General

6.1.1

Shaft tunnels are to be watertight.

See also Ch 11, Sec 2, [2].

7. Watertight ventilators and trunks

7.1 General

7.1.1

Ref. SOLAS Ch. II-1, Part B, Reg. 19.1

Watertight ventilators and trunks are to be carried at least up to the freeboard deck.

8. Fuel oil tanks

8.1 General

8.1.1

Ref. SOLAS Ch. II-2, Part B, Reg. 4.2

The arrangements for the storage, distribution and utilisation of the fuel oil are to be such as to ensure the safety of the ship and persons on board.

8.1.2

Ref. SOLAS Ch. II-2, Part B, Reg. 4.2

As far as practicable, fuel oil tanks are to be part of the ship's structure and are to be located outside machinery spaces of category A.

Where fuel oil 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, *they are 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 may not contain fuel oil having a flashpoint of less than 60°C.

8.1.3

Ref. SOLAS Ch. II-2, Part B, Reg. 4.2

Fuel oil tanks may not be located where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces.

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.

Fuel oil tanks in boiler spaces may not be located immediately above the boilers or in areas subjected to high temperatures, unless special arrangements are provided in agreement with the Society.

8.1.4

Where a compartment intended for goods or coal is situated in proximity of a heated liquid container, suitable thermal insulation is to be provided.

Chapter 2 – General arrangement design

Welcome JBP

Section 3 - ACCESS ARRANGEMENT

1. General

1.1 Means of access to cargo and other spaces

1.1.1

Ref. SOLAS Ch. II-1, Part A-1, Reg. 3.6 - 2.1 (according to Resolution MSC.151(78))

Each space is to be provided with means of access to enable, throughout the life of a ship, overall and close-up inspections and thickness measurements of the ship's structures. Such means of access are to comply with [1.3] and [2].

1.1.2

Ref. SOLAS Ch. II-1, Part A-1, Reg. 3.6-2.2 (according to Resolution MSC.151(78))

Where a permanent means of access may be susceptible to damage during normal cargo loading and unloading operations or where it is impracticable to fit permanent means of access, the Administration may allow, in lieu thereof, the provision of movable or portable means of access, as specified in [2], provided that the means of attaching, rigging, suspending or supporting the portable means of access forms a permanent part of the ship's structure. All portable equipment are to be capable of being readily erected or deployed by ship's personnel.

1.1.3

Ref. SOLAS Ch. II-1, Part A-1, Reg. 3.6-2.3 (according to Resolution MSC.151(78))

The construction and materials of all means of access and their attachment to the ship's structure are to be to the satisfaction of the Society.

1.2 Safe access to cargo holds, cargo tanks, ballast tanks and other spaces

1.2.1

Ref. SOLAS Ch. II-1, Part A-1, Reg. 3.6-3.1 (according to Resolution MSC.151(78) and IACS Draft UI SC [191])

Safe access to cargo holds, cofferdams, ballast tanks, cargo tanks and other spaces in the cargo area are to be direct from the open deck and such as to ensure their complete inspection. Safe access to double bottom spaces or to forward ballast tanks may be from a pump-room, deep cofferdam, pipe tunnel, cargo hold, double hull space or similar compartment not intended for the carriage of oil or hazardous cargoes.

Access to a double side skin space may be either from a topside tank or double bottom tank or from both.

1.2.2

Ref. SOLAS Ch. II-1, Part A-1, Reg. 3.6-3.2 (according to Resolution MSC.151(78))

Tanks, and subdivisions of tanks, having a length of 35 m or more, are to be fitted with at least two access hatchways and ladders, as far apart as practicable.

Tanks less than 35 m in length are to be served by at least one access hatchway and ladder.

When a tank is subdivided by one or more swash bulkheads or similar obstructions which do not allow ready means of access to the other parts of the tank, at least two hatchways and ladders are to be fitted.

1.2.3

Ref. SOLAS Ch. II-1, Part A-1, Reg. 3.6-3.3 (according to Resolution MSC.151(78))

Each cargo hold is to be provided with at least two means of access as far apart as practicable. In general, these accesses are to be arranged diagonally, for example one access near the forward bulkhead on the port side, the other one near the aft bulkhead on the starboard side.

1.3 General technical specifications

1.3.1

Ref. SOLAS Ch. II-1, Part A-1, Reg. 3.6-5.1 (according to Resolution MSC.151(78) and IACS Draft UI SC [191])

For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is to be not less than 600 mm x 600 mm, with a corner radii up to 100 mm maximum.

In such a case where as a consequence of structural analysis the stress is to be reduced around the opening, it is considered appropriate to take measures to increase the clear opening, e.g. 600 x 800 with 300 mm radii, in which a clear opening of 600 x 600 mm with corner radii up to 100mm maximum fits.

When access to a cargo hold is arranged through the cargo hatch, the top of the ladder is to be placed as close as possible to the hatch coaming. Access hatch coamings having a height greater than 900 mm are also to have steps on the outside in conjunction with the ladder.

1.3.2

Ref. SOLAS Ch. II-1, Part A-1, Reg. 3.6-5.2 (according to Resolution MSC.151(78) and IACS Draft UI SC [191]

For access through vertical openings, or manholes, in swash bulkheads, floors, girders and web frames providing passage through the length and breadth of the space, the minimum opening is to be not less than 600 mm x 800 mm with corner radii of 300 mm at a height of not more than 600 mm from the bottom shell plating unless gratings or other foot holds are provided.

Subject to verification of easy evacuation of injured person on a stretcher the vertical opening 850 mm x 620 mm with wider upper half than 600 mm , while the lower half may be less than 600 mm with the overall height not less than 850 mm is considered acceptable alternative to the opening of 600 mm x 800 mm with corner radii of 300 mm

2. Technical provisions for means of access

2.1 Definitions

Ref. IMO Technical Provisions, 2 (according to Resolution MSC.158(78))

2.1.1 Rung

Rung means the step of vertical ladder or step on the vertical surface.

2.1.2 Tread

Tread means the step of inclined ladder, or step for the vertical access opening.

2.1.3 Flight of a ladder

Flight of an inclined ladder means the actual stringer length of an inclined ladder.

For vertical ladders, it is the distance between the platforms.

2.1.4 Stringer

Stringer means:

1) the frame of a ladder; or
2) the stiffened horizontal plating structure fitted on side shell, transverse bulkheads and/or longitudinal bulkheads in the space. For the purpose of ballast tanks of less than 5 m width forming double side spaces, the horizontal plating structure is credited as a stringer and a longitudinal permanent means of access, if it provides a continuous passage of 600 mm or more in width past frames or stiffeners on the side shell or longitudinal bulkhead. Openings in stringer plating utilized as permanent means of access are to be arranged with guard rails or grid covers to provide safe passage on the stringer or safe access to each transverse web.

2.1.5 Vertical ladder

Vertical ladder means a ladder of which the inclined angle is 70º and over up to 90º. Vertical ladder is to be not skewed by more than 2º.

2.1.6 Overhead obstructions

Overhead obstructions mean the deck or stringer structure including stiffeners above the means of access.

2.1.7 Distance below deck head

Distance below deck head means the distance below the plating.

2.1.8 Cross deck

Cross deck means the transverse area of main deck which is located inboard and between hatch coamings.

2.2 Permanent means of access

2.2.1

Ref. IMO Technical Provisions, 3.1 & 3.2 (according to Resolution MSC.158(78))

Structural members, except those in double bottom spaces, are to be provided with a permanent means of access to the extent as specified in [2.7] to [2.13].

Permanent means of access are, as far as possible, to be integral to the structure of the ships , thus ensuring that they are robust and at the same time contributing to the overall strength of the structure, of the ship.

2.2.2

Ref. IMO Technical Provisions, 3.3 (according to Resolution MSC.158(78) and IACS Draft UI SC [191])

Elevated passageways forming sections of a permanent means of access, where fitted, are to have a minimum clear width of 600 mm, except for going around vertical webs where the minimum clear width may be reduced to 450 mm, and to have guard rails over the open side of their entire length. For stand alone passageways guard rails are to be fitted on both sides of these structures.

Sloping structure providing part of the access and that are sloped by 5 or more degrees from horizontal plane when a ship is in upright position at even-keel, is to be of a non-skid construction.

Guard rails are to be 1,000 mm in height and consist of a rail and intermediate bar 500 mm in height and of substantial construction. Stanchions are to be not more than 3 m apart.

2.2.3

Ref. IMO Technical Provisions, 3.4 (according to Resolution MSC.158(78))

Access to permanent means of access and vertical openings from the ship's bottom are to be provided by means of easily accessible passageways, ladders or treads. Treads are to be provided with lateral support for the foot. Where the rungs of ladders are fitted against a vertical surface, the distance from the centre of the rungs to the surface is to be at least 150 mm. Where vertical manholes are fitted higher than 600 mm above the walking level, access is to be facilitated by means of treads and hand grips with platform landings on both sides.

2.3 Construction of ladders

2.3.1 General

Ref. IMO Technical Provisions, 3.5 (according to Resolution MSC.158(78))

Permanent inclined ladders are to be inclined at an angle of less than 70º. There are to have no obstructions within 750 mm of the face of the inclined ladder, except that in way of an opening this clearance may be reduced to 600 mm. Resting platforms of adequate dimensions are normally to be provided at a maximum of 6 m vertical height. Ladders and handrails are to be constructed of steel or equivalent material of adequate strength and stiffness and securely attached to the tank structure by stays. The method of support and length of stay is to be such that vibration is reduced to a practical minimum. In cargo holds, ladders are to be designed and arranged so that cargo handling difficulties are not increased and the risk of damage from cargo handling gear is minimized.

2.3.2 Inclined ladders

Ref. IMO Technical Provisions, 3.6 (according to Resolution MSC.158(78))

The width of inclined ladders between stringers is to be not less than 400 mm. The treads are to be equally spaced at a distance apart, measured vertically, of between 200 mm and 300 mm. When steel is used, the treads are to be formed of two square bars of not less that 22 mm by 22 mm in section, fitted to form a horizontal step with the edges pointing upward. The treads are to be carried through the side stringers and attached thereto by double continuous welding. All inclined ladders are to be provided with handrails of substantial construction on both sides, fitted at a convenient distance above the treads.

2.3.3 Vertical or spiral ladders

Ref. IMO Technical Provisions, 3.7 (according to Resolution MSC.158(78))

For vertical ladders or spiral ladders, the width and construction are to be in accordance with international or national standards.

2.4 Access through openings

2.4.1 Access through horizontal openings, hatches or manholes

Ref. IMO Technical Provisions, 3.10 (according to Resolution MSC.158(78))

For access through horizontal openings, hatches or manholes, the minimum clear opening is to be not less than 600 mm x 600 mm. When access to a cargo hold is arranged through the cargo hatch, the top of the ladder is to be placed as close as possible to the hatch coaming.

Access hatch coamings having a height greater than 900 mm are also to have steps on the outside in conjunction with the ladder.

2.4.2 Access through vertical openings, or manholes

Ref. IMO Technical Provisions, 3.11 (according to Resolution MSC.158(78))

For access through vertical openings, or manholes, in swash bulkheads, floors, girders and web frames providing passage through the length and breadth of the space, the minimum opening is to be not less than 600 mm x 800 mm at a height of not more than 600 mm from the passage unless gratings or other foot holds are provided.

2.5 Access ladders to cargo holds and other spaces

2.5.1 General

Ref. IMO Technical Provisions, 3.13.1 & 3.13.2 (according to Resolution MSC.158(78))

Access ladders to cargo holds and other spaces are to be:

a) where the vertical distance between the upper surface of adjacent decks or between deck and the bottom of the cargo space is not more than 6 m, either a vertical ladder or an inclined ladder.

b) where the vertical distance between the upper surface of adjacent decks or between deck and the bottom of the cargo space is more than 6 m, an inclined ladder or series of inclined ladders at one end of the cargo hold, except the uppermost 2.5 m of a cargo space measured clear of overhead obstructions and the lowest 6 m may have vertical ladders, provided that the vertical extent of the inclined ladder or ladders connecting the vertical ladders is not less than 2.5 m.

2.5.2

Ref. IMO Technical Provisions, 3.13.2 (according to Resolution MSC.158(78))

The second means of access at the other end of the cargo hold may be formed of a series of staggered vertical ladders, which have to comprise one or more ladder linking platforms spaced not more than 6 m apart vertically and displaced to one side of the ladder. Adjacent sections of ladder are to be laterally offset from each other by at least the width of the ladder. The uppermost, entrance section, of the ladder directly exposed to a cargo hold is to be vertical for a distance of 2.5 m measured clear of overhead obstructions and connected to a ladder-linking platform.

2.5.3

Ref. IMO Technical Provisions, 3.13.3 (according to Resolution MSC.158(78))

A vertical ladder may be used as a means of access to topside tanks, where the vertical distance is 6 m or less between the deck and the longitudinal means of access in the tank or the stringer or the bottom of the space immediately below the entrance. The uppermost, entrance section from deck, of the vertical ladder of the tank is to be vertical for a distance of 2.5 m measured clear of the overhead obstructions and comprises a ladder linking platform unless landing on the longitudinal means of access, the stringer or the bottom within the vertical distance, it should be displaced to one side of a vertical ladder.

2.5.4

Ref. IMO Technical Provisions, 3.13.4 (according to Resolution MSC.158(78))

Unless allowed in [2.5.3], an inclined ladder or combination of ladders are to be used for access to a tank or a space where the vertical distance is greater than 6 m between the deck and a stringer immediately below the entrance, between stringers, or between the deck or a stringer and the bottom of the space immediately below the entrance.

2.5.5

Ref. IMO Technical Provisions, 3.13.5 (according to Resolution MSC.158(78))

In case of [2.5.4], the uppermost, entrance section from deck, of the ladder is to be vertical for a distance of 2.5 m clear of the overhead obstructions and connected to a landing platform and continued with an inclined ladder. The flights of inclined ladders are to be not more than 9 m in actual length and the vertical height is normally to be not more than 6 m. The lowermost section of the ladders may be vertical for a vertical distance of not less than 2.5 m.

2.5.6

Ref. IMO Technical Provisions, 3.13.6 (according to Resolution MSC.158(78))

In double side skin spaces of less than 2.5 m width, the access to the space may be by means of vertical ladders that comprises one or more ladder linking platforms spaced not more than 6 m apart vertically and displace to one side of the ladder.

Adjacent sections of ladder are to be laterally offset from each other by at least the width of the ladder.

2.5.7

Ref. IMO Technical Provisions, 3.13.7 (according to Resolution MSC.158(78))

A spiral ladder is considered acceptable as an alternative for inclined ladders. In this regard, the uppermost 2.5 m can continue to be comprised of the spiral ladder and need not change over to vertical ladders.

2.6 Access ladders to tanks

2.6.1

Ref. IMO Technical Provisions, 3.14 (according to Resolution MSC.158(78))

The uppermost, entrance section from deck, of the vertical ladder providing access to a tank should be vertical for a distance of 2.5 m measured clear of the overhead obstructions and comprises a ladder linking platform. It should be displaced to one side of a vertical ladder. The vertical ladder can be between 1.6 m and 3 m below deck structure if it lands on a longitudinal or athwartship permanent means of access fitted within that range.

2.7 Access to underdeck structure of cargo holds

2.7.1

Ref. IMO Technical Provisions, Tab 2, 1.1 (according to Resolution MSC.158(78))

Permanent means of access shall be fitted to provide access to the overhead structure at both sides of the cross deck and in the vicinity of the centerline.

Each means of access is to be accessible from the cargo hold access or directly from the main deck and installed at a minimum of 1.6 m to a maximum of 3 m below the deck.

2.7.2

Ref. IMO Technical Provisions, Tab 2, 1.2 (according to Resolution MSC.158(78))

An athwartship permanent means of access fitted on the transverse bulkhead at a minimum 1.6 m to a maximum 3 m below the cross-deck head is accepted as equivalent to [2.7.1].

2.7.3

Ref. IMO Technical Provisions, Tab 2, 1.3 (according to Resolution MSC.158(78))

Access to the permanent means of access to overhead structure of the cross deck may also be via the upper stool.

2.7.4

Ref. IMO Technical Provisions, Tab 2, 1.4 (according to Resolution MSC.158(78) and IACS Draft UI SC [191])

Ships having transverse bulkheads with full upper stools, i.e. stools with a full extension between top side tanks and between hatch end beams, with access from the main deck which allows monitoring of all framing and plates from inside, do not require permanent means of access of the cross deck.

2.7.5

Ref. IMO Technical Provisions, Tab 2, 1.5 (according to Resolution MSC.158(78))

Alternatively, movable means of access may be utilized for access to the overhead structure of cross deck if its vertical distance is 17 m or less above the tank top.

2.8 Access to double side skin tanks in double side bulk carriers

2.8.1

Ref. IMO Technical Provisions, Tab 2, 2.8 & Tab 1, 2.1 (according to Resolution MSC.158(78))

For double side spaces above the upper knuckle point of the bilge hopper sections, permanent means of access are to be provided in accordance with the following requirements:

a) where the vertical distance between horizontal uppermost stringer and deck head is 6 m or more, one continuous longitudinal permanent means of access shall be provided for the full length of the tank with a means to allow passing through transverse webs installed at a minimum of 1.6 m to a maximum of 3 m below the deck head with a vertical access ladder at each end of the tank;

b) continuous longitudinal permanent means of access, which are integrated in the structure, at a vertical distance not exceeding 6 m apart; and
c) plated stringers shall, as far as possible, be in alignment with horizontal girders of transverse bulkheads.

2.9 Access to vertical structures of cargo holds in single side bulk carriers

2.9.1

Ref. IMO Technical Provisions, Tab 2, 1.6 (according to Resolution MSC.158(78))

Permanent means of vertical access shall be provided in all cargo holds and built into the structure to allow for an inspection of a minimum of 25 % of the total number of hold frames port and starboard equally distributed throughout the hold including at each end in way of transverse bulkheads. But in no circumstance shall this arrangement be less than 3 permanent means of vertical access fitted to each side (fore and aft ends of hold and mid-span).

Permanent means of vertical access fitted between two adjacent hold frames is counted for an access for the inspection of both hold frames. A means of portable access may be used to gain access over the sloping plating of lower hopper ballast tanks.

2.9.2

Ref. IMO Technical Provisions, Tab 2, 1.7 (according to Resolution MSC.158(78))

In addition, portable or movable means of access are to be utilized for access to the remaining hold frames up to their upper brackets and transverse bulkheads.

2.9.3

Ref. IMO Technical Provisions, Tab 2, 1.8 (according to Resolution MSC.158(78))

Portable or movable means of access may be utilized for access to hold frames up to their upper bracket in place of the permanent means required in [2.8.1]. These means of access are to be carried on board the ship and readily available for use.

2.9.4

Ref. IMO Technical Provisions, Tab 2, 1.9 (according to Resolution MSC.158(78))

The width of vertical ladders for access to hold frames is to be at least 300 mm, measured between stringers.

2.9.5

Ref. IMO Technical Provisions, Tab 2, 1.10 (according to Resolution MSC.158(78))

A single vertical ladder over 6 m in length is acceptable for the inspection of the hold side frames in a single skin construction.

2.10 Access to vertical structures of cargo holds in double side bulk carriers

2.10.1

Ref. IMO Technical Provisions, Tab 2, 1.11 (according to Resolution MSC.158(78))

For double side skin construction no vertical ladders for the inspection of the cargo hold surfaces are required. Inspection of this structure should be provided from within the double hull space.

2.11 Access to top side ballast tanks in single side bulk carriers

2.11.1

Ref. IMO Technical Provisions, Tab 2, 2.1 (according to Resolution MSC.158(78))

For each topside tank of which the height is 6 m and over, one longitudinal continuous permanent means of access is to be provided along the side shell webs and installed at a minimum of 1.6 m to a maximum of 3 m below deck with a vertical access ladder in the vicinity of each access to that tank.

2.11.2

Ref. IMO Technical Provisions, Tab 2, 2.2 (according to Resolution MSC.158(78))

If no access holes are provided through the transverse webs within 600 mm of the tank base and the web frame rings have a web height greater than 1 m in way of side shell and sloping plating, then step rungs/grab rails are to be provided to allow safe access over each transverse web frame ring.

2.11.3

Ref. IMO Technical Provisions, Tab 2, 2.3 (according to Resolution MSC.158(78))

Three permanent means of access, fitted at the end bay and middle bay of each tank, are to be provided spanning from tank base up to the intersection of the sloping plate with the hatch side girder. The existing longitudinal structure, if fitted on the sloping plate in the space may be used as part of this means of access.

2.11.4

Ref. IMO Technical Provisions, Tab 2, 2.4 (according to Resolution MSC.158(78))

For topside tanks of which the height is less than 6 m, alternative or a portable means may be utilized in lieu of the permanent means of access.

2.12 Access to bilge hopper ballast tanks

2.12.1

Ref. IMO Technical Provisions, Tab 2, 2.5 (according to Resolution MSC.158(78) and IACS Draft UI SC [191])

For each bilge hopper tank of which the height is 6 m and over, one longitudinal continuous permanent means of access is to be provided along the side shell webs and installed at a minimum of 1.2 m below the top of the clear opening of the web ring with a vertical access ladder in the vicinity of each access to the tank.

An access ladder between the longitudinal continuous permanent means of access and the bottom of the space is to be provided at each end of the tank .

Alternatively, the longitudinal continuous permanent means of access can be located through the upper web plating above the clear opening of the web ring, at a minimum of 1.6 m below the deck head, when this arrangement facilitates more suitable inspection of identified structurally critical areas. An enlarged longitudinal frame, of at least 600 mm clear width can be used for the purpose of the walkway.

For double side skin bulk carriers the longitudinal continuous permanent means of access may be installed within 6 m from the knuckle point of the bilge, if used in combination with alternative methods to gain access to the knuckle point.

2.12.2

Ref. IMO Technical Provisions, Tab 2, 2.6 (according to to Resolution MSC.158(78))

If no access holes are provided through the transverse ring webs within 600 mm of the tank base and the web frame rings have a web height greater than 1 m in way of side shell and sloping plating, then step rungs/grab rails are to be provided to allow safe access over each transverse web frame ring.

2.12.3

Ref. IMO Technical Provisions, Tab 2, 2.7 (according to Resolution MSC.158(78))

For bilge hopper tanks of which the height is less than 6 m, alternative or a portable means may be utilized in lieu of the permanent means of access. Such means of access are to be demonstrated that they can be deployed and made readily available in the areas where needed.

2.13 Access to fore peak tanks

2.13.1

Ref. IMO Technical Provisions, Tab 2, 2.9 (according to Resolution MSC.158(78))

For fore peak tanks with a depth of 6 m or more at the centre line of the collision bulkhead, a suitable means of access is to be provided for access to critical areas such as the underdeck structure, stringers, collision bulkhead and side shell structure.

2.13.2

Ref. IMO Technical Provisions, Tab 2, 2.9.1 (according to Resolution MSC.158(78))

Stringers of less than 6 m in vertical distance from the deck head or a stringer immediately above are considered to provide suitable access in combination with portable means of access.

2.13.3

Ref. IMO Technical Provisions, Tab 2, 2.9.2 (according to Resolution MSC.158(78))

In case the vertical distance between the deck head and stringers, stringers or the lowest stringer and the tank bottom is 6 m or more, alternative means of access are to be provided.

3. Shaft tunnels

3.1 General

3.1.1

Tunnels are to be large enough to ensure easy access to shafting.

3.1.2

Access to the tunnel is to be provided by a watertight door fitted on the aft bulkhead of the engine room in compliance with Ch 2, Sec 1, [6], and an escape trunk which can also act as watertight ventilator is to be fitted up to the subdivision deck, for tunnels greater than 7 m in length.

4. Access to steering gear compartment

4.1

4.1.1

The steering gear compartment is to be readily accessible and, as far as practicable, separated from machinery spaces.

4.1.2

Suitable arrangements to ensure working access to steering gear machinery and controls are to be provided. These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

Welcome JBP

Section 1 - MATERIAL

1. General

1.1 Standard of material

1.1.1

The requirements in this Section are intended for vessels of welded construction using steels having characteristics complying with the Society Rules for Materials.

1.1.2

Materials with different characteristics may be accepted, provided their specification (manufacture, chemical composition, mechanical properties, welding, etc.) is submitted to the Society for approval.

1.2 Testing of materials

1.2.1

Materials are to be tested in compliance with the applicable requirements of Society Rules for Materials.

1.3 Manufacturing processes

1.3.1

The requirements of this Section presume that welding and other cold or hot manufacturing processes are carried out in compliance with current sound working practice and the applicable requirements of Society Rules for Materials. In particular:

- parent material and welding processes are to be within the limits stated for the specified type of material for which they are intended
- specific preheating may be required before welding
- welding or other cold or hot manufacturing processes may need to be followed by an adequate heat treatment.

2. Hull structural steel

2.1 General

2.1.1

Tab 1 gives the mechanical characteristics of steels currently used in the construction of ships.

Table 1: Mechanical properties of hull steels

Steel grades	Minimum yield stress R_{eH} , in N/mm^2	Ultimate minimum tensile strength R_m , in N/mm^2
A-B-D-E - t ≤ 100mm	235	400 - 520
AH32-DH32-EH32 - t ≤ 100mm FH32 - t ≤ 50mm	315	440 - 590
AH36-DH36-EH36 - t ≤ 100mm FH36 - t ≤ 50mm	355	490 - 620
AH40-DH40-EH40 FH40 - t ≤ 50mm	390	510 - 650

2.1.2

Where higher strength steels are to be used for hull construction, the drawings showing the scope and locations of the used place together with the type and scantlings are to be submitted for the approval of the Society. For the structures where higher strength steels are used, limitation of permissible stresses due to buckling and fatigue strength criteria may be required.

2.1.3

Higher strength steels other than those indicated in Tab 1 are considered by the Society on a case by case basis.

2.1.4

When steels with a minimum guaranteed yield stress R_{eH} other than 235 N/mm^2 are used on a ship, hull scantlings are to be determined by taking into account the material factor k defined in [2.2].

2.1.5

It is advised to keep on board a plan indicating the steel types and grades adopted for the hull structures. Where steels other than those indicated in Tab 1 are used, their mechanical and chemical properties, as well as any workmanship requirements or recommendations, are to be available on board together with the above plan

2.2 Material factor k

2.2.1

Unless otherwise specified, the material factor k of normal and higher strength steel for scantling purposes is to be taken as defined in Tab 2, as a function of the minimum yield stress R_{eH}.

For intermediate values of R_{eH}, k may be obtained by linear interpolation.

Steels with a yield stress lower than 235 N/mm^2 or greater than 390 N/mm^2 are considered by the Society on a case by case basis

Table 2: Material factor k

Minimum yield stress R_{eH} , in N/mm^2	k
235	1.0
315	0.78
355	0.72
390	0.68

2.3 Grades of steel

2.3.1

Steel materials in the various strength members are not to be of lower grade than those corresponding to classes I, II and III, as given in Tab 3for the material classes given in Tab 4.

For strength members not mentioned in Tab 3, grade A/AH may generally be used.

2.3.2

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

2.3.3

Bedplates of seats for propulsion and auxiliary engines inserted in the inner bottom are to be of class I. In other cases, the steel may generally be of grade A. Different grades may be required by the Society on a case by case basis.

2.3.4

Plating at corners of large hatch openings on decks located below the strength deck, in the case of hatches of holds for refrigerated cargoes, and insert plates at corners of large openings on side shell plating are generally to be of class III.

2.3.5

The steel grade is to correspond to the as-built gross thickness when this is greater than the gross thickness obtained from the net thickness required by the Rules.

Table 3: Material grade requirements for classes I, II and III

Class	I		II		III	
Thickness (mm)	NSS	HSS	NSS	HSS	NSS	HSS
$t \le 15$	A	AH	A	AH	A	AH
$15 < t \le 20$	A	AH	A	AH	B	AH
$20 < t \le 25$	A	AH	B	AH	D	DH
$25 < t \le 30$	A	AH	D	DH	D	DH
$30 < t \le 35$	B	AH	D	DH	E	EH
$35 < t \le 40$	B	AH	D	DH	E	EH
$40 < t \le 50$	D	DH	E	EH	E	EH
Note ; NSS : Normal strength steel, HSS : Higher strength steel						

Table 4: Application of material classes and grades

<table>
<tr><th rowspan="2">Structural member category</th><th colspan="2">Material class</th></tr>
<tr><th>Within 0.4L amidship</th><th>Outside 0.4L amidship</th></tr>
<tr><td colspan="3">A. SECONDARY</td></tr>
<tr><td>A1. Longitudinal bulkhead strakes, other than that belonging to the Primary category</td><td rowspan="3">I</td><td rowspan="3">A/AH</td></tr>
<tr><td>A2. Deck Plating exposed to weather, other than that belonging to the Primary or Special category</td></tr>
<tr><td>A3. Side plating</td></tr>
<tr><td colspan="3">B. PRIMARY</td></tr>
<tr><td>B1. Bottom plating, including keel plate</td><td rowspan="5">II</td><td rowspan="5">A/AH</td></tr>
<tr><td>B2. Strength deck plating, excluding that belonging to the Special category</td></tr>
<tr><td>B3. Continuous longitudinal members above strength deck, excluding hatch coamings</td></tr>
<tr><td>B4. Uppermost strake in longitudinal bulkhead</td></tr>
<tr><td>B5. Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank</td></tr>
<tr><td colspan="3">C. SPECIAL</td></tr>
<tr><td>C1. Sheer strake at strength deck [1], [8]</td><td rowspan="7">III</td><td rowspan="7">II
(I outside 0.6L amidships)</td></tr>
<tr><td>C2. Stringer plate in strength deck [1], [8]</td></tr>
<tr><td>C3. Deck strake at longitudinal bulkhead [2], [8]</td></tr>
<tr><td>C5. Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch openings configuration [4]</td></tr>
<tr><td>C6. Bilge strake [5], [6], [8]</td></tr>
<tr><td>C7. Longitudinal hatch coamings of length greater than 0.15 L. [7]</td></tr>
<tr><td>C8. End brackets and deck house transition of longitudinal cargo hatch coamings [7]</td></tr>
<tr><td colspan="3">Notes:
[1] Not to be less than grade E/EH within 0.4L amidships in ships with length exceeding 250 meters.
[2] Excluding deck plating in way of inner-skin bulkhead of double hull ships.
[3] Not to be less than class III within the length of the cargo region.
[4] Not to be less than class III within 0.6L amidships and class II within the remaining length of the cargo region.
[5] May be of class II in ships with a double bottom over the full breadth and with length less than 150 meters.
[6] Not to be less than grade D/DH within 0.4L amidships in ships with length exceeding 250 meters.
[7] Not to be less than grade D/DH.
[8] Single strakes required to be of class III or of grade E/EH and within 0.4L amidships are to have breadths not less than 800+5L (mm), need not be greater than 1800 mm, unless limited by the geometry of the ship's design.</td></tr>
</table>

2.3.6

Steel grades of plates or sections of gross thickness greater than the limiting thicknesses in Tab 1 are considered by the Society on a case by case basis.

2.3.7

In specific cases, such as [2.3.6], with regard to stress distribution along the hull girder, the classes required within 0,4L amidships may be extended beyond that zone, on a case by case basis.

2.3.8
The material classes required for the strength deck plating, the sheerstrake and the upper strake of longitudinal bulkheads within 0,4L amidships are to be maintained for an adequate length across the poop front and at the ends of the bridge, where fitted.

2.3.9
Rolled products used for welded attachments on hull plating, such as gutter bars and bilge keels, are to be of the same grade as that used for the hull plating in way.

Where it is necessary to weld attachments to the sheerstrake or stringer plate, attention is to be given to the appropriate choice of material and design, the workmanship and welding and the absence of prejudicial undercuts and notches, with particular regard to any free edges of the material.

2.3.10
In the case of grade D plates with a nominal thickness equal to or greater than 36 mm, or in the case of grade DH plates with a nominal thickness equal to or greater than 31 mm, the Society may, on a case by case basis, require the impact test to be carried out on each original "rolled unit", where the above plates:

- either are to be placed in positions where high local stresses may occur, for instance at breaks of poop and bridge, or in way of large openings on the strength deck and on the bottom, including relevant doublings, or
- are to be subjected to considerable cold working.

2.3.11
In the case of full penetration welded joints located in positions where high local stresses may occur perpendicular to the continuous plating, the Society may, on a case by case basis, require the use of rolled products having adequate ductility properties in the through thickness direction, such as to prevent the risk of lamellar tearing (Z type steel).

2.3.12
In highly stressed areas, the Society may require that plates of gross thickness greater than 20 mm are of grade D/DH or E/EH.

2.3.13
For certain uses, grade B steel with controlled toughness at 0°C may be required for plates of gross thickness less than 30 mm.

2.4 Structures exposed to low air temperature

2.4.1
The application of steels for ships designed to operate in area with low air temperatures is to comply with [2.4.2] to [2.4.6].

2.4.2

For ships intended to operate in areas with low air temperatures (below and including - 20°C), e.g. regular service during winter seasons to Arctic or Antarctic waters, the materials in exposed structures are to be selected based on the design temperature t_D, to be taken as defined in [2.4.3].

2.4.3

The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation, where:

Mean: Statistical mean over observation period (at least 20 years).

Average: Average during one day and night.

Lowest: Lowest during year.

Fig 1 illustrates the temperature definition for Arctic waters.

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

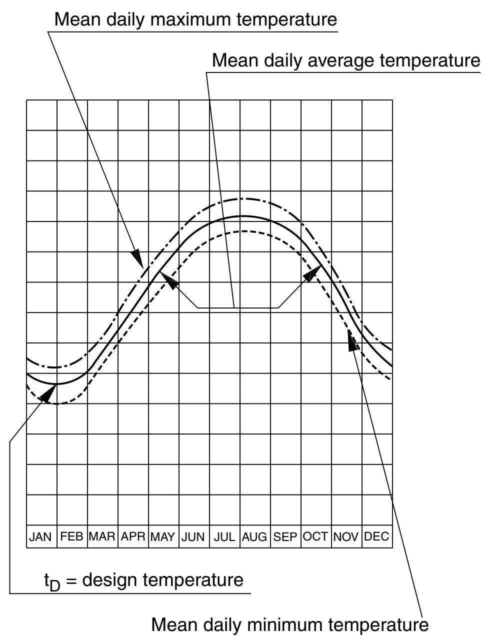


Figure 1: Commonly used definitions of temperatures

2.4.4

Materials in the various strength members above the lowest ballast water line (BWL) exposed to air are not to be of lower grades than those corresponding to classes I, II and III as given in Tab 5, depending on the categories of structural members(SECONDARY, PRIMARY and SPECIAL).

For non-exposed structures and structures below the lowest ballast water line, see [2.3]

2.4.5

The material grade requirements for hull members of each class depending on thickness and design temperature are defined in Tab 6, 7 and 8. For design temperatures $t_D < -55°C$, materials are to be specially considered by the Society.

2.4.6

Single strakes required to be of class III or of grade E /EH and FH are to have breadths not less than the values given by the following formula, but need not to be greater than 1800 mm:

$$b = 5L + 800 \text{ (mm)}$$

Table 5: Application of material classes and grades - Structures exposed at low temperature

Structural member category	Material class	
	Within 0.4L amidship	Outside 0.4L amidship
SECONDARY		
A1. Deck plating exposed to weather, in general A2. Side plating above BWL A3. Transverse bulkheads above BWL	I	I
PRIMARY		
B1. Strength deck plating [1] B2. Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings B3. Longitudinal bulkhead above BWL B4. Top wing tank bulkhead above BWL	II	I
SPECIAL		
C1. Sheer strake at strength deck [2] C2. Stringer plate in strength deck [2] C3. Deck strake at longitudinal bulkhead [3] C4. Continuous longitudinal hatch coamings [4]	III	II
Note; [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 meters. [3] In ships with a breadth exceeding 70 meters at least three deck strakes to be class III [4] Not to be less than grade D/DH.		

Table 6: Material grade requirements for class I at low temperature

Thickness (mm)	-20 / -25 °C		-26 / -35 °C		-36 / -45 °C		-45 / -55 °C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	A	AH	B	AH	D	DH	D	DH
10 < t ≤ 15	B	AH	D	DH	D	DH	D	DH
15 < t ≤ 20	B	AH	D	DH	D	DH	E	EH
20 < t ≤ 25	D	DH	D	DH	D	DH	E	EH
25 < t ≤ 30	D	DH	D	DH	E	EH	E	EH
30 < t ≤ 35	D	DH	D	DH	E	EH	E	EH
35 < t ≤ 45	D	DH	E	EH	E	EH	-	FH
45 < t ≤ 50	E	EH	E	EH	-	FH	-	FH
Note: "NSS" and "HSS" mean, respectively "Normal Strength Steel" and "Higher Strength Steel"								

Table 7: Material grade requirements for class II at low temperature

Thickness (mm)	-20 / -25 °C		-26 / -35 °C		-36 / -45 °C		-45 / -55 °C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	B	AH	D	DH	D	DH	E	EH
10 < t ≤ 20	D	DH	D	DH	E	EH	E	EH

20 < t ≤ 30	D	DH	E	EH	E	EH	-	FH
30 < t ≤ 40	E	EH	E	EH	-	FH	-	FH
40 < t ≤ 45	E	EH	-	FH	-	FH	-	-
45 < t ≤ 50	E	EH	-	FH	-	FH	-	-
Note: "NSS" and "HSS" mean, respectively "Normal Strength Steel" and "Higher Strength Steel"								

Table 8: Material grade requirements for class III at low temperature

Thickness (mm)	-20 / -25 °C		-26 / -35 °C		-36 / -45 °C		-45 / -55 °C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	D	DH	D	DH	E	EH	E	EH
10 < t ≤ 20	D	DH	E	EH	E	EH	-	FH
20 < t ≤ 25	E	EH	E	EH	-	FH	-	FH
25 < t ≤ 30	E	EH	E	EH	-	FH	-	FH
30 < t ≤ 40	E	EH	-	FH	-	FH	-	-
40 < t ≤ 45	E	EH	-	FH	-	FH	-	-
45 < t ≤ 50	-	FH	-	FH	-	-	-	-
Note: "NSS" and "HSS" mean, respectively "Normal Strength Steel" and "Higher Strength Steel"								

3. Steels for forging and casting

3.1 General

3.1.1

Mechanical and chemical properties of steels for forging and casting to be used for structural members are to comply with the applicable requirements of the Society Rules for Materials.

3.1.2

Steels of structural members intended to be welded are to have mechanical and chemical properties deemed appropriate for this purpose by the Society on a case by case basis.

3.1.3

The steels used are to be tested in accordance with the applicable requirements of the Society Rules for Materials.

3.2 Steels for forging

3.2.1

For the purpose of testing, which is to be carried out in accordance with the applicable requirements of the Society Rules for Materials, the above steels for forging are assigned to class 1.

3.2.2

Rolled bars may be accepted in lieu of forged products, after consideration by the Society on a case by case basis.

In such case, compliance with the applicable requirements of the Society Rules for Materials, relevant to the quality and testing of rolled parts accepted in lieu of forged parts, may be required.

3.3 Steels for casting

3.3.1

Cast parts intended for stems, sternframes, rudders, parts of steering gear and deck machinery in general may be made of C and C-Mn weldable steels of quality 1, having tensile strength R_m = 400 N/mm^2 or 440 N/mm^2, in accordance with the applicable requirements of the Society Rules for Materials.

Items which may be subjected to high stresses may be required to be of quality 2 steels of the above types.

3.3.2

For the purpose of testing, which is to be carried out in accordance with the applicable requirements of the Society Rules for Materials, the above steels for casting are assigned to class 1 irrespective of their quality.

3.3.3

The welding of cast parts to main plating contributing to hull strength members is considered by the Society on a case by case basis.

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

3.3.4

Heavily stressed cast parts of steering gear, particularly those intended to form a welded assembly and tillers or rotors mounted without key, are to be subjected to non-destructive examination to check their internal structure.

4. Aluminium alloy structures

4.1 General

4.1.1

The characteristics of aluminium alloys are to comply with the requirements of the Society Rules for Materials.

Series 5000 aluminium-magnesium alloys or series 6000 aluminium-magnesium-silicon alloys are generally to be used.

4.1.2

In the case of structures subjected to low service temperatures or intended for other specific applications, the alloys to be employed are defined in each case by the Society, which states the acceptability requirements and conditions.

4.1.3

Unless otherwise specified, the Young’s modulus for aluminium alloys is equal to 70000 N/mm^2 and the Poisson’s ratio equal to 0,33.

4.2 Extruded plating

4.2.1

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

4.2.2
In general, the application is limited to decks, bulkheads, superstructures and deckhouses. Other uses may be permitted by the Society on a case by case basis.

4.2.3
Extruded plating is preferably to be oriented so that the stiffeners are parallel to the direction of main stresses.

4.2.4
Connections between extruded plating and primary members are to be given special attention.

4.3 Influence of welding on mechanical characteristics

4.3.1
Welding heat input lowers locally the mechanical strength of aluminium alloys hardened by work hardening (series 5000 other than condition 0 or H111) or by heat treatment (series 6000).

4.3.2
Consequently, where necessary, a drop in the mechanical characteristics of welded structures with respect to those of the parent material is to be considered in the heat-affected zone.

The heat-affected zone may be taken to extend 25 mm on each side of the weld axis.

4.3.3
Aluminium alloys of series 5000 in 0 condition (annealed) or in H111 condition (annealed flattened) are not subject to a drop in mechanical strength in the welded areas.

4.3.4
Aluminium alloys of series 5000 other than condition 0 or H111 are subject to a drop in mechanical strength in the welded areas.

The mechanical characteristics to consider are normally those of condition 0 or H111.

Higher mechanical characteristics may be taken into account, provided they are duly justified.

4.3.5
Aluminium alloys of series 6000 are subject to a drop in mechanical strength in the vicinity of the welded areas.

The mechanical characteristics to be considered are normally indicated by the supplier.

4.4 Material factor k

4.4.1
The material factor k for aluminium alloys is to be obtained from the following formula:

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

where:

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

$R'_{p0,2} = \eta_1 R_{p0,2}$

$R'_m = \eta_2 R_m$

$R_{p0,2}$: Minimum guaranteed yield stress, in N/mm^2, of the parent metal in delivery condition

R_m : Minimum guaranteed tensile stress, in N/mm^2, of the parent metal in delivery condition

η_1 and η_2 are given in Tab 9.

4.4.2

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

Table 9: Aluminium alloys for welded construction

Aluminium alloy	η_1	η_2
Alloys without work-hardening treatment (series 5000 in annealed condition 0 or annealed flattened condition H111)	1	1
Alloys hardened by work hardening (series 5000 other than condition 0 or H111)	$R'_{p0,2} / R_{p0,2}$	R'_m / R_m
Alloys hardened by heat treatment (series 6000) **(1)**	$R'_{p0,2} / R_{p0,2}$	0,6
(1) When no information is available, coefficient η_1 is to be taken equal to the metallurgical efficiency coefficient β defined in Tab 10. $R'_{p0,2}$: Minimum guaranteed yield stress, in N/mm^2, of material in welded condition R'_m : Minimum guaranteed tensile stress, in N/mm^2, of material in welded condition		

Table 10: Aluminium alloys - Metallurgical efficiency coefficient β

Aluminium alloy	Temper condition	Gross thickness, in mm	β
6005 A (Open sections)	T5 or T6	$t \leq 6$	0,45
		$t > 6$	0,40
6005 A (Closed sections)	T5 or T6	All	0,50
6061 (Sections)	T6	All	0,53
6082 (Sections)	T6	All	0,45

4.4.3

For welded constructions in hardened aluminium alloys (series 5000 other than condition 0 or H111 and series 6000), greater characteristics than those in welded condition may be considered, provided that welded connections are located in areas where stress levels are acceptable for the alloy considered in annealed or welded condition.

4.5 Other materials and products

4.6 General

4.6.1

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

4.6.2

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

4.6.3

Materials used in welding processes are to comply with the applicable requirements of the Society Rules for Materials.

4.7 Iron cast parts

4.7.1

As a rule, the use of grey iron, malleable iron or spheroidal graphite iron cast parts with combined ferritic/perlitic structure is allowed only to manufacture low stressed elements of secondary importance.

4.7.2

Ordinary iron cast parts may not be used for windows or sidescuttles; the use of high grade iron cast parts of a suitable type will be considered by the Society on a case by case basis.

Chapter 3 – Structural design principles

Welcome JBP

Section 2 – NET SCANTLING APPROACH

Symbols

t_{as_built} : *As-built Thickness*: the actual thickness, in mm, provided at the newbuilding stage, including $t_{voluntary\_addition}$, if any.

t_C : *Corrosion Addition Thickness*: as defined in Ch 3 Sec 3, in mm.

$t_{gross\_offered}$: *Gross Thickness Offered*: the actual gross (full) thickness, in mm, provided at the newbuilding stage, excluding $t_{voluntary\_addition}$, the owner's extra margin for corrosion wastage, if any.

$t_{gross\_required}$: *Gross Thickness Required*: the gross (full) thickness, in mm, obtained by adding t_C to the Net Thickness Required.

$t_{net\_offered}$: *Net Thickness Offered*: the net thickness, in mm, obtained by subtracting t_C from the Gross Thickness Offered

$t_{net\_required}$: *Net Thickness Required*: the net thickness, in mm, as required by the Rules that satisfy all the structural strength requirements.

$t_{voluntary\_addition}$: *Thickness for Voluntary Addition*: the thickness, in mm, voluntarily added as the owner's extra margin for corrosion wastage in addition to t_C.

1. General philosophy

1.1.1

Net Scantling Approach is to clearly specify the "net scantling" that is to be maintained right from the newbuilding stage throughout the ship's design life to satisfy the structural strength requirements. This approach clearly separates the net thickness from the thickness added for corrosion that is likely to occur during the ship-in-operation phase.

2. Application criteria

2.1 General

2.1.1

The scantlings obtained by applying the criteria specified in this Rule are net scantlings as specified in [3.1] to [3.3]; i.e. those which provide the strength characteristics required to sustain the loads, excluding any addition for corrosion and voluntarily added thickness such as the owner's extra margin, if any. The following gross offered scantlings are exceptions; i.e. they already include additions for corrosion but without voluntarily added values such as the owner's extra margin:

- scantlings obtained from the yielding checks of the hull girder in Ch 5, Sec 1,
- scantlings of rudder structures in Ch 10, Sec 1,
- scantlings of massive pieces made of steel forgings, steel castings.

2.1.2

The required strength characteristics are:

- thickness, for plating including that which constitutes primary supporting members
- section modulus, shear area, moments of inertia and local thickness for ordinary stiffeners and, as the case may be, primary supporting members
- section modulus, moments of inertia and first moment for the hull girder.

2.1.3

The ship is to be built at least with the gross scantlings obtained by adding the corrosion additions, specified in Ch 3, Sec 3, to the net scantlings. The voluntarily added thicknesses such as the owner's extra margin are to be added as extra.

3. Net scantling approach

3.1 Net scantling definition

3.1.1 Offered thickness

The gross offered thickness, $t_{gross\_offered}$, is the gross thickness provided at the newbuilding stage, which is obtained by deducting the thickness for voluntary addition (owner's extra margin for corrosion wastage) from the as-built thickness as follows:

$$t_{gross\_offered} = t_{as\_built} - t_{voluntary\_addition}$$

3.1.2 Net thickness for plate

Net thickness offered, $t_{net\_ offered}$, is obtained by subtracting t_C from the gross offered thickness as follows:

$$t_{net\ offered} = t_{gross\_offered} - t_C = t_{as\_built} - t_{voluntary\_addition} - t_C$$

3.1.3 Net section modulus for stiffener

The net transverse section scantling is to be obtained by deducting t_C from the gross offered thickness of the elements which constitute the stiffener profile.

For bulb profiles, an equivalent angle profile, as specified in Ch 3, Sec 6, may be considered.

The net strength characteristics are to be calculated for the net transverse section.

In assessing the net strength characteristics of stiffeners reflecting the hull girder stress and stress due to local bending of the local structure such as double bottom structure, the section modulus of hull girder or rigidity of structure is obtained by deducting $0.5t_C$ from the gross offered thickness of the related elements.

3.2 Net scantling for direct strength analysis

3.2.1

The net thickness of plating which constitutes primary supporting members to be checked according to Ch 7 is to be obtained by deducting $0.5t_C$ from the gross offered thickness.

3.3 Net scantling for fatigue check

3.3.1

The net thickness of structural members to be checked for fatigue according to Ch 8 is to be obtained by deducting $0.5t_C$ from the gross offered thickness.

3.4 Available information on structural drawings

3.4.1

The structural drawings are to indicate the gross scantling of each structural element.

If voluntarily added thicknesses such as the owner's extra margin are included in the as-built thicknesses, they are to be clearly mentioned and identified on the drawings.

Welcome JBP

Section 3 – CORROSION ADDITIONS

Symbols

t_C : Corrosion addition, in mm, defined in Tab 1

1. Corrosion additions

1.1 General

1.1.1

The values of the corrosion additions specified in this section are to be applied in relation with the relevant protective coatings required by the present Rules.

For materials different from carbon steel, special consideration is to be given to the corrosion addition.

1.2 Corrosion addition determination

1.2.1 Corrosion additions for steel

The corrosion addition for each of the two sides of a structural member, t_{C1} or t_{C2}, is specified in Tab 1.

The total corrosion addition for both sides of the structural member is obtained by summing up t_{C1} and t_{C2}, and is not to be taken less than 2 mm in any case.

For an internal member within a given compartment, or for a plating forming the boundary between two compartments of the same type, the corrosion addition to be considered is twice the value specified in Tab 1 for one side exposure to that compartment.

When a structural member is affected by more than one value of corrosion addition (e.g. a plate in a dry bulk cargo hold extending above the lower zone), the scantling criteria are generally to be applied considering the severest value of corrosion addition applicable to the member.

1.2.2 Corrosion additions for aluminium alloys

For structural members made of aluminium alloys, the corrosion addition t_C is to be taken equal to 0.

Table 1 Corrosion addition on one side of structural members

<table>
<tr><th rowspan="2">Compartment Type</th><th rowspan="2" colspan="2">Structural member</th><th colspan="2">Corrosion addition, t_{C1} or t_{C2} in mm</th></tr>
<tr><th>Notation BC-A or BC-B</th><th>Notation BC-C or Bulk Carriers with L< 150m</th></tr>
<tr><td rowspan="4">Ballast water tank</td><td rowspan="2">Face plate of primary members</td><td>Within 3 m below the top of tank 3)</td><td colspan="2">2.0</td></tr>
<tr><td>Elsewhere</td><td colspan="2">1.5</td></tr>
<tr><td rowspan="2">Other members</td><td>Within 3 m below the top of tank 3)</td><td colspan="2">1.7</td></tr>
<tr><td>Elsewhere</td><td colspan="2">1.2</td></tr>
<tr><td rowspan="8">Dry bulk cargo hold 1)</td><td rowspan="3">Transverse bulkhead</td><td>Upper part 2)</td><td>2.0</td><td>1.0</td></tr>
<tr><td>Lower stool sloping plate</td><td>4.4</td><td>2.2</td></tr>
<tr><td>Other parts</td><td>2.2</td><td>1.2</td></tr>
<tr><td rowspan="3">Other members</td><td>Upper part 2) and webs and flanges of upper brackets</td><td>1.8</td><td>1.0</td></tr>
<tr><td>Webs and flanges of the lower end brackets</td><td>2.2</td><td>1.2</td></tr>
<tr><td>Other parts</td><td>2.0</td><td>1.2</td></tr>
<tr><td rowspan="2">Sloped plating of hopper tank, inner bottom plating</td><td>Continuous wooden ceiling</td><td>2.0</td><td>1.2</td></tr>
<tr><td>No continuous wooden ceiling</td><td>3.7</td><td>2.4</td></tr>
<tr><td rowspan="2">Exposed to atmosphere</td><td colspan="2">Horizontal member</td><td colspan="2">1.7</td></tr>
<tr><td colspan="2">Vertical member</td><td colspan="2">1.0</td></tr>
<tr><td colspan="3">Exposed to sea water 4)</td><td colspan="2">1.0</td></tr>
<tr><td rowspan="2">Fuel oil tanks</td><td colspan="2">Heated</td><td colspan="2">[1.2] [5)]</td></tr>
<tr><td colspan="2">Other</td><td colspan="2">0.5</td></tr>
<tr><td colspan="3">Compartments other than the above, i.e. void space, fresh water tank, machinery space, etc.</td><td colspan="2">0.5</td></tr>
</table>

Notes :

1) Dry bulk cargo hold includes holds, intended for the carriage of dry bulk cargoes, which may carry oil or water ballast.
2) Upper part of the cargo holds corresponds to an area above the connection between the top side and the inner hull. If there is no top side, the upper part corresponds to the upper one third of the cargo hold height.
3) This is not to be applied to tanks in the double bottom.
4) Duct keel is to be considered as water ballast tank.
5) [This is to be applied to the boundary plating between fuel oil tank and ballast water tank.]

Chapter 3 – Structural design principles

Welcome JBP

Section 4 – LIMIT STATES

1. General

1.1 General principle

1.1.1

The structural strength assessment indicated in Tab 1 are covered by the requirements of the present Rules.

Table 1: Structural strength assessment

		Yielding check	Buckling Check	Ultimate strength check	Fatigue check
Local Structures	Ordinary stiffeners	✓	✓	✓*1	✓*2
	Plating subjected to lateral pressure	✓	✓	✓*3	—
Primary supporting members		✓	✓	✓*	✓*2
Hull Girder		✓	✓*4	✓	—

Note: ✓ indicates that the structural assessment is to be carried out.

*1: The ultimate strength check of stiffeners is included in the buckling check of stiffeners.

*2: The fatigue check of stiffeners and primary supporting members is the fatigue check of connection details of these members.

*3: The ultimate strength check of plating is included in the yielding check formula of plating.

*4: The buckling check of stiffeners and plating taking part to hull girder strength is performed against hull girder bending stress.

1.1.2

Strength of hull structures in flooded condition is to be assessed.

1.2 Limit states

1.2.1 Serviceability limit state

Serviceability limit state, which concerns the normal use, includes:

- local damage which may reduce the working life of the structure or affect the efficiency or appearance of structural members;
- unacceptable deformations which affect the efficient use and appearance of structural members or the functioning of equipment.

1.2.2 Ultimate limit state

Ultimate limit state, which corresponds to the maximum load-carrying capacity, or in some cases, the maximum applicable strain or deformation, includes:

- attainment of the maximum resistance capacity of sections, members or connections by rupture or excessive deformations;
- instability of the whole structure or part of it.

1.2.3 Fatigue limit state

Fatigue limit state relate to the possibility of failure due to cyclic loads.

1.2.4 Progressive collapse limit state

Progressive collapse limit state, which may be stated such that the flooding in any one compartment does not progress to other compartments, includes:

- the maximum load-carrying capacity of bulkhead structure
- the maximum load-carrying capacity of double bottom structure
- the maximum load-carrying capacity of hull girder.

2. Strength criteria

2.1 Serviceability limit states

2.1.1 Ordinary stiffener

The stress of the ordinary stiffener corresponding to a load at 10^{-8} probability level is not to exceed the yielding stress of the material.

2.1.2 Plate

The stress of a plate constituting a primary supporting members corresponding to a load at 10^{-8} probability level is not to exceed the yielding stress of the material.

The stress of a plate constituting a primary supporting members corresponding to a load at 10^{-8} probability level is not to exceed the critical buckling stress of the panel.

2.1.3 Hull girder

The stress of the hull girder corresponding to a load at 10^{-8} probability level is not to exceed the yielding stress of the material.

2.2 Ultimate limit states

2.2.1 Ordinary stiffener

The ultimate strength of the ordinary stiffener is to withstand the load at 10^{-8} probability level.

2.2.2 Plating

The ultimate strength of the plating between ordinary stiffeners and primary supporting members is to withstand the load at 10^{-8} probability level .

2.2.3 Hull girder

The ultimate strength of the hull girder is to withstand the maximum vertical longitudinal bending moment at $10^{[-8.7]}$ probability level.

2.3 Fatigue limit state

2.3.1 Structural details

The fatigue life of representative structural details such as connections of ordinary stiffeners and primary supporting members, obtained from reference pressures at 10^{-4}, is to be not less than the ship's design life.

2.4 Progressive collapse limit state

2.4.1 Bulkhead structure

Bulkhead structure in cargo hold flooding is to be assessed in accordance with Ch 6, Sec 4.

2.4.2 Double bottom structure

Double bottom structure in cargo hold flooding is to be assessed in accordance with Ch 6, Sec 4.

2.4.3 Hull girder

Longitudinal strength of hull girder in cargo hold flooding is to be assessed in accordance Ch 5, Sec 2.

3. Strength Check against Impact Load

3.1 General

3.1.1

Structural response against the impact loads such as forward bottom slamming, bow flare slamming and grab falling depends on the loaded area, magnitude of loads and structural grillage.

3.1.2

The ultimate strength of structural members that constitute the grillage, i.e. platings between ordinary stiffeners and primary supporting members and ordinary stiffeners with attached plating, is to withstand the maximum impact loads acting on them.

3.1.3

The stress in primary supporting members surrounding a panel, due to impact load acting on this panel,is not to exceed the yielding stress of the material. .

Chapter 3 – Structural design principles

Welcome JBP

Section 5 – CORROSION PROTECTION

1. General

1.1 Structures to be protected

1.1.1

All seawater ballast tanks, cargo holds and ballast holds are to have a corrosion protective system fitted in accordance with [1.2], [1.3] and [1.4] respectively.

1.1.2

Corrosion protective coating is not required for internal surfaces of spaces intended for the carriage of fuel oil.

1.1.3

Narrow spaces are generally to be filled by an efficient protective product, particularly at the ends of the ship where inspections and maintenance are not easily practicable due to their inaccessibility.

1.2 Protection of seawater ballast tanks

1.2.1

All dedicated seawater ballast tanks are to have an efficient corrosion prevention system, such as hard protective coatings or equivalent, applied in accordance with the manufacturer's recommendation.

The coatings are to be of a light colour, i.e. a colour easily distinguishable from rust which facilitates inspection.

Where appropriate, sacrificial anodes, fitted in accordance with [2], may also be used.

1.3 Protection of cargo hold spaces

1.3.1 Coating

It is the responsibility of the shipbuilder and of the Owner to choose coatings suitable for the intended cargoes, in particular for the compatibility with the cargo.

1.3.2 Application

All internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of cargo holds (side and transverse bulkheads), excluding the inner bottom area and part of the hopper tank sloping plate, are to have an efficient protective coating, of an epoxy type or equivalent, applied in accordance with the manufacturer's recommendation.

The side and transverse bulkhead areas to be coated are specified in [1.3.3] and [1.3.4]

Where a ship is intended to carry wood chips exclusively, the area except the inside of upper deck which are expected to be effectively protected against corrosion of steel by the secretion of chips of wood may not have an efficient protective coating.

1.3.3 Side areas to be coated

The areas to be coated are the internal surfaces of:

- the inner side plating
- the internal surfaces of the topside tank sloping plates and the hopper tank sloping plates for a distance of 300 mm below their upper ends.

These areas are shown in Fig 1.

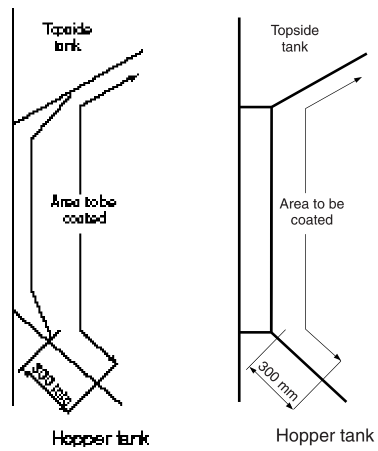


Figure 1: Side – Areas to be coated

1.3.4 Transverse bulkhead areas to be coated

The areas to be coated are the upper parts down to 300 mm below the top of the lower stool. Where there is no lower stool, the area to be coated is the whole transverse bulkhead. These areas are shown in Fig 2

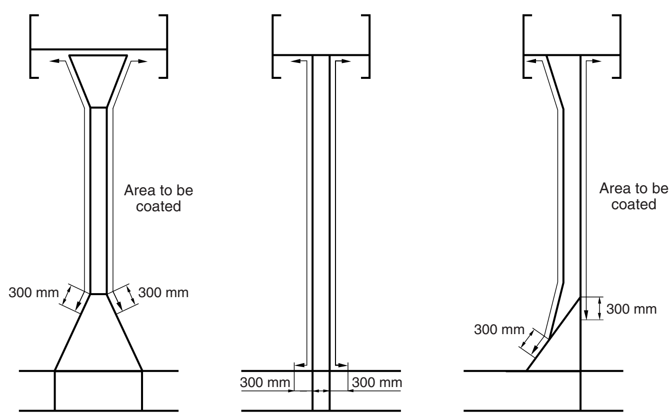


Figure 2: Transverse bulkheads – Areas to be coated

1.4 Protection of ballast hold spaces

1.4.1 Application

All internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of ballast holds are to have an effective protective coating, of an epoxy type or equivalent, applied in accordance with the manufacturer's recommendation.

2. Sacrificial anodes

2.1 General

2.1.1

Anodes are to have steel cores and are to be declared by the Manufacturer as being sufficiently rigid to avoid resonance in the anode support and designed so that they retain the anode even when it is wasted.

The steel inserts are to be attached to the structure by means of a continuous weld. Alternatively, they may be attached to separate supports by bolting, provided a minimum of two bolts with lock nuts are used. However, other mechanical means of clamping may be accepted.

2.1.2

The supports at each end of an anode may not be attached to separate items which are likely to move independently.

2.1.3

Where anode inserts or supports are welded to the structure, they are to be arranged by the Shipyard so that the welds are clear of stress peaks.

3. Protection of bottom by ceiling

3.1 General

3.1.1

Ceiling on the inner bottom and lateral bilges, if any, is to comply with [3.2] and [3.3].

3.2 Arrangement

3.2.1

Planks forming ceiling over the bilges and on the inner bottom are to be easily removable to permit access for maintenance.

3.2.2

Where the double bottom is intended to carry fuel oil, ceiling on the inner bottom is to be separated from the plating by means of battens 30 mm high, in order to faclilitate the drainage of oil leakages to the bilges.

3.2.3

Where the double bottom is intended to carry water, ceiling on the inner bottom may lie next to the plating, provided a suitable protective composition is applied beforehand.

3.2.4

The Shipyard is to take care that the attachment of ceiling does not affect the tightness of the inner bottom.

3.2.5

In single bottom ships, ceiling is to be fastened to the reversed frames by galvanised steel bolts or any other equivalent detachable connection.

A similar connection is to be adopted for ceiling over the lateral bilges in double bottom ships.

3.3 Scantlings

3.3.1

The thickness of ceiling boards, when made of pine, is to be not less than 60 mm. Under cargo hatchways, the thickness of ceiling is to be increased by 15 mm.

Where the floor spacing is large, the thicknesses may be considered by the Society on a case by case basis.

Section 6 – STRUCTURAL ARRANGEMENT PRINCIPLES

Symbols

For symbols not defined in this Section, refer to the list defined in Ch 4 Sec 1.

b_h: breadth, in m, of cargo hatch opening

l_b: length, in m, of the free edge of the end bracket

1. Application

The requirements of this section apply to the cargo hold area. For other areas, the requirements of Ch 9, Sec 1, 2 and 3 is to be applied..

2. General principles

2.1 Definition

2.1.1 Primary frame spacing

Primary frame spacing, in m, is defined as the distance between the primary supporting members.

2.1.2 Secondary frame spacing

Secondary frame spacing, in mm, is defined as the distance between ordinary stiffeners.

2.2 Structural continuity

2.2.1 General

The reduction in scantling from the midship part to the end parts is to be effected as gradually as practicable.

Attention is to be paid to the structural continuity in way of changes in the framing system, at the connections of primary supporting members or ordinary stiffeners and in way of the ends of the fore and aft parts and machinery space and in way of the ends of superstructures.

2.2.2 Longitudinal members

Longitudinal members are to be so arranged as to maintain the continuity of strength.

Longitudinal members contributing to the hull girder longitudinal strength are to extend continuously for a sufficient distance towards the end of ship.

In particular, the continuity of the longitudinal bulkheads, including vertical and horizontal primary supporting members, extended over the cargo hold area is to be ensured beyond the cargo area . Scarfing brackets are a possible means.

2.2.3 Primary supporting members

Primary supporting members are to be arranged in such a way that they ensure adequate continuity of strength.

Abrupt changes in heights or cross section are to be avoided.

2.2.4 Ordinary stiffeners

Ordinary stiffeners contributing to the hull girder longitudinal strength are generally to be continuous when crossing primary supporting members.

2.2.5 Platings

A change in plating thickness greater than 8 mm is to be avoided, by the insertion of a transition plating. The butt weld preparation is to be in accordance with the requirements of Ch 11 Sec 1.

2.2.6 Stress concentrations

Where stress concentration may occur in way of structural discontinuity, sufficient consideration is to be paid to reduce the stress concentration and adequate compensation and reinforcements are to be provided.

Openings are to be avoided, as far as practicable in way of highly stressed areas.

Where openings are arranged, the shape of openings is to be specially designed to reduce the stress concentration.

Openings are to be well rounded with smooth edges.

Weld joints are to be properly shifted from places where the stress may highly concentrate.

2.3 Connections with higher tensile steel

2.3.1 Connections with higher tensile steel

Where steels of different strengths are mixed in a hull structure, due consideration is to be given to the stress in the lower tensile steel adjacent to higher tensile steel.

Where stiffeners of lower tensile steel are supported by primary supporting members of higher tensile steel, due consideration is to be given to the stiffness of primary supporting members and scantlings to avoid excessive stress in the stiffeners due to the deformation of primary supporting members.

Where higher tensile steel is used at deck structures and bottom structure, members not contributing to the hull girder longitudinal strength and welded to the strength deck or bottom plating and bilge strake, such as hatch coamings, gutter bars, strengthening of deck openings, bilge keel, etc., are generally to be made of the same higher tensile steel. The same requirement is applicable for non continuous ordinary stiffeners welded on the web of a primary members contributing to the hull girder longitudinal strength as hatch coamings, stringers and girders.

3. Plating

3.1 Structural continuity of plating

3.1.1 Insert plate and doubler

A local increase in plating thickness is generally to be achieved to through insert plates. Local doublers may be accepted by the Society on a case by case basis., In any case, doublers and insert plate are to be made of the materials of a quality (yield & grade) at least equal to that of the plates on which they are welded.

4. Ordinary stiffener

4.1 Profile of stiffeners

4.1.1 Stiffener profile with a bulb section

A bulb section may be taken as equivalent to a built-up section. The dimensions of the equivalent angle section are to be obtained, in mm, from the following formulae.

$$h_w = h'_W - \frac{h'_W}{9.2} + 2$$

$$b_f = \alpha\left(t'_W + \frac{h'_W}{6.7} - 2\right)$$

$$t_f = \frac{h'_W}{9.2} - 2$$

where:

h_w' and t_w' : Height and net thickness of a bulb section, in mm, as shown in Fig 1.

α : Coefficient equal to

$1.1 + \frac{(120 - h'_W)^2}{3000}$ for $h'_W \le 120$

1.0 for $h'_W > 120$

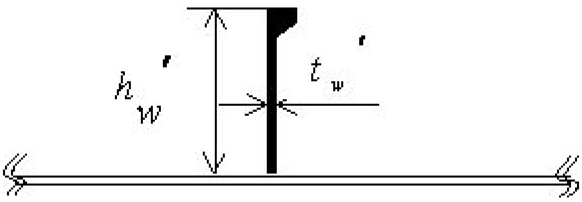


Figure 1: Dimensions of stiffeners

4.2 Span of ordinary stiffeners

4.2.1 Ordinary stiffener

The span ℓ of ordinary stiffeners is to be measured as shown in Fig 2.

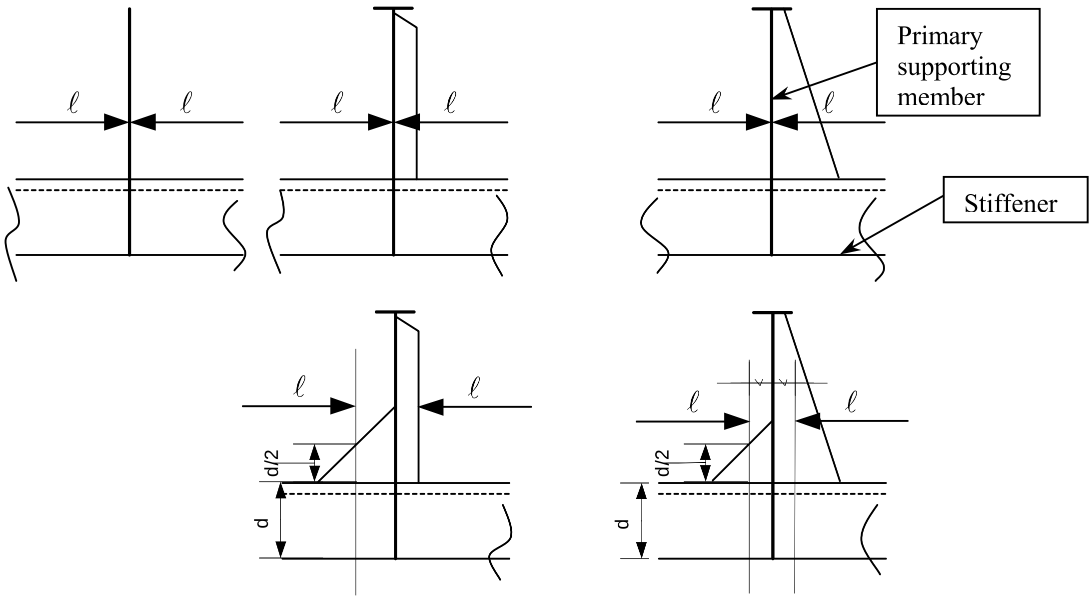


Figure 2: Span of ordinary stiffeners

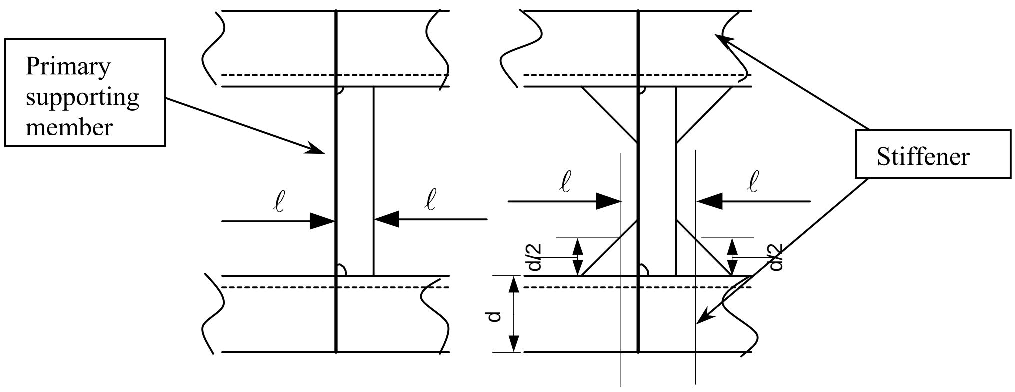


Figure 3: Span of ordinary stiffeners within a double hull

4.2.2 Ordinary stiffener within a double hull

The span ℓ of ordinary stiffeners fitted inside a double hull i.e. when the web of the primary supporting members are connected with the 2 hulls acting as its flanges, is to be measured as shown in Fig 3.

4.2.3 Ordinary stiffeners supported by struts

The span ℓ of ordinary stiffeners supported by one strut fitted at mid distance of the primary supporting members is to be taken as 0.7 ℓ_1.

In case where 2 struts are fitted between primary supporting members, the span ℓ of ordinary stiffeners is to be taken as the greater of 1.4 ℓ_1 and 0.7 ℓ_2.

ℓ_1 and ℓ_2 are the spans defined in Fig 4 and 5.

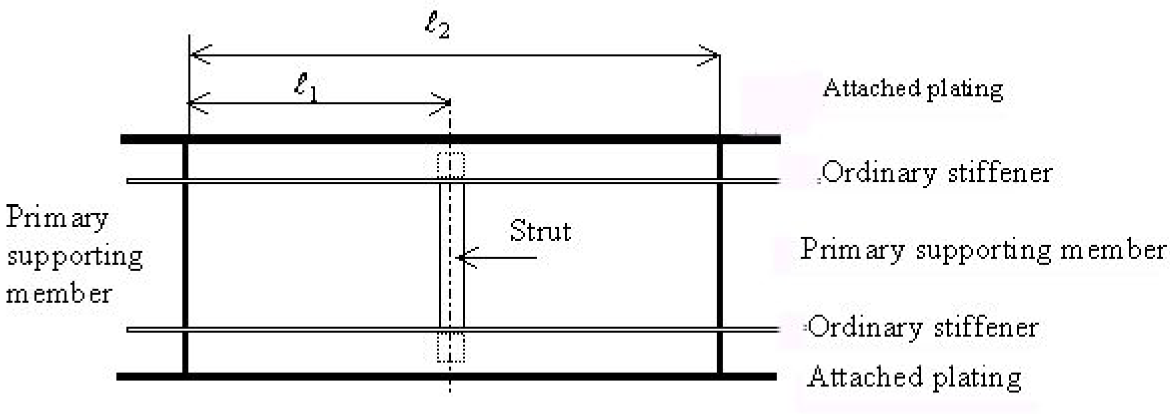


Figure 4: Span of ordinary stiffeners with one strut

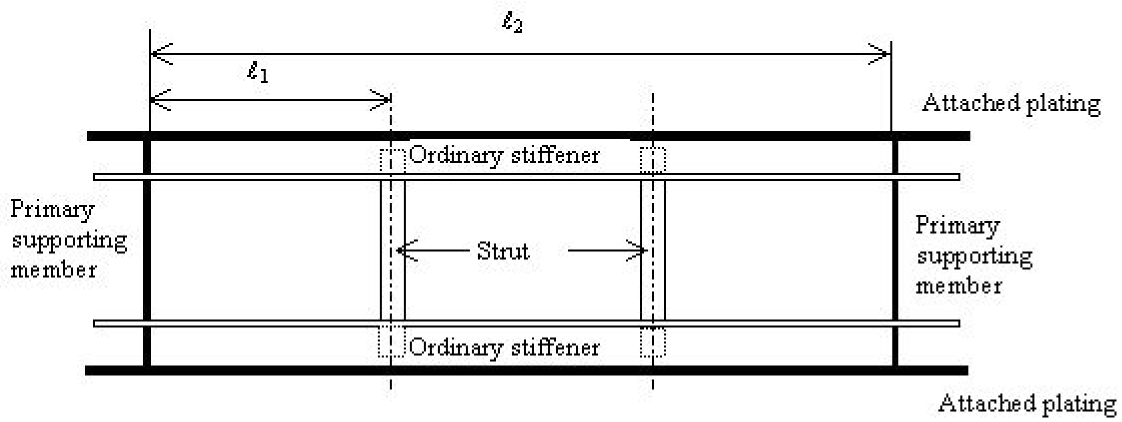


Figure 5: Span of ordinary stiffeners with 2 struts

4.3 Attached plating

4.3.1 Effective breadth for yielding check

The effective width b_p of the attached plating to be considered in the actual net section modulus for the yielding check of ordinary stiffeners is to be obtained, in m, from the following formulae :

- Where the plating extends on both sides of the ordinary stiffener:

  $b_p = 0.2\ \ell$, or

  $b_p = s$

  whichever is lesser.

- Where the plating extends on one side of the ordinary stiffener (i.e. ordinary stiffeners bounding openings):

  $b_p = 0.5\ s$

  $b_p = 0.1\ \ell$

  whichever is lesser.

4.3.2 Effective width for buckling check

The effective width of the attached plating of ordinary stiffeners for checking the buckling of ordinary stiffeners is defined in Ch 6 Sec 3.

4.4 Geometric property of ordinary stiffeners

4.4.1 General

Geometric properties of stiffeners such as moment of inertia, section modulus, shear sectional area, slenderness ratio of web plating, etc., are to be calculated based on the net thickness as defined in Ch 3 Sec 2.

4.4.2 Stiffener not perpendicular to the attached plating

The actual stiffener's net section modulus is to be calculated about an axis parallel to the attached plating.

Where the stiffener is not perpendicular to the attached plating, the actual net section modulus can be obtained, in cm^3, from the following formula.

$$w = w_0 \sin\alpha$$

where:

w_0 : Actual net section modulus, in cm^3, of the stiffener assumed to be perpendicular to the attached plating

α : Angle, in degrees, between the stiffener web and the attached plating, as shown in Fig 6, but not to be taken less than 75 degrees.

The correction is to be applied when α is equal and more than 75 degrees.

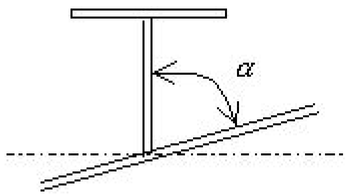


Figure 6: Angle between stiffener web and attached plating

Where the angle between the web plate of stiffener and the attached plating is less than 75 degrees, tripping bracket is to be fitted at suitable spacing. If the angle between the web plate of an unsymmetrical stiffener and the attached plating is less than 75 degrees, the face plate of the stiffener is to be fitted on the side of open bevel, as shown in Fig 7.

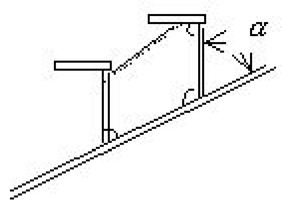


Figure 7: Orientation of stiffener when the angle is less than 75 degrees.

4.5 End connections of ordinary stiffeners

4.5.1 General

Where ordinary stiffeners are to be continuous through primary supporting members, they are to be properly connected to the web plating so as to ensure proper transmission of loads. Some sample connections are shown in Figures 8 through 11.

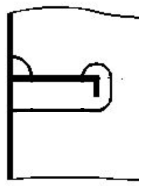


Figure 8: Connection without collar plate

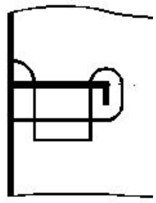


Figure 9: Connection with Collar plate

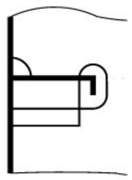


Figure 10: Connection with one large collar plate

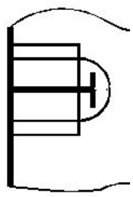


Figure 11: Connection with two large collar plates

4.5.2 Structural continuity of stiffeners

Where ordinary stiffeners are cut at primary supporting members, brackets are to be fitted to ensure structural continuity. In this case, the net section modulus and net sectional area of the brackets are to be not less than those of the ordinary stiffener.

The net thickness of brackets is to be not less than that of ordinary stiffeners.

The brackets are to be flanged or stiffened by a welded face plate where:

- the net thickness of the bracket, in mm, is less than $15l_b$, where l_b is the length, in m, of the free edge of the end bracket or brackets; or
- the longer arm of the bracket is greater than 800 mm.

The net sectional area, in cm^2, of the flanged edge or faceplate is to be at least equal to $10l_b$.

4.5.3 End connections

End connection of stiffeners is to be sufficiently supported by the primary supporting members. Generally, a stiffener or a bracket to support the ordinary stiffener is to be provided.

At end connections in way of primary supporting members where high shearing stress and/or compressive stress is expected, slots for penetration of stiffeners are to be reinforced with collars of the same materials as the primary supporting members.

Brackets or stiffeners to support the ordinary stiffeners are to be of sufficient sectional area and moment of inertia with respect to structural continuity, and should have appropriate shape with respect to fatigue strength. If brackets or stiffeners to support the ordinary stiffeners are not fitted, or special slot configurations considering the fatigue strength are provided, fatigue strength assessment for slots may be required by the Society.

5. Primary supporting members

5.1 General

5.1.1

Where arrangements of primary supporting members are ensured adequate based on the results of FE analysis, Fatigue assessment and ultimate strength assessment, primary supporting member may be arranged in accordance with the result of such assessment.

5.2 Stiffening arrangement

5.2.1

Webs of primary supporting members are generally to be stiffened where the height, in mm, is greater than 100t, where t is the web net thickness, in mm, of the primary supporting member.

In general, the web stiffeners of primary supporting members are to be spaced not more than 110t.

5.2.2

Additional stiffeners are to be fitted in way of end brackets, at the connection with cross ties, etc. of transverse primary supporting members where shearing stress and/or compressive stress is expected to be high. These parts are not to have holes. Cut outs for penetration of ordinary stiffeners in these parts are to be reinforced with collar plates.

Depth of stiffener is to be more than 1/8 of stiffener length.

5.2.3

Tripping brackets (see Figure 12:) welded to the face plate are generally to be fitted:

- at every fourth spacing of ordinary stiffeners, without exceeding 4 m.
- at the toe of end brackets
- at rounded face plates
- in way of cross ties
- in way of concentrated loads.

Where the width of the symmetrical face plate is greater than 400 mm, backing brackets are to be fitted in way of the tripping brackets. Where the face plate of the primary supporting member exceeds 180 mm on either side of the web, tripping bracket is to support the face plate as well.

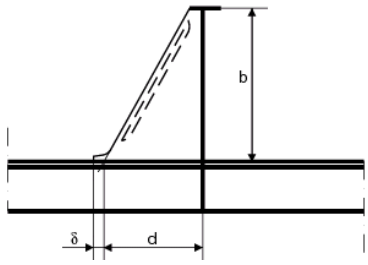


Figure 12: Primary supporting member: web stiffener in way of ordinary stiffener

5.2.4

In general, the width of the primary supporting member face plate is to be not less than one tenth of the depth of the web, where tripping brackets are spaced as specified in [5.2.3].

5.2.5

The arm length of tripping brackets is to be not less than the greater of the following values, in m:

$$d = 0.38b$$

$$d = 0.85\sqrt{\frac{s_t}{t}}$$

where:

b : Height, in m, of tripping brackets, shown in Figure 12:

s_t : Spacing, in m, of tripping brackets

t : Net thickness, in mm, of tripping brackets.

It is recommended that the bracket toe should be designed as shown in Figure 12:

5.2.6

Tripping brackets with a net thickness, in mm, less than $15L_b$ are to be flanged or stiffened by a welded face plate.

The net sectional area, in cm^2, of the flanged edge or the face plate is to be not less than $10L_b$, where L_b is the length, in m, of the free edge of the bracket.

Where the depth of tripping brackets is greater than 3 m, an additional stiffener is to be fitted parallel to the bracket free edge

5.2.7Lightening hole

Where lightening holes are provided, the dimensions and locations of lightening holes are generally to be as shown in Figure 13:

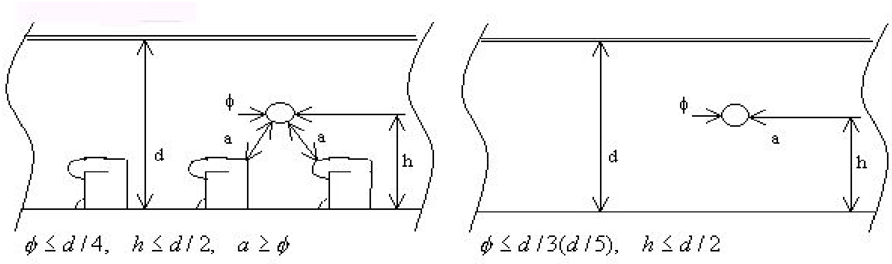


Figure 13: Location and dimensions of lightening holes

5.3 Span of primary supporting members

5.3.1 Primary supporting member with end brackets

The span ℓ, in m, of a primary supporting member is to be determined in accordance with [4.2].

5.4 Effective breadth of primary supporting member

5.4.1 General

The effective breadth of the attached plating of a primary supporting member to be considered in the actual net section modulus for the yielding check is to be determined in accordance with [4.3.1].

5.5 Geometric properties

5.5.1 General

Geometric properties of primary supporting members such as moment of inertia, section modulus, shear sectional area, slenderness ratio of web plating, etc., are to be calculated based on the net thickness as specified in Ch3 Sec 2.

5.5.2 Shear sectional area in the case of large openings in web

Where large openings are made in the web of primary supporting members (e.g. where a pipe tunnel is fitted in the double bottom), their influence is to be taken into account by assigning an equivalent shear sectional area to the primary supporting member.

This equivalent net shear sectional area is to be obtained, in cm^2, from the following formula:

$$Ash = \frac{Ash1}{1 + \dfrac{0.0032 l^2 Ash1}{I_1}} + \frac{Ash2}{1 + \dfrac{0.0032 l^2 Ash2}{I_2}}$$

where (see Figure 14:):

I_1, I_2: Net moments of inertia, in cm^4, of deep webs (1) and (2), respectively, with attached plating around their neutral axes parallel to the plating

A_{Sh1}, A_{Sh2} : Net shear sectional areas, in cm^2, of deep webs (1) and (2), respectively, to be calculated according to [4.3.2]

ℓ: Span, in cm, of deep webs (1) and (2).

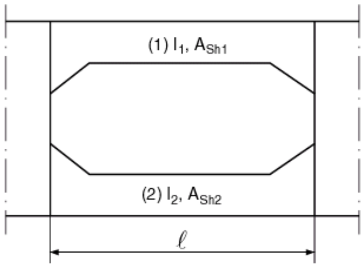


Figure 14: Large openings in the web of primary supporting members

5.6 Bracketed end connection

5.6.1 General

Where the ends of the primary supporting members are connected to bulkheads, inner bottom, etc., the end connections of all primary supporting members are to be balanced by effective supporting members on the opposite side of bulkheads, inner bottoms, etc.

Tripping brackets are to be provided on the web plate of the primary supporting members at the inner edge of end brackets and connection parts of the other primary supporting members and also at the proper intervals to support the primary supporting members effectively.

5.6.2 Dimensions of brackets

Arm length of bracket is generally not to be less than one-eighth of span length of the primary member, unless otherwise specified. Arm lengths of brackets at both ends are to be equal, as far as practicable.

The height of end brackets is to be not less than that of the primary supporting member. The net thickness of the end bracket web is not to be less than that of the web plate of the primary supporting member.

The scantlings of end brackets are generally to be such that the section modulus of the primary supporting member with end brackets is not less than that of the primary supporting member at mid-span.

The width, in mm, of the face plate of end brackets is to be not less than 50(Lb+1),

Moreover, the net thickness of the face plate is to be not less than that of the bracket web.

Stiffening of end brackets is to be designed such that it provides adequate buckling web stability.

As guidance, the following prescriptions may be applied:

- where the length Lb is greater than 1,5 m, the web of the bracket is to be stiffened
- the net sectional area, in cm^2, of web stiffeners is to be not less than $16,5\ell$, where ℓ is the span, in m, of the stiffener
- tripping flat bars are to be fitted to prevent lateral buckling of web stiffeners. Where the width of the symmetrical face plate is greater than 400 mm, additional backing brackets are to be fitted.

5.7 Cut-outs and holes

5.7.1

Cut-outs for the passage of ordinary stiffeners are to be as small as possible and well rounded with smooth edges.

In general, the depth of cut-outs is to be not greater than 50% of the depth of the primary supporting member.

5.7.2

Where openings such as lightening holes are cut in primary supporting members, they are to be equidistant from the face plate and corners of cut-outs and, in general, their height is to be not greater than 20% of the web height. Where lightening holes are cut in the brackets, the distance from the circumference of the hole to the free flange of brackets is not to be less than the diameter of the lightening hole.

5.7.3

Openings may not be fitted in way of toes of end brackets.

5.7.4

Over half of the span of primary supporting members, the length of openings is to be not greater than the distance between adjacent openings.

At the ends of the span, the length of openings is to be not greater than 25% of the distance between adjacent openings.

5.7.5

In the case of large openings in the web, the secondary stresses in primary supporting members are to be considered for the reinforcement of the openings.

6. Double bottom

6.1 General

6.1.1 Double bottom extend

A double bottom is to be fitted extending from the collision bulkhead to the afterpeak bulkhead

(SOLAS, Chapter II-1, Part B, Regulation 12-1)

6.1.2 Framing system

For ships greater than 120m in length, the bottom, the double bottom and the sloped bulkheads of hopper tanks are, in general, to be of longitudinal system of frame arrangement at least within the cargo hold area. The double bottom and the sloped bulkheads of hopper tanks may be transversely framed in ships equal to or less than 120 m in length, when this is deemed acceptable by the Society on a case-by-case basis. In this case, however, the floor spacing is to be not greater than 2 frame spaces.

6.1.3 Height of double bottom

Unless otherwise specified, the height of double bottom is not to be less than B/20 or 2m whichever is the lesser.

Where the height of the double bottom varies, the variation is generally to be made gradually and over an adequate length; the knuckles of inner bottom plating are to be located in way of plate floors.

Where this is impossible, suitable longitudinal structures such as partial girders, longitudinal brackets etc., fitted across the knuckle are to be arranged.

6.1.4 Dimensions of double bottom

The breadth of double bottom is normally taken as shown in Fig 15.

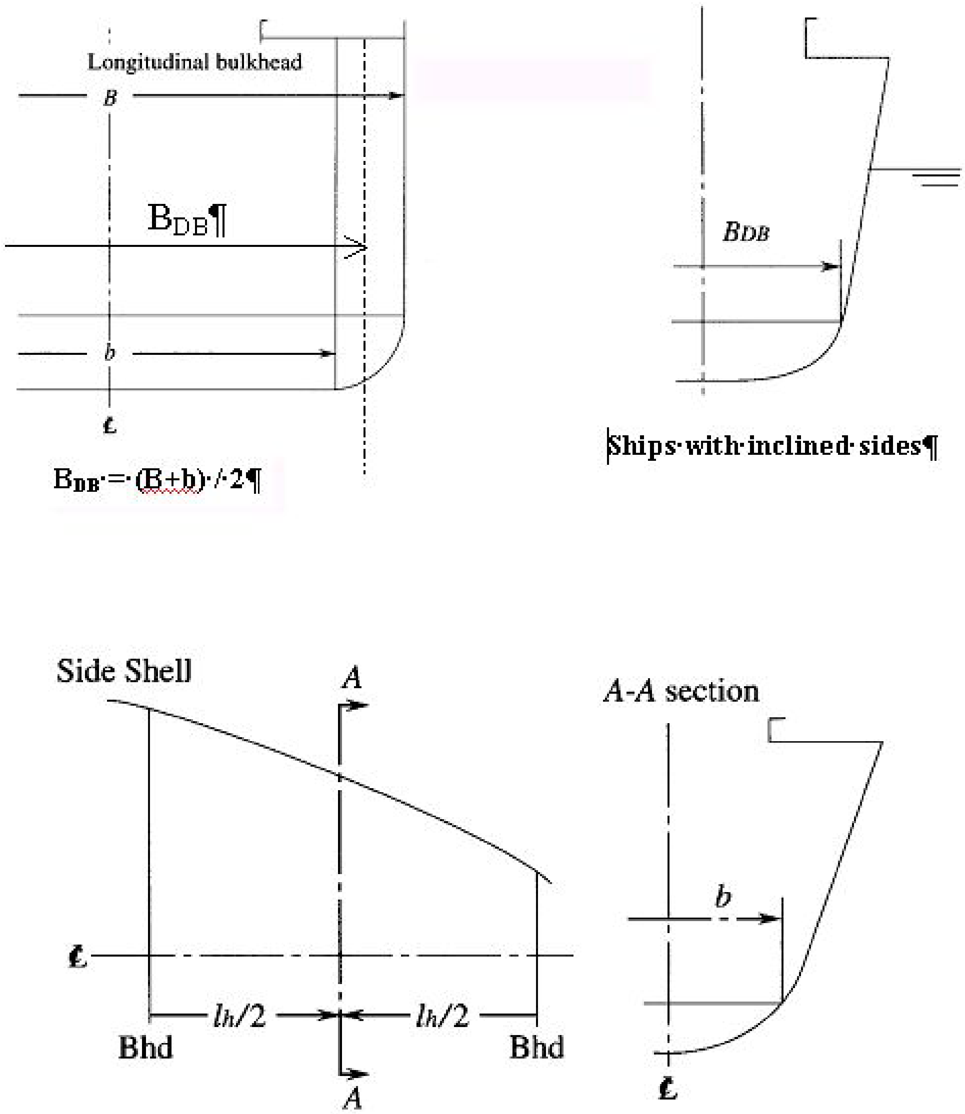


Figure 15: Breadth of double bottom

When bilge hopper tanks are provided, the breadth of the double bottom is taken as the distance between the inner ends of hoppers.

6.1.5 Docking

The bottom is to have sufficient strength to withstand the loads resulting from the drydocking of the ship. In general, docking brackets are to be provided between solid floors connecting the centerline girder to the bottom shell plating as well as the adjacent bottom longitudinals.

6.1.6 Continuity of strength

Where the framing system changes from longitudinal to transverse , special attention is to be paid to the continuity of strength by means of additional intercostal girders or floors. Where such a height variation occurs within 0.6 L amidships, the inner bottom is generally to be maintained continuous by means of inclined plating.

Bottom and inner bottom longitudinal ordinary stiffeners are generally to be continuous through the floors.

The actual net thickness and the yield stress of the lower strake of the sloped bulkhead of hopper tanks, if any, are not to be less than these ones of the inner bottom with which the connection is made.

6.1.7 Reinforcement

The bottom is to be locally stiffened where concentrated loads are envisaged such as under the main engine and thrust seat.

Girders and floors are to be fitted under each line of pillars, toes of end brackets of bulkhead stiffeners and slant plate of lower stool of bulkhead. In case girders and floors are not fitted, suitable reinforcement is to be provided by means of additional primary supporting members.

When solid ballast is fitted, it is to be securely positioned. If necessary, intermediate floors may be required for this purpose.

[The thickness of the bottom plating is to be locally increased under ballast suction bell mouths, as this area is subject to accelerated erosion wastage.]

6.1.8 Manholes and lightning holes

Manholes and lightening holes are to be provided in all non-watertight members to ensure accessibility and ventilation as a rule.

The number of manholes in tank tops is to be kept to the minimum compatible with securing free ventilation and ready access to all parts of the double bottom.

6.1.9 Air holes and drain holes

Air and drain holes are to be provided in all non-watertight members.

Air holes are to be cut as near to the inner bottom and draining holes as near to the bottom shell as practicable.

6.1.10 Drainage of tank top

Effective arrangements are to be provided for draining water from the tank top. Where wells are provided for the drainage, such wells are not to extend for more than one-half depth of the height of double bottom

6.1.11 Striking plate

Striking plates of adequate thickness or other arrangements are to be provided under sounding pipes to prevent the sounding rod from damaging the bottom plating.

6.1.12 Duct keel

Where a duct keel is arranged, the centre girder may be replaced by two girders generally spaced, no more than 2 m apart.

The structures in way of the floors are to ensure sufficient continuity of the latter.

6.2 Keel

6.2.1

The width of the keel is to be not less than the value obtained, in m, from the following formula:

$b = 0.8 + L/200$

6.3 Girders

6.3.1 Center girder

The center girder is to extend forward and aft as far as practicable, and is to be continuous within the full length of the ship.

Where double bottom compartments are used for the carriage of fuel oil, fresh water or ballast water, the center girder is to be watertight, except for the case such as narrow tanks at the end parts or when other watertight girders are provided within 0.25 B from the centerline, etc.

6.3.2 Side girders

The side girders are to extend forward and aft as far as practicable.

6.3.3 Spacing

The spacing of adjacent girders, in m, is generally to be not less than 4.6 m or 4 times the spacing of bottom or inner bottom ordinary stiffeners.. Greater spacing may be accepted depending on the result of the analysis carried out according to Ch 7.

6.4 Floors

6.4.1 Spacing

The spacing of floors, in m, is generally to be not greater than 3.5 m or 3 frame spaces. Greater spacing may be accepted depending on the result of the analysis carried out according to Ch 7.

6.4.2 Floors in way of transverse bulkheads

Additional floors are to be fitted in way of transverse watertight bulkheads.

The thickness and material properties of the supporting floors and pipe tunnel beams are to be not less than those required for the bulkhead plating or, when a stool is fitted, of the stool side plating.

6.4.3 Stiffener

Floors are generally to be provided with stiffeners in way of longitudinal ordinary stiffeners.

Such stiffeners are generally to be made of the same material as the floor.

6.5 Bilge strake and bilge keel

6.5.1 Continuity of strength at bilge part

Where some of the longitudinal stiffeners at the bilge part are omitted, longitudinal stiffeners are to be provided as near to the turns of bilge as practicable and suitably constructed to maintain the continuity of strength.

6.5.2 Bilge keel

Bilge keels are not be welded directly to the shell plating. An intermediate flat whose thickness is equal to that of the bilge strake is required on the shell plating. The ends of the bilge keel are to be snipped at an angle of 15 degrees or rounded with large radius. The ends are to be located in way of transverse bilge stiffeners inside the shell plating.

The bilge keel and the intermediate flat are to be made of steel with the same yield stress and grade as that of the bilge strake. The bilge keel with its length less than 0.15 L may be made of grade “A” mild steel regardless of the kind and grade of steels of bilge strake.

The net thickness of the intermediate flat is to be equal to that of the bilge strake. However, this thickness may generally not be greater than 15 mm.

7. Double Side structure

7.1 Application

The requirement of this article apply to longitudinally or transversely framed side structure.

The transversely framed side structures are built with transverse frames possibly supported by horizontal side girders.

The longitudinally framed side structures are built with longitudinal ordinary stiffeners supported by vertical primary supporting members.

The side within the hopper and topside tanks is, in general, to be longitudinally framed. It may be transversely framed when this is accepted for the double bottom and the deck according to [6.1.1] and [9.1.1], respectively.

7.2 General arrangement

7.2.1 General

Double side structures are to be thoroughly stiffened by providing web frames and side stringers within the double hull.

Continuity of the inner side structures, including stringers, is to be ensured beyond the cargo area. Scarfing brackets are a possible means.

7.2.2 Primary supporting member spacing

The spacing of transverse side primary supporting members is to be not greater than 3 frame spaces.

Greater spacing may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Ch 7 for the primary supporting members in the cargo holds.

The vertical distance between horizontal primary members of the double side is not to exceed 6 m.

7.2.3 Primary supporting member fitting

Transverse side primary supporting members are to be fitted in line with web frames in topside tanks and hopper, or alternatively with the floor if no hopper tank is fitted.

Transverse bulkheads in double side space are to be arranged in line with the cargo hold transverse bulkheads.

Vertical primary supporting members are to be fitted in way of hatch end beams.

Unless otherwise specified, horizontal side girders are to be fitted aft of the collision bulkhead up to 0.2 L aft of the fore end, in line with fore peak girders.

7.2.4 Transverse ordinary stiffeners

The transverse ordinary stiffeners of the shell and the inner side are to be continuous or fitted with bracket end connections within the height of the double side. The transverse ordinary stiffeners are to be effectively connected to stringers. At their upper and lower ends, opposing shell and inner side transverse ordinary stiffeners and supporting stringer plates are to be connected by brackets.

7.2.5 Longitudinal ordinary stiffeners

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

7.2.6 Sheer strake

The width of the sheer strake is to be not less than the value obtained, in m, from the following formula:

$b = 0.715 + 0.425 L/100$

The sheer strake may be either welded to the stringer plate or rounded.

If it is rounded, the radius, in mm, is to be not less than $17t_S$, where t_S is the net thickness, in mm, of the sheer strake.

The fillet weld at the connection of the welded sheer strake and deck plate may be either full penetration or deep penetration weld.

The upper edge of the welded sheer strake is to be rounded and free of notches. Fixtures such as bulwarks, eye plates are not to be directly welded on the upper edge of sheer strake, except fore and aft parts.

Longitudinal seam welds of rounded sheer strake are to be located outside the bent area at a distance not less than 5 times the maximum net thicknesses of the sheer strake

The transition from a rounded sheer strake to an angled sheer strake associated with the arrangement of superstructures at the ends of the ship is to be carefully designed so as to avoid any discontinuities.

7.2.7 Plating connection

At the locations where the inner hull plating and the inner bottom plating are connected, attention is to be paid to the structural arrangement so as not to cause stress concentration.

Knuckles of the inner side are to be adequately stiffened by ordinary stiffeners or equivalent means, fitted in line with the knuckle.

The connections of hopper tank plating with inner hull and with inner bottom are to be supported by a primary supporting members.

7.3 Longitudinally framed double side

7.3.1 General

Adequate continuity of strength is to be ensured in way of breaks or changes in the width of the double side.

7.4 Transversely framed double side

7.4.1 General

Transverse frames of side and inner side may be connected by means of struts. Struts are generally to be connected to transverse frames by means of vertical brackets.

8. Single side structure

8.1 Application

This article apply to the single side structure with transversely framed.

If single side structure is supported by transversely and longitudinally primary supporting members, the requirements in [7] above apply to these primary supporting member as regarded to ones in double side skin.

8.2 General arrangement

8.2.1

Side frame is to be arranged at every frame space.

8.3 Side frame

8.3.1 General

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

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

$$r = \frac{0{,}3 \cdot b_f^2}{t_f + t_s}$$

where:

t_s : corrosion addition specified in Ch3, Sec.3,

b_f and t_f : the flange width and net thickness of the curved flange, in mm. The end of the flange is to be sniped.

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

The dimension of side frame is defined in Fig 16,

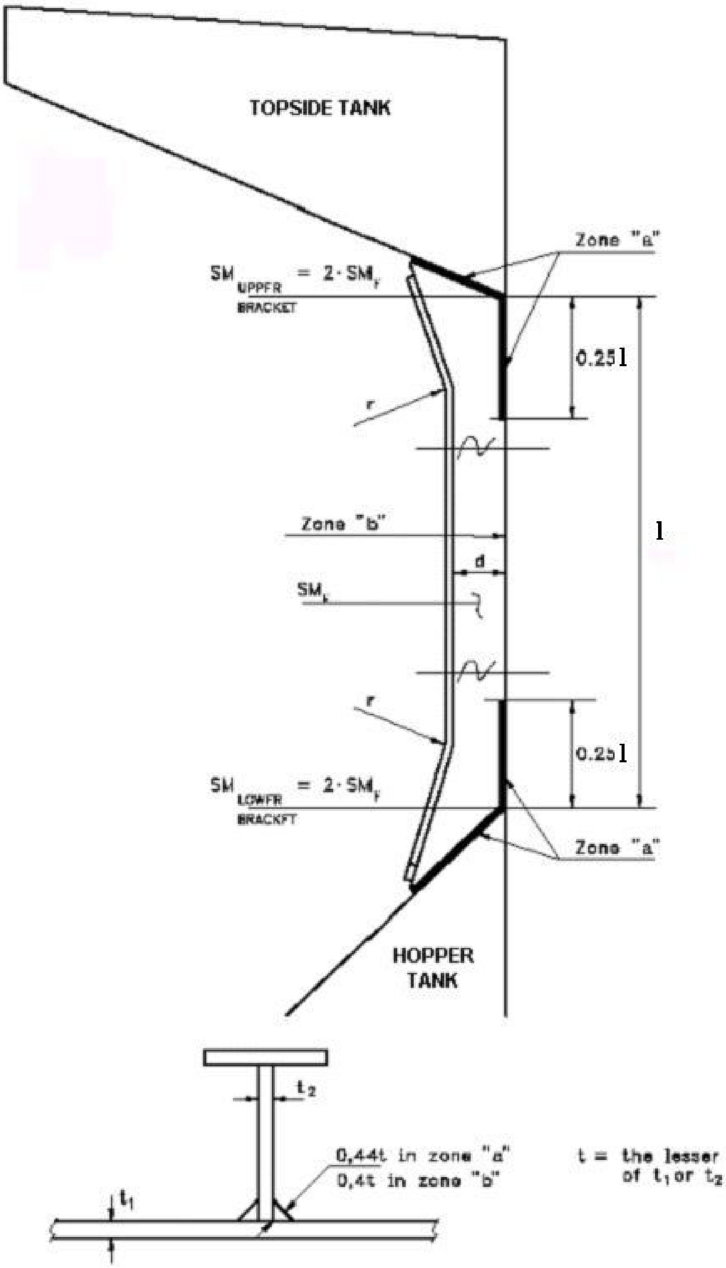


Figure 16: Side frames parameters

8.4 Upper and Lower brackets

8.4.1

The face plates or flange of the brackets is to be snipped at both ends.

Brackets are to be arranged with soft toes

The as built thickness of the tripping brackets is to be not less than the as-built thickness of the side frame webs to which they are connected

8.4.2

The dimensions of of the lower brackets and upper brackets are to be not less than those shown in Fig 17 and Fig 18.

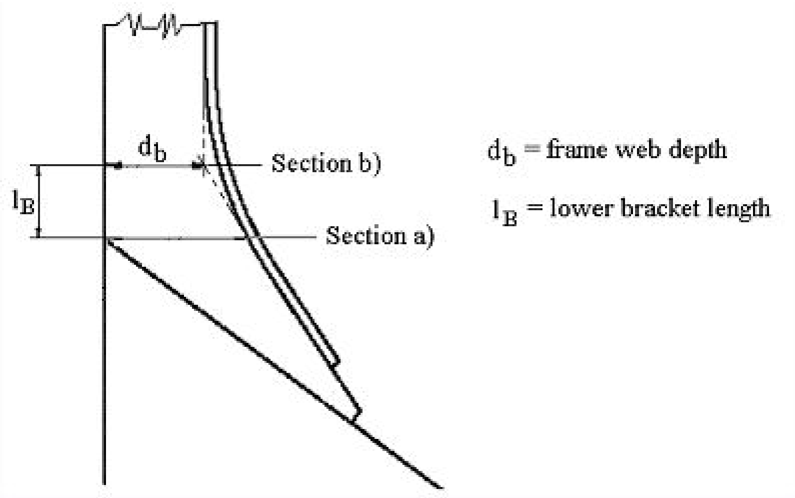


Figure 17: Lower bracket

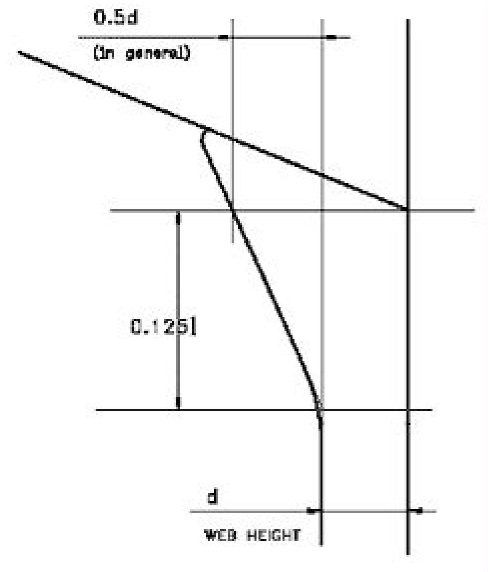


Figure 18: Upper bracket

8.5 Tripping brackets

8.5.1

In way of the foremost hold and in the holds of BC-A ships, side frames of asymmetrical section are to be fitted with tripping brackets at every two frames, as shown in Fig 19.

The as-built thickness of the tripping brackets is to be not less than the as-built thickness of the side frame webs to which they are connected.

Double continuous welding is to be adopted for the connections of tripping brackets with side shell frames and plating.

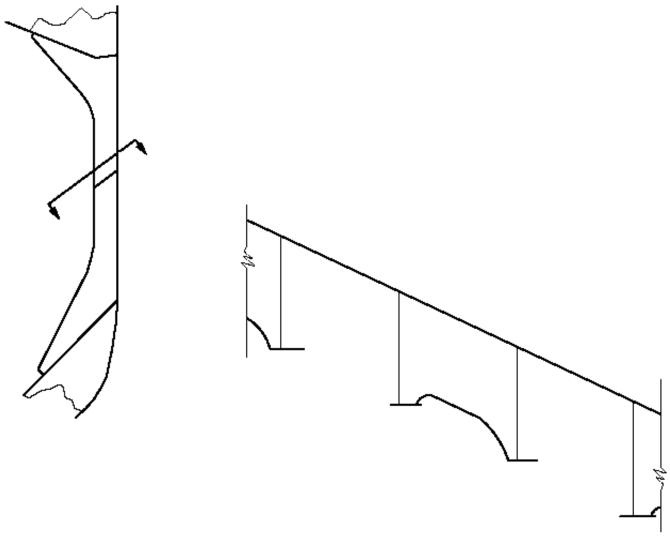


Figure 19: Tripping brackets to be fitted in way of foremost hold

8.6 Support structure

8.6.1

Structural continuity with the lower and upper end connections of side frames is to be ensured within hopper and topside tanks by connecting brackets as shown in Fig 20. The brackets are to be stiffened against buckling according to [5.6.2].

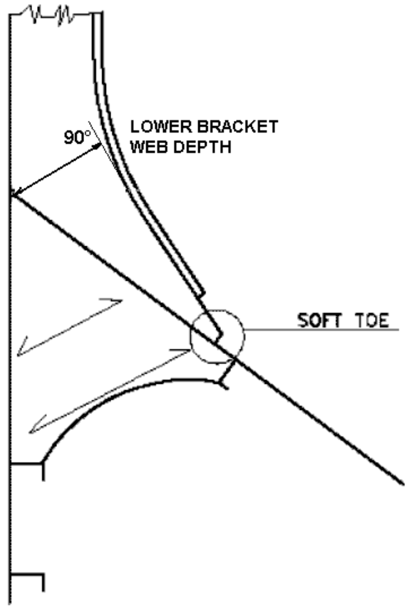


Figure 20: Support structure

9. Deck structure

9.1 Application

9.1.1

In ships greater than 120 m in length, the deck outside the line of hatches and the topside tank sloping plates are to be longitudinally framed.

9.2 General arrangement

9.2.1

The spacing of web frames in topside tanks is generally to be not greater than 6 frame spaces.

Greater spacing may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to Ch 7.

9.2.2

The deck supporting structure is to be made of ordinary stiffeners longitudinally or transversely arranged, supported by primary supporting members.

9.2.3 Deck between hatches

Inside the line of openings, a transverse structure is to be generally adopted for the cross deck structures, beams are to be adequately supported by girders and extended up to the second longitudinal from the hatch side girders towards the bulwark. Where this is impracticable, intercostal stiffeners are to be fitted between the hatch side girder and the second longitudinal.

Smooth connection of the strength deck at side with the deck between hatches is to be ensured by a plate of intermediate thickness.

9.2.4 Topside tank structures

Topside tank structures are to extend as far as possible within the machinery space and are to be adequately tapered.

9.2.5 Stringer plate

The width of the stringer plate is to be not less than the value obtained, in m, from the following formula:

$b = 0.35 + 0.5\ L/100$

Rounded stringer plate, where adopted, are to have a radius complying with the requirements in [7.2.6].

9.2.6

Adequate continuity of strength is to be ensured in way of:

- stepped strength deck
- changes in the framing system

9.2.7

Deck supporting structures under deck machinery, cranes, king post and equipment such as towing equipment, mooring equipment, etc., are to be adequately stiffened.

9.2.8
Pillars or other supporting structures are to be generally fitted under heavy concentrated cargoes.

9.2.9
Stiffeners are to be fitted in way of the ends and corners of deckhouses and partial superstructures.

9.2.10 Connection of hatch end beams with deck structures
The connection of hatch end beams with deck structures is to be properly ensured by fitting inside the topside tanks additional web frames or brackets.

9.2.11 Construction of deck plating
Hatchways or other openings on decks are to have rounded corners, and compensation is to be suitably provided as necessary.

9.3 Longitudinally framed deck

9.3.1 General
Deck longitudinals are to be continuous, as far as practicable, in way of deck transverses and transverse bulkheads. Other arrangements may be considered, provided adequate continuity of longitudinal strength is ensured.

9.3.2 Longitudinal ordinary stiffeners
In ships equal to or greater than 120 m in length, strength deck longitudinal ordinary stiffeners are to be continuous through the watertight bulkheads and/or deck transverses.

Longitudinal beams are to be continuous or to be connected with brackets at their ends in order to have sufficient strength to bending, and shear.

9.4 Transversely framed deck

9.4.1 General
In general, deck beams are to be fitted at each frame.

Transverse beams are to be connected to side structure or frames by brackets.

9.5 Hatch supporting structures

9.5.1
Hatch side girders and hatch end beams of reinforced scantlings are to be fitted in way of cargo hold openings.

9.5.2
Clear of openings, adequate continuity of strength of longitudinal hatch coamings is to be ensured by underdeck girders.

The connection of hatch end beams to longitudinal girders and web frames is to be ensured. Hatch end beams are to be properly aligned with transverse web frames in topside tanks.

9.5.3

At hatchway corners, the face plate of hatch coamings and longitudinal deck girders or their extension parts and the face plates of hatch end girders on both sides are to be effectively connected so as to maintain the continuity in strength.

9.5.4

Wire rope grooving in way of cargo holds openings is to be prevented by fitting protection bars (i.e. half-round bar) on the hatch side girders (i.e. upper portion of top side tank plates)/hatch end beams in cargo hold and upper portion of hatch coamings. As an alternative, inward inclination of hatch coamings may be adopted.

9.6 Openings in the strength deck

9.6.1 General

Openings in the strength deck are to be kept to a minimum and spaced as far as apart from one another and from the breaks of effective superstructures as practicable. Openings are to be cut as far as practicable from hatchway corners, hatch side coamings and side shell platings.

9.6.2 Small opening location

Openings are generally to be cut outside the limits as shown in Fig 21 in dashed area, defined by:

- the bent area of a rounded sheer strake, if any, or the side shell
- $e = 0.25(B - b)$ from top of corner of the hatch opening.
- $c = 0.07l + 0.1b \; or \; 0.25b$, whichever is greater

where:

b: width, in m, of the hatchway considered, measured in the transverse direction.(See Fig 21)

ℓ : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction. (See Fig 21)

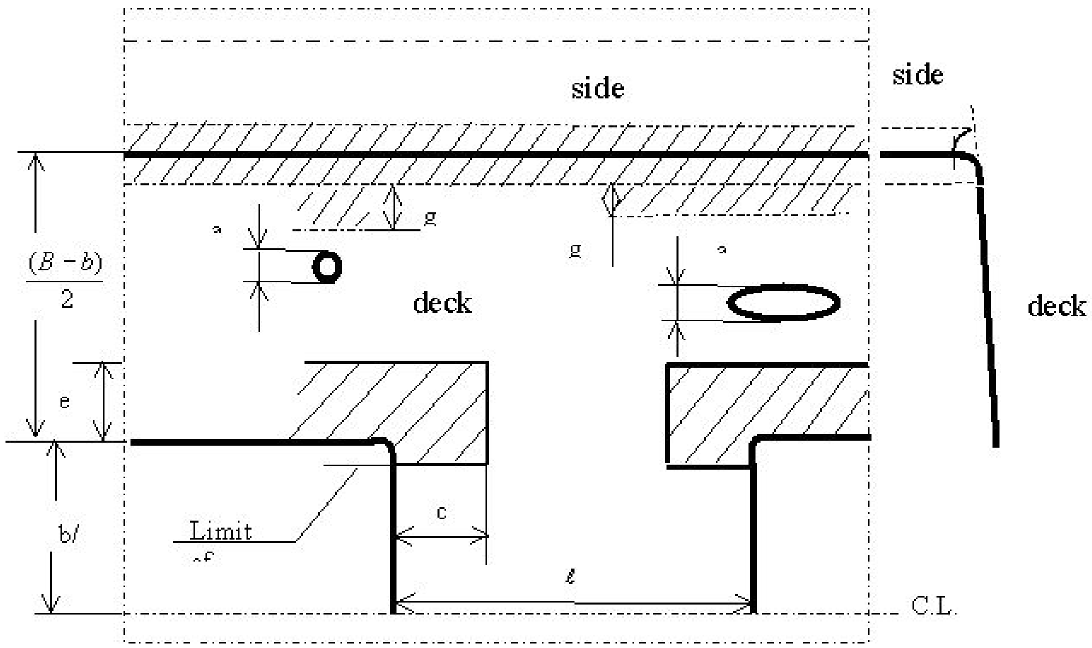


Figure 21: Position of openings in strength deck

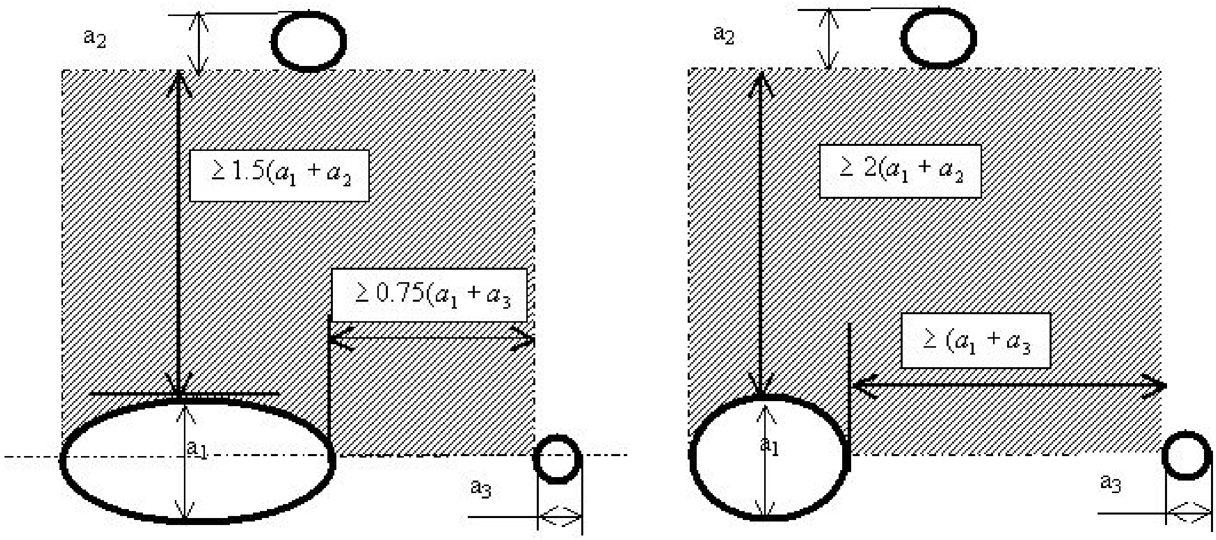


Figure 22: Circular openings on the strength deck

Moreover the transverse distance between these limits and holes or between holes together is not to be less than the followings:

- Transverse distance between the above limits and openings:
  - $g_2 = 2a_2$ for circular openings
  - $g_1 = a_1$ for elliptical openings

  where

  a_1: diameter of circular openings

  a_2: short diameter of elliptical openings
- Transverse distance between openings as shown in Fig 22
  - 2 (a_1+a_2) for circular openings
  - 1.5 (a_1+a_2) for elliptical openings
- The longitudinal distance between holes is not to be less than the followings:
  - (a_1+a_2) for circular openings
  - 0.75 (a_1+a_2) for elliptical openings and for an elliptical opening in line with a circular one.

9.6.3 Corner of hatchways

For hatchways located within the cargo area, insert plates, whose thickness is to be determined according to the formula given after, are generally to be fitted in way of corners where the plating cut-out has a circular profile. The radius of circular corners is to be not less than:

- 5% of the hatch width, where a continuous longitudinal deck girder is fitted below the hatch coaming

Corner radius, in the case of the arrangement of two or more hatchways athwartship, is considered by the Society on a case by case basis.

For hatchways located within the cargo area, insert plates are, in general, not required in way of corners where the plating cut-out has an elliptical or parabolic profile and the half axes of elliptical openings, or the half lengths of the parabolic arch, are not less than:

- 1/20 of the hatchway width or 600 mm, whichever is the lesser, in the transverse direction

- twice the transverse dimension, in the fore and aft direction.

Where insert plates are required, their net thickness is obtained, in mm, from the following formula:

$t_{INS} = (0.8+0.4\ \ell / b_h)\ t$

without being taken less than t or greater than 1,6t

where:

ℓ : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction (see Fig 21)

b : Width, in m, of the hatchway considered, measured in the transverse direction (see Fig 21)

t : Actual net thickness, in mm, of the deck at the side of the hatchways.

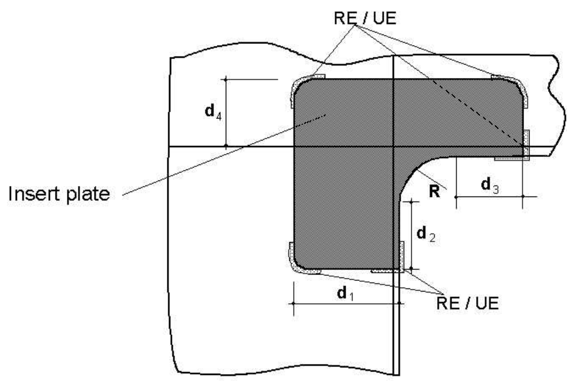


Figure 23: Hatch corner insert plate

For the extreme corners of end hatchways, the thickness of insert plates is to be 60% greater than the actual thickness of the adjacent deck plating. A lower thickness may be accepted by the Society on the basis of calculations showing that stresses at hatch corners are lower than permissible values.

Where insert plates are required, the arrangement is shown in Fig 23, in which d_1, d_2, d_3 and d_4 are to be greater than the ordinary stiffener spacing.

For hatchways located outside the cargo area, a reduction in the thickness of the insert plates in way of corners may be considered by the Society on a case by case basis.

10. Bulkhead structure

10.1 Application

10.1.1

The requirements of this article apply to longitudinal and transverse bulkhead structures which may be plane or corrugated.

10.1.2 Plane bulkeads

Plane bulkheads may be horizontally or vertically stiffened.

Horizontally framed bulkheads are made of horizontal ordinary stiffeners supported by vertical primary supporting members.

Vertically framed bulkheads are made of vertical ordinary stiffeners which may be supported by horizontal girders.

10.2 General

10.2.1

For ships greater than 150 m in length, longitudinal corrugated bulkheads are to have horizontal corrugations.
The web height of vertical primary supporting members of bulkheads may be gradually tapered from bottom to deck with a maximum slope of 0.08 to 1.

10.2.3

A doubling plate of the same net thickness as the bulkhead plating is to be fitted on the after peak bulkhead in way of the stern tube, unless the net thickness of the bulkhead plating is increased by at least 60%

10.3 Plane bulkheads

10.3.1 General

Where a bulkhead does not extend up to the uppermost continuous deck, suitable strengthening is to be provided in the extension of the bulkhead.

Bulkheads are to be stiffened in way of the deck girders.

The vertical stiffener webs of hopper and topside tank watertight bulkheads are generally to be aligned with the webs of longitudinal stiffeners of sloping plates of inner hull.

A primary supporting member is to be provided in way of any vertical knuckle in longitudinal bulkheads. The distance between the knuckle and the primary supporting member is to be taken not greater than 70 mm. When the knuckle is not vertical, it is to be adequately stiffened by ordinary stiffeners or equivalent means, fitted in line with the knuckle.

Plate floors are to be fitted in the double bottom in way of plate transverse bulkhead.

10.3.2 End connection of ordinary stiffeners

The crossing of ordinary stiffeners through a watertight bulkhead is to be watertight.

In general, end connections of ordinary stiffeners are to be bracketed. If bracketed end connections cannot be applied due to hull lines, etc., snipped ends may be accepted, provided the scantling of ordinary stiffeners are modified accordingly.

10.3.3 Sniped end of ordinary stiffener

Where snipped ordinary stiffeners are fitted, the snipe angle is not to be greater than 30 degrees, and their ends are to be extended as far as practicable to the boundary of the bulkhead.

10.3.4 Bracketed ordinary stiffeners

Where bracketed ordinary stiffeners are fitted, the arm lengths of end brackets of ordinary stiffeners, as shown in Fig 24 and 25 , are to be not less than the following values, in mm:

- for arm length a:
  - brackets of horizontal stiffeners and bottom bracket of vertical stiffeners:

    $a = 100\ \ell$
  - upper bracket of vertical stiffeners:

    $a = 80\ \ell$

- for arm length b, the greater of

  $b = 80\ ((w+20)/t)^{0.5}$

  $b = \alpha\ p\ s\ \ell\ /\ t$

where:

ℓ : Span, in m, of the stiffener measured between supports

w : Net section modulus, in cm^3, of the stiffener

t : Net thickness, in mm, of the bracket

p : Design pressure, in kN/m^2, calculated at mid-span

α : Coefficient equal to:

α = 4,9 for tank bulkheads

α = 3,6 for watertight bulkheads.

The connection between the stiffener and the bracket is to be such that the net section modulus of the connection is not less than that of the stiffener.

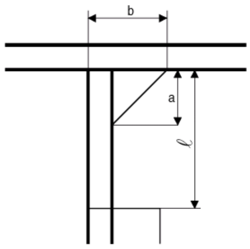


Figure 24: Bracket at upper end of ordinary stiffener on plane bulkhead

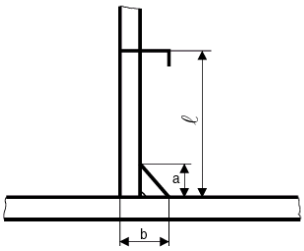


Figure 25: Bracket at lower end of ordinary stiffener on plane bulkhead

10.4 Corrugated bulkheads

10.4.1 General

Transverse vertically corrugated watertight bulkheads are to be fitted with a lower stool and, in general, with an upper stool below the deck. In smaller ships, corrugations may extend from the inner bottom to the deck.

10.4.2 Construction

The main dimensions A, R, c, d, t, φ and s_1 of corrugated bulkheads are defined in Fig 26.

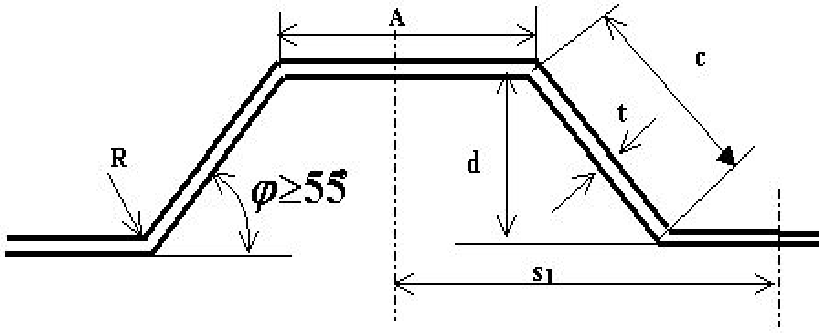


Figure 26: Dimensions of a corrugated bulkhead

The bending radius is not to be less than the following values, in mm:

R= 2.5 t for mild steel

R= 3.0 t for higher tensile steel

where :

t : net thickness, in mm, of the corrugated plate.

The corrugation angle φ shown in Fig 26 is to be not less than 55°.

The thickness of the lower part of corrugations is to be maintained for a distance from the inner bottom (if no lower stool is fitted) or the top of the lower stool not less than $0,15\ell_C$.

The thickness of the middle part of corrugations is to be maintained for a distance from the deck (if no upper stool is fitted) or the bottom of the upper stool not greater than $0,3\ell_C$.

The section modulus of the corrugations in the remaining upper part of the bulkhead is to be not less than 75% of that required for the middle part, corrected for different minimum yield stresses.

When welds in a direction parallel to the bend axis are provided in the zone of the bend, the welding procedures are to be submitted to the Society for approval.

Moreover, when the gross thickness of the bulkhead plating is greater than 20 mm, the Society may require the use of steel grade E or EH.

10.4.3 Actual section modulus of corrugations

The net section modulus of a corrugation is to be obtained, in cm^3, from the following formula:

$w = t\ d\ (3A + c)\ /6\ 10^{-3}$

where:

t : Net thickness of the plating of the corrugation, in mm

d, A, c : Dimensions of the corrugation, in mm, shown in Fig 26.

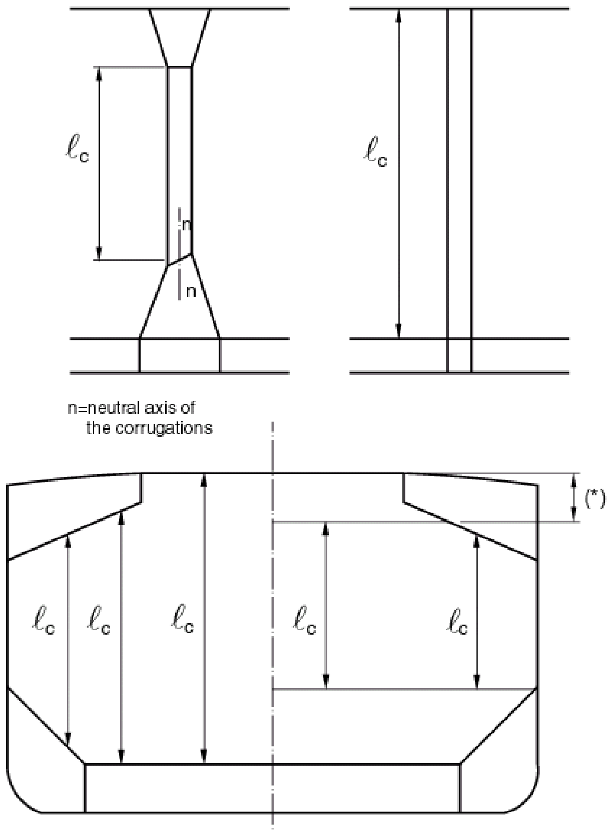
Where the web continuity is not ensured at ends of the bulkhead, the net section modulus of a corrugation is to be obtained, in cm^3, from the following formula:

$w = 0,5\ A\ t\ d\ 10^{-3}$

10.4.4 Span of corrugations

The span ℓ_C of the corrugations is to be taken as the distance shown in Fig 27.

For the definition of ℓ_C, the height of the upper and lower stools may not be taken smaller than the values specified in [10.4.7] and [10.4.8].



(*) upper stool height

Figure 27: Span of the corrugations

10.4.5 Structural arrangements

The strength continuity of corrugated bulkheads is to be ensured at the ends of corrugations.

Where corrugated bulkheads are cut in way of primary supporting members, attention is to be paid to ensure correct alignment of corrugations on each side of the primary member.

Where vertically corrugated transverse bulkheads or longitudinal bulkheads are welded on the inner bottom, plate floors or girders are to be fitted in way of flanges of corrugations, respectively.

In general, upper part and lower parts of horizontally corrugated bulkheads are to be plane over a depth equal to 0.1 D from deck and bottom.

Where stools are fitted at the lower part of transverse bulkheads, the net thickness of adjacent floors is to be not less than that of the stool plating.

10.4.6 Bulkhead stools

In general, plate diaphragms or web frames are to be fitted in bottom stools in way of the double bottom longitudinal girders or plate floors, as the case may be.

Brackets or deep webs are to be fitted to connect the upper stool to the deck transverse or hatch end beams, as the case may be.

The continuity of the corrugated bulkhead with the stool plating is to be adequately ensured. In particular, upper strake of the lower stool is to be of the same net thickness and yield stress as those of the lower strake of the bulkhead.

10.4.7 Lower stool

The lower stool, when fitted, is to have a height in general not less than 3 times the depth of the corrugations.

The thickness and material of the stool top plate are to be not less than those required for the bulkhead plating above. The thickness and material properties of the upper portion of vertical or sloping stool side plating within the depth equal to the corrugation flange width from the stool top are to be not less than the required flange plate thickness and material to meet the bulkhead stiffness requirement at the lower end of the corrugation.

The ends of stool side ordinary stiffeners when fitted in a vertical plane, are to be attached to brackets at the upper and lower ends of the stool.

The distance d from the edge of the stool top plate to the surface of the corrugation flange is to be in accordance with Fig 28.

The stool bottom is to be installed in line with double bottom floors or girders as the case may be, and is to have a width not less than 2,5 times the mean depth of the corrugation.

The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders or floors as the case may be, for effective support of the corrugated bulkhead. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

Where corrugations are cut at the lower stool, the weld of corrugations and stool side plating to the stool top plate are to be full penetration one. The weld of stool side plating and supporting floors to the inner bottom plating are to be full penetration one.

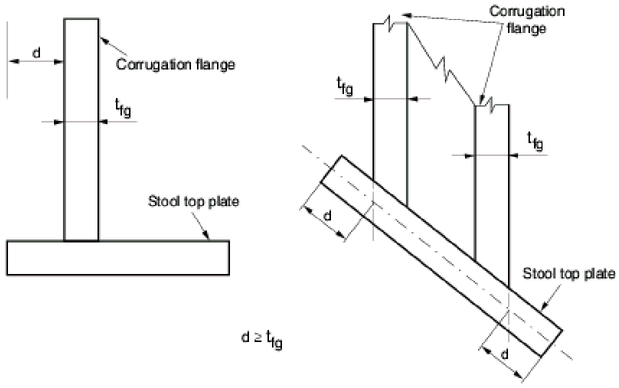


Figure 28: Permitted distance, d, from the edge of the stool top plate to the surface of the corrugation flange

10.4.8 Upper stool

The upper stool, when fitted, is to have a height in general between 2 and 3 times the depth of corrugations. Rectangular stools are to have a height in general equal to twice the depth of corrugations, measured from the deck level and at the hatch side girder.

The upper stool of transverse bulkhead is to be properly supported by deck girders or deep brackets between the adjacent hatch end beams.

The width of the upper stool bottom plate is generally to be the same as that of the lower stool top plate. The stool top of non-rectangular stools is to have a width not less than twice the depth of corrugations.

The thickness and material of the stool bottom plate are to be the same as those of the bulkhead plating below. The thickness of the lower portion of stool side plating is to be not less than 80% of that required for the upper part of the bulkhead plating where the same material is used.

The ends of stool side ordinary stiffeners when fitted in a vertical plane, are to be attached to brackets at the upper and lower end of the stool.

The stool is to be fitted with diaphragms in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders or transverse deck primary supporting members as the case may be, for effective support of the corrugated bulkhead.

Scallops in the brackets and diaphragms in way of the connection to the stool bottom plate are to be avoided.

10.4.9 Alignment

At deck, if no upper stool is fitted, two transverse or longitudinal reinforced beams as the case may be, are to be fitted in line with the corrugation flanges.

At bottom, if no lower stool is fitted, the corrugation flanges are to be in line with the supporting floors or girders.

The weld of corrugations and floors or girders to the inner bottom plating are to be full penetration ones . The thickness and material properties of the supporting floors or girders are to be not less than those of the corrugation flanges. Moreover, the cut-outs for connections of the inner bottom longitudinals to double bottom floors are to be closed by collar plates. The supporting floors or girders are to be connected to each other by suitably designed shear plates.

Stool side plating is to align with the corrugation flanges; lower stool side vertical stiffeners and their brackets in the stool are to align with the inner bottom structures as longitudinals or similar, to provide appropriate load transmission between these stiffening members.

Lower stool side plating may not be knuckled anywhere between the inner bottom plating and the stool top plate.

10.4.10 Effective width of the compression flange

The effective width of the corrugation flange to be considered for the strength check of the bulkhead is to be obtained, in m, from the following formula:

$b_{EF} = C_E A$

where:

C_E : Coefficient to be taken equal to:

$$C_E = \frac{2.25}{\beta} - \frac{1.25}{\beta^2} \quad \text{for } \beta > 1.25$$

$$C_E = 1.0 \quad \text{for } \beta \leq 1.25$$

β : Coefficient to be taken equal to:

$$\beta = 10^3 \frac{A}{t_f}\sqrt{\frac{R_{eH}}{E}}$$

A : Width, in m, of the corrugation flange (see Figure 26)

t_f : Net flange thickness, in mm.

10.4.11 Effective shedder plates

Effective shedder plates are those which:

- are not knuckled
- are welded to the corrugations and the lower stool top plate according to Ch 11
- are fitted with a minimum slope of 45°, their lower edge being in line with the lower stool side plating
- have thickness not less than 75% of that required for the corrugation flanges
- have material properties not less than those required for the flanges.

10.4.12 Effective gusset plates

Effective gusset plates are those which:

- are in combination with shedder plates having thickness, material properties and welded connections as requested for shedder plates in [10.4.12],
- have a height not less than half of the flange width,
- are fitted in line with the lower stool side plating,
- are welded to the lower stool plate, corrugations and shedder plates according to Ch 11, and
- have thickness and material properties not less than those required for the flanges.

10.4.13 Section modulus at the lower end of corrugations

a) The section modulus at the lower end of corrugations (Figure 29 to Figure 32) is to be calculated with the compression flange having an effective flange width b_{ef} not larger than that indicated in [10.4.10] .

b) Webs not supported by local brackets

Except in case e), if the corrugation webs are not supported by local brackets below the stool top plate (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

c) Effective shedder plates

Provided that effective shedder plates, as defined in [10.4.11], are fitted (see Figures 29 and 30), when calculating the section modulus of corrugations at the lower end (cross sections 1 in Figures 29 and 30), the area of flange plates may be increased by the value obtained, in cm^2, from the following formula:

$$I_{SH} = 2.5A\sqrt{t_F t_{SH}}$$

without being taken greater than $2,5At_F$,

where:

A : Width, in m, of the corrugation flange (see Figure 26)

t_{SH} : Net shedder plate thickness, in mm

t_F : Net flange thickness, in mm.

d) Effective gusset plates

Provided that effective gusset plates, as defined in [10.4.12], are fitted (see Figures 31 to 33), when calculating the section modulus of corrugations at the lower end (cross-sections 1 in Figures 31 to 33), the area of flange plates may be increased by the value obtained, in cm^2, from the following formula:

$I_G = 7\ h_G\ t_F$

where:

h_G : Height, in m, of gusset plates (see Figures 31 to 33), to be taken not greater than $(10/7)S_{GU}$

S_{GU} : Width, in m, of gusset plates

t_F : Net flange thickness, in mm, based on the as-built condition.

e) Sloping stool top plate

If the corrugation webs are welded to a sloping stool top plate which has an angle not less than 45° with the horizontal plane, the section modulus of the corrugations may be calculated considering the corrugation webs fully effective. For angles less than 45°, the effectiveness of the web may be obtained by linear interpolation between 30% for 0° and 100% for 45°.

Where effective gusset plates are fitted, when calculating the section modulus of corrugations the area of flange plates may be increased as specified in d) above. No credit may be given to shedder plates only.

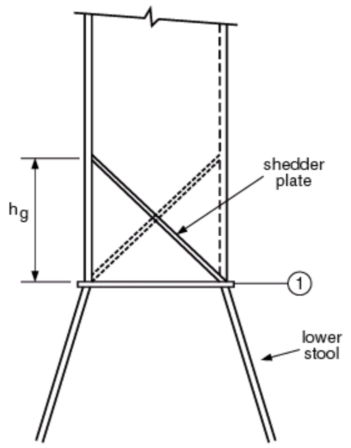


Figure 29: Symmetrical shedder plates

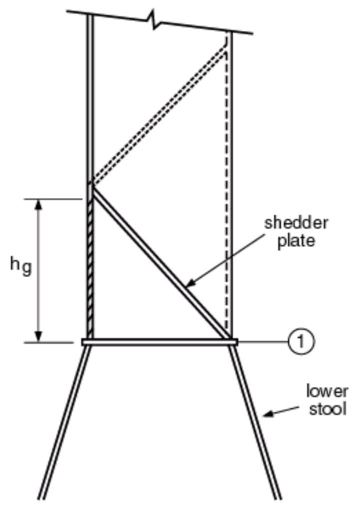


Figure 30: Asymmetrical shedder plates

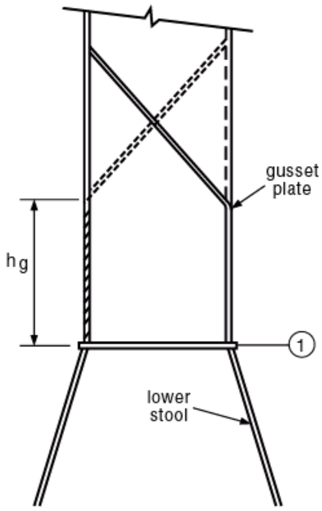


Figure 31: Symmetrical gusset/shedder plates

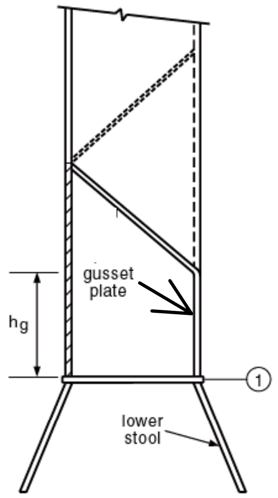


Figure 32: Asymmetrical gusset/shedder plates

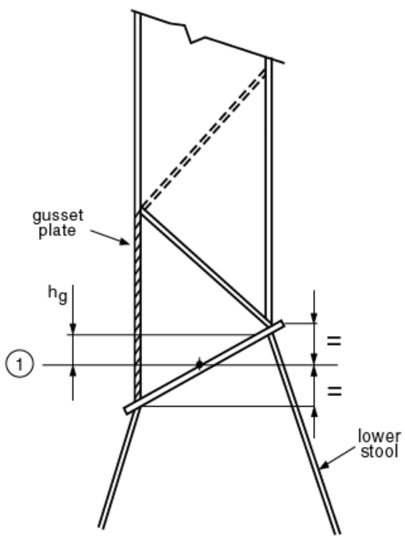


Figure 33: Asymmetrical gusset/shedder plates Sloping stool top plate

10.4.14 Section modulus at sections other than the lower end of corrugations

The section modulus is to be calculated with the corrugation webs considered effective and the compression flange having an effective flange width, b_{EF}, not larger than that obtained in [10.4.10].

10.4.15 Shear area

The shear area is to be reduced in order to account for possible non-perpendicularity between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by (sin φ), φ being the angle between the web and the flange (see Figure 26)

10.5 Non-tight bulkheads

10.5.1 Non-tight bulkheads not acting as pillars

Non-tight bulkheads not acting as pillars are to be provided with vertical stiffeners with a maximum spacing equal to:

- 0,9 m, for transverse bulkheads
- two frame spacings, with a maximum of 1,5 m, for longitudinal bulkheads.

10.5.2 Non-tight bulkheads acting as pillars

Non-tight bulkheads acting as pillars are to be provided with vertical stiffeners with a maximum spacing equal to:

- two frame spacings, when the frame spacing does not exceed 0,75 m,
- one frame spacing, when the frame spacing is greater than 0,75 m.

Each vertical stiffener, in association with a width of plating equal to 35 times the plating net thickness, is to comply with the applicable requirements in Ch 6, Sec 2, for the load being supported.

In the case of non-tight bulkheads supporting longitudinally framed decks, vertical girders are to be provided in way of deck transverse.

10.6 Watertight bulkheads of trunks and tunnels

10.6.1

Watertight trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be to the satisfaction of the Society.

(SOLAS II-1, Reg 19.1)

11. Pillars

11.1 General

11.1.1

Pillars are to be fitted, as far as practicable, in the same vertical line.

Pillars in between decks are to be arranged directly above those under the deck, or effective means are to be provided for transmitting their loads to the supports below.

11.1.2

Manholes may not be cut in the girders and floors below the heels of pillars.

11.1.3 Connections

Heads and heels of pillars are to be secured by thick doubling plates and brackets as necessary. Where the pillars are likely to be subjected to tensile loads such as those in tanks, the head and heel of pillars are to be efficiently secured to withstand the tensile loads and the doubling plates replaced by insert plate.

In general, the net thickness of doubling plates is to be not less than 1,5 times the net thickness of the pillar.

Pillars are to be attached at their heads and heels by continuous welding.

Chapter 4 – Design loads

Welcome JBP

Section 1 – GENERAL

1. General

1.1

1.1.1

The equivalent design wave (EDW) method is used to set the design loads which include lateral loads and hull girder loads in still water and in waves.

1.1.2

External hydrostatic pressure and internal static pressure due to cargo and ballast are considered as lateral loads in still water. External hydrodynamic pressure and internal inertial pressure due to cargo and ballast are considered as lateral loads in waves.

1.1.3

Still water vertical bending moment, wave-induced vertical bending moment and wave-induced horizontal bending moment are considered as the hull girder loads. Still water vertical shear force and wave-induced vertical shear force may additionally be considered if necessary.

1.1.4

The stresses due to the lateral loads in waves and the hull girder loads in waves are to be combined using load combination factors determined for each equivalent design wave.

Chapter 4 – Design loads

Welcome JBP

Section 2 – SHIP MOTIONS AND ACCELERATIONS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

a_0 = acceleration parameter, taken equal to:

$$a_0 = f_p\left(1.58 - 0.47C_B\right)\left(\frac{2.4}{\sqrt{L}} + \frac{34}{L} - \frac{600}{L^2}\right)$$

T_R : Roll period, in s, defined in [2.1.1]

θ : Single roll amplitude, in deg, defined in [2.1.1]

T_P : Pitch period, in s, defined in [2.2.1]

Φ : Single pitch amplitude, in deg, defined in [2.2.1]

f_p : Coefficient corresponding to the probability level, taken equal to:

f_P = 1.0 for strength assessments corresponding to the probability level of 10^{-8}

f_P = 0.5 for strength assessments corresponding to the probability level of 10^{-4}

1. General

1.1

1.1.1

Ship motions and accelerations are assumed to be periodic. The motion amplitudes, defined by the formulae in this Section, are half of the crest to trough amplitudes.

1.1.2

As an alternative to the formulae in this Section, the Society may accept the values of ship motions and accelerations derived from direct calculations or obtained from model tests, when justified on the basis of the ship's characteristics and intended service. In general, the values of ship motions and accelerations to be determined are those which can be reached with a probability level of 10^{-8} or 10^{-4}. In any case, the model tests or the calculations, including the assumed sea scatter diagrams and spectra, are to be submitted to the Society for approval.

2. Ship absolute motions and accelerations

2.1 Roll

2.1.1

The roll period T_R, in s, and the single roll amplitude θ, in deg, are given by:

$$T_R = \frac{2.3k_r}{\sqrt{GM}}$$

$$\theta = \frac{9000(1.25 - 0.025 T_R) f_p k_b}{(B + 75)\pi}$$

where:

k_b : Coefficient taken equal to:

$k_b = 1.2$ for ships without bilge keel

$k_b = 1.0$ for ships with bilge keel

k_r = roll radius of gyration, in m, in the considered loading condition. When k_r is not known, the values indicated in Tab 1 may be assumed.

GM = metacentric height, in m, in the considered loading condition. When GM is not known, the values indicated in Tab 1 may be assumed.

Table 1: Values of k_r and GM

Loading condition	k_r	GM
Full load condition (alternate or homogeneous loading)	0,35B	0,12B
Normal ballast condition	0,45B	0,33B
Heavy ballast condition	0,40B	0,25B

2.2 Pitch

2.2.1

The pitch period T_P, in s, and the single pitch amplitude Φ, in deg, are given by:

$$T_P = \sqrt{\frac{2\pi\lambda}{g}}$$

$$\Phi = f_p \frac{960}{L} \sqrt[4]{\frac{V}{C_B}}$$

where:

$$\lambda = 0.6\left(1 + \frac{T_{LC}}{T}\right) L$$

2.3 Heave

2.3.1

The vertical acceleration due to heave, in m/s^2, is given by:

$$a_{heave} = a_0 g$$

2.4 Sway

2.4.1

The transverse acceleration due to sway, in m/s^2, is given by:

$$a_{sway} = 0.3 a_0 g$$

2.5 Surge

2.5.1

The longitudinal acceleration due to surge, in m/s^2, is given by:

$a_{surge} = 0.2 a_0 g$

3. Ship relative accelerations

3.1 General

3.1.1

At any point, the accelerations in X, Y and Z direction are the acceleration components which result from the ship absolute motions and accelerations defined in [2.1] to [2.5].

3.2 Accelerations

3.2.1

The reference values of the longitudinal, transverse and vertical accelerations at any point are obtained from the following formulae:

- In longitudinal direction:

  $a_X = C_{XG}\, g\sin\Phi + C_{XS}\, a_{surge} + C_{XP}\, a_{pitch\ x}$
- In transverse direction:

  $a_Y = C_{YG}\, g\sin\theta + C_{YS}\, a_{sway} + C_{YR}\, a_{roll\ y}$
- In vertical direction:

  $a_Z = C_{ZH}\, a_{heave} + C_{ZR}\, a_{roll\ z} + C_{ZP}\, a_{pitch\ z}$

where:

C_{XG}, C_{XS}, C_{XP}, C_{YG}, C_{YS}, C_{YR}, C_{ZH}, C_{ZR}, C_{ZP}: Load combination factors defined in Ch 4, Sec 4, [2.2]

$a_{pitch\ x}$ = longitudinal acceleration due to pitch, in m/s^2

$$a_{pitch\,x} = \Phi \frac{\pi}{180}\left(\frac{2\pi}{T_P}\right)^2 R$$

$a_{roll\ y}$ = transverse acceleration due to roll, in m/s^2

$$a_{roll\,y} = \theta \frac{\pi}{180}\left(\frac{2\pi}{T_R}\right)^2 R$$

$a_{roll\ z}$ = vertical acceleration due to roll, in m/s^2

$$a_{roll\,z} = \theta \frac{\pi}{180}\left(\frac{2\pi}{T_R}\right)^2 y_G$$

$a_{pitch\ z}$ = vertical acceleration due to pitch, in m/s^2

$$a_{pitch\,z} = \Phi \frac{\pi}{180}\left(\frac{2\pi}{T_P}\right)^2 \left|(x_G - 0.45L)\right|$$

where $\left|(x_G - 0.45L)\right|$ is to be taken not less than 0.2L

$R \quad = z_G - \min\left(\frac{D}{4} + \frac{T_{LC}}{2}, \frac{D}{2}\right)$

x_G : longitudinal distance of the centre of gravity of the compartment, in m, from the origin of the ship co-ordinate system located on aft perpendicular

y_G : transverse distance of the centre of gravity of the compartment, in m, from the origin of the ship co-ordinate system located on centreline

y_G is taken as positive when the center of gravity of the tank is on the weather side, and negative when the considered center of gravity of the tank is on the lee side.

z G : vertical distance of the centre of gravity of the compartment, in m, from the origin of the ship co-ordinate system located on baseline

Chapter 4 – Design loads

Welcome JBP

Section 3 – HULL GIRDER LOADS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

x : X co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system

f_p : Coefficient corresponding to the probability, defined in Ch 4, Sec 2

1. General

1.1 Sign conventions of bending moments and shear forces

1.1.1

Absolute values are to be taken for bending moments and shear forces introduced in this Section. The sign of bending moments and shear forces is to be considered according to Sec 4, Tab 3. The sign conventions of vertical bending moments, horizontal bending moments and shear forces at any ship transverse section are as shown in Fig 1, namely:

- the vertical bending moments M_{SW} and M_{WV} are positive when it induces tensile stresses in the strength deck (hogging bending moment); negative in the opposite case (sagging bending moment)
- the horizontal bending moment M_{WH} is positive when it induce tensile stresses in the starboard; negative in the opposite case.
- the vertical shear force Q is positive in the case of downward resulting forces preceding and upward resulting forces following the ship transverse section under consideration; it is negative in the opposite case.

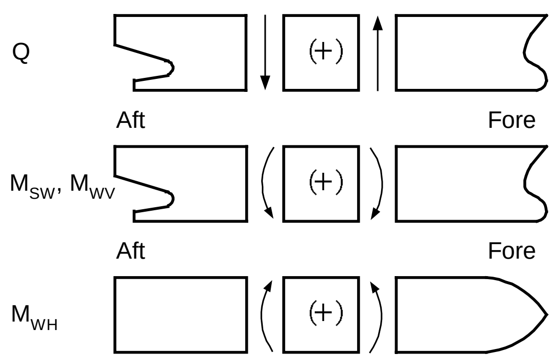


Figure 1: Sign conventions for shear forces Q and bending moments M_{SW}, M_{WV}, M_H

2. Still water loads

2.1 General

2.1.1

In general the vertical still water bending moment and the shear force of the individual loading condition is to be applied. The shipbuilder has to submit for each of the loading condition defined in Ch 4, Sec 7 a longitudinal strength calculation.

The values of still water vertical bending moment and shear force are to be treated as the upper limits with respect to hull girder strength.

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

2.1.2 Partially filled ballast tanks in ballast loading conditions

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

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

• for BC-A and BC_B ships, longitudinal strength of hull girder in flooded condition according to Ch 5, Sec 1, [2.1.4] is complied with for all filling levels between empty and full.

However, for the purpose of design, it is acceptable if, in each condition at departure, arrival and, where required by [2.1.1], any intermediate condition, the tanks intended to be partially filled are assumed to be empty and full. In addition, the specified partly filled level in the intended condition is to be considered.

2.1.3 Partially filled ballast tanks in cargo loading conditions

In cargo loading conditions, the requirement in [2.1.2]. applies to the peak tanks only.

2.2 Still water bending moment

2.2.1

The design still water bending moments $M_{SW,H}$ and $M_{SW,S}$ at any hull transverse section are the maximum still water bending moments calculated, in hogging and sagging conditions, respectively, at that hull transverse section for the loading conditions, as defined in [2.1.1]. Greater values may be considered if defined by the Designer.

2.2.2

If the design still water bending moments are not defined, at a preliminary design stage, at any hull transverse section, the longitudinal distributions shown in Fig 2 may be considered.

In Fig 2, M_{SW} is the design still water bending moment amidships, in hogging or sagging conditions, whose values are to be taken not less than those obtained, in kN.m, from the following formulae:

- hogging conditions:

$$M_{SW,H} = 175CL^2B(C_B + 0,7)10^{-3} - M_{WV,H}$$

- sagging conditions:

$$M_{SW,S} = 175CL^2B(C_B + 0,7)10^{-3} - M_{WV,S}$$

where $M_{WV,H}$, $M_{WV,S}$ are the vertical wave bending moments, in kN.m, defined in [3.1].

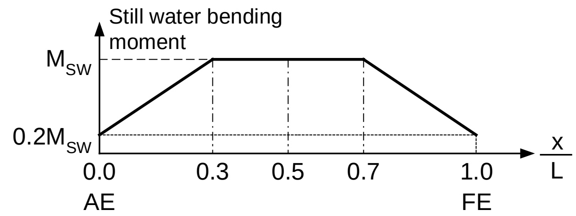


Figure 2: Preliminary still water bending moment distribution

2.3 Still water shear force

2.3.1

The design still water shear force Q_{SW} at any hull transverse section is the maximum positive or negative shear force calculated, at that hull transverse section, for the loading conditions, as defined in [2.1.1]. Greater values may be considered if defined by the Designer.

2.4 Still water bending moment in damaged condition

2.4.1

The still water bending moment in damaged condition is to be determined for the flooding scenario considering each cargo hold individually flooded up to the equilibrium waterline.

This means that double side spaces may not be considered flooded, and the cargo holds may not be considered completely flooded, but only up to the equilibrium waterline.

2.4.2

To calculate the weight of ingressed water, the following assumptions are to be made:

a) The permeability of empty cargo spaces and volume left in loaded cargo spaces above any cargo is to be taken as 0.95.

b) Appropriate permeabilities and bulk densities are to be used for any cargo carried. For iron ore, a minimum permeability of 0.3 with a corresponding bulk density of 3.0 t/m^3 is to be used. For cement, a minimum permeability of 0.3 with a corresponding bulk density of 1.3 t/m^3 is to be used. In this respect, "permeability" for solid bulk cargo means the ratio of the floodable volume between the particles, granules or any larger pieces of the cargo, to the gross volume of the bulk cargo.

For packed cargo conditions (such as steel mill products), the actual density of the cargo should be used with a permeability of zero.

2.4.3

To quantify the effects of ingressed water on the hull girder still water bending moments, specific calculations are to be carried out. The loading conditions on which the design of the ship has been based are to be considered and, for each of them, the cargo holds are to be considered as being individually flooded up to the equilibrium waterline. The still water bending moments are therefore to be calculated for any combination of considered loading conditions and flooded cargo holds.

3. Wave-loads

3.1 Vertical wave bending moments

3.1.1 Intact condition

The vertical wave bending moments in intact condition at any hull transverse section are obtained, in kN.m, from the following formulae:

- hogging conditions:

  $M_{WV,H} = 190\ F_M\ f_p\ C\ L^2\ B\ C_B\ 10^{-3}$

- sagging conditions:

  $M_{WV,S} = 110\ F_M\ f_p\ C\ L^2\ B\ (C_B + 0,7)\ 10^{-3}$

where:

F_M : Distribution factor defined in Tab 1 (see also Fig 3).

Table 1: Distribution factor F_M

Hull transverse section location	Distribution factor F_M
$0 \le x < 0,4\ L$	$2,5\dfrac{x}{L}$
$0,4\ L \le x \le 0,65\ L$	1,0
$0,65\ L < x \le L$	$2,86\left(1-\dfrac{x}{L}\right)$

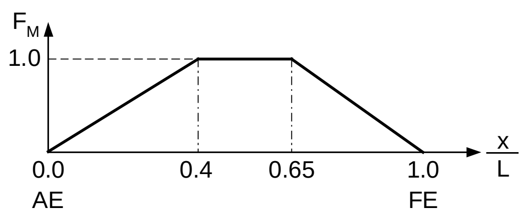


Figure 3: Distribution factor F_M

3.1.2 Flooded condition

For BC-A and BC_B ships, the vertical wave bending moments in flooded condition at any hull transverse section are obtained, in kN.m, from the following formulae:

$$M_{WV,F} = 0.8 M_{WV}$$

where M_{WV} is defined in [3.1.1].

3.1.3 Harbour condition

The vertical wave bending moments in harbour condition at any hull transverse section are obtained, in kN.m, from the following formulae:

$$M_{WV,H} = 0,4 M_{WV}$$

where M_{WV} is defined in [3.1.1].

3.2 Vertical wave shear force

3.2.1 Intact condition

The vertical wave shear force in intact condition at any hull transverse section is obtained, in kN, from the following formula:

$Q_{WV} = 30\ F_Q\ f_p\ C\ L\ B\ (C_B + 0{,}7)\ 10^{-2}$

where:

F_Q : Distribution factor defined in Tab 2 for positive and negative shear forces (see also Fig 4).

Table 2: Distribution factor F_Q

Hull transverse section location	Distribution factor F_Q	
	Positive wave shear force	Negative wave shear force
$0 \le x < 0{,}2\ L$	$4{,}6A\dfrac{x}{L}$	$4{,}6\dfrac{x}{L}$
$0{,}2\ L \le x \le 0{,}3\ L$	0,92 A	0,92
$0{,}3\ L < x < 0{,}4\ L$	$(9{,}2A-7)\left(0{,}4-\dfrac{x}{L}\right)+0{,}7$	$2{,}2\left(0{,}4-\dfrac{x}{L}\right)-0{,}7$
$0{,}4\ L \le x \le 0{,}6\ L$	0,7	0,7
$0{,}6\ L < x < 0{,}7\ L$	$3\left(\dfrac{x}{L}-0{,}6\right)+0{,}7$	$(10A-7)\left(\dfrac{x}{L}-0{,}6\right)-0{,}7$
$0{,}7\ L \le x \le 0{,}85\ L$	1	A
$0{,}85\ L < x \le L$	$6{,}67\left(1-\dfrac{x}{L}\right)$	$6{,}67A\left(1-\dfrac{x}{L}\right)$
Note 1: $A = \dfrac{190 C_B}{110(C_B+0{,}7)}$		

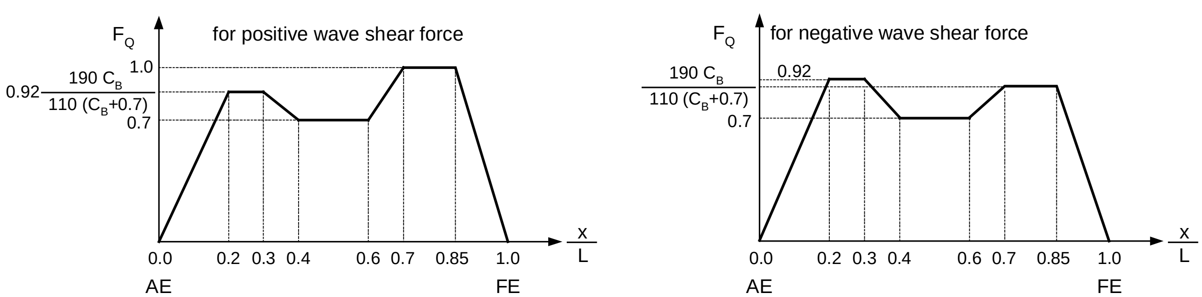


Figure 4: Distribution factor F_Q

3.2.2 Flooded condition

For BC-A and BC_B ships, the vertical wave shear force in flooded condition at any hull transverse section are obtained, in kN.m, from the following formulae:

$$Q_{WV,F} = 0.8 Q_{WV}$$

where Q_{WV} is defined in [3.1.1].

3.2.3 Harbour condition

The vertical wave shear force in harbour condition at any hull transverse section are obtained, in kN.m, from the following formulae:

$$Q_{WV,H} = 0,4 Q_{WV}$$

where Q_{WV} is defined in [3.1.1].

3.3 Horizontal wave bending moment

3.3.1

The horizontal wave bending moment at any hull transverse section, in kN.m, is given by:

$$M_{WH} = \left(0.3 + \frac{L}{2000}\right) F_M \, f_p C L^2 T_{LC} C_B$$

where F_M is the distribution factor defined in [3.1.1]

Chapter 4 – Design loads

Welcome JBP

Section 4 – LOAD CASES

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

a_{surge}, $a_{pitch\ x}$, a_{sway}, $a_{roll\ y}$, a_{heave}, $a_{roll\ z}$, $a_{pitch\ z}$, :components of accelerations, defined in Ch 4, Sec 2

1. General

1.1 Application

1.1.1

The load cases described in this section are those to be used for:

- the local strength analysis of plating and ordinary stiffeners, according to the applicable requirements of Ch 6, Sec 1 and Ch 6, Sec 2, respectively,
- the direct strength analysis of structural members, according to the applicable requirements of Ch 7,
- the fatigue check of structural details, according to the applicable requirements of Ch 8.

1.1.2

For the local strength analysis and for the direct strength analysis, the load cases are the mutually exclusive load cases H1, H2, F1, F2, R1, R2, P1 and P2 described in [2].

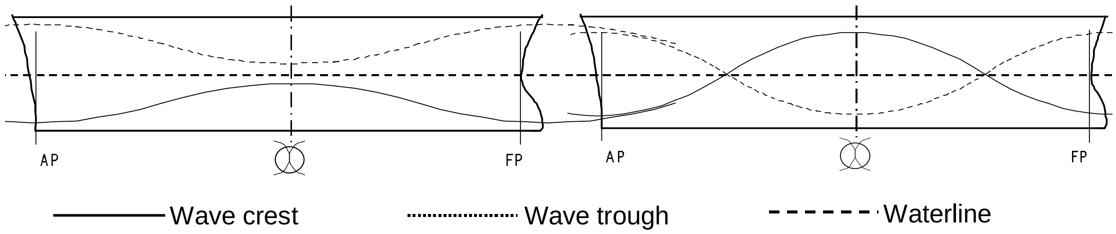
1.2 Equivalent design wave

1.2.1

Regular waves that generate response values equivalent to the long-term response values of the load components considered being predominant to the structural members are set as Equivalent Design Waves (EDWs). They consist of:

- Regular waves when the vertical wave bending moment becomes maximum in head sea (EDW "H")
- Regular waves when the vertical wave bending moment becomes maximum in following sea (EDW "F")
- Regular waves when the roll motion becomes maximum (EDW "R")
- Regular waves when the hydrodynamic pressure at the waterline becomes maximum (EDW "P")

The definitions of wave crest and wave trough in the EDW "H" and EDW "F" are given in Fig. 1. The definitions of weather side down and weather side up for the EDW "R" and EDW "P" are given in Fig. 2.



(a) for EDW “H” (b) for EDW ”F”

Figure 1: Definition of wave crest and wave trough for EDWs “H” and “F”

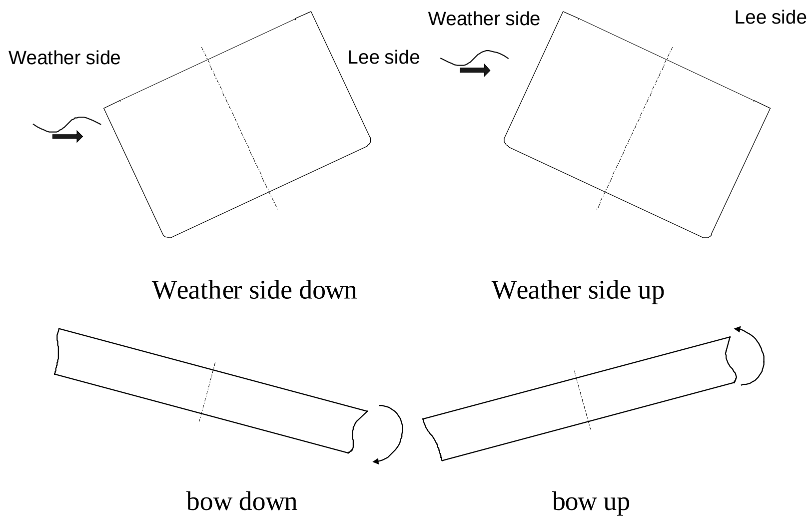


Figure 2: Definitions of ship motion

2. Load cases

2.1 General

2.1.1

The load cases corresponding to the Equivalent Design Waves (EDWs) are defined in Tab 1. The corresponding hull girder loads and motions of the ship are indicated in Tab 2.

Table 1: Definition of load cases

Load case	***H1***	***H2***	***F1***	***F2***	***R1***	***R2***	***P1***	***P2***
EDW	“H”		“F”		“R”		“P”	
Heading	Head		Follow		Beam		Beam	
Effect	Max Bending Moment		Max Bending Moment		Max. roll		Max Ext. Pressure	
	Sagging	Hogging	Sagging	Hogging)	(+)	(-)	(+)	(-)

Table 2: Reference hull girder loads and motions of ship

Load case	*H1*	*H2*	*F1*	*F2*	*R1*	*R2*	*P1*	*P2*
Vert. BM & SF	*Yes*		*Yes*		-		*Yes*	
Hor. BM	-		-		*Yes*		-	
Heave	*Down*	*Up*	-	-	*Down*	*Up*	*Down*	*Up*
Pitch	*Bow down*	*Bow up*	-	-	-	-	-	-
Roll	-	-	-	-	*Stbd up*	*Stbd down*	*Stbd up*	*Stbd down*
Surge	*Bow*	*Bow*	-	-	-	-	-	-
Sway	-	-	-	-	-	-	*Port*	*Port*

2.2 Load combination factors

2.2.1

The hull girder loads and the acceleration components to be considered in each load case H1, H2, F1, F2, R1, R2, P1 and P2 are to be obtained by multiplying the reference absolute value of each component by the relevant load combination factor LCF defined in Tab 3.

2.2.2

The still water vertical bending moment is to be added to the hull girder loads in waves, calculated with load combination factors.

2.2.3

The internal loads are the sum of static pressures or forces induced by the weights carried, including those carried on decks, and of inertial pressures or forces induced by the accelerations on these weights and calculated with load combination factors.

Table 3: Load combination factors LCF

	LCF	*H1*	*H2*	*F1*	*F2*	*R1*	*R2*	*P1*	*P2*
M_{WV}	C_{WV}	-1	1	-1	1	0	0	$0,4-\frac{T_{LC}}{T}$	$\frac{T_{LC}}{T}-0,4$
Q_{WV}	C_{QW}*	-1	1	-1	1	0	0	$0,4-\frac{T_{LC}}{T}$	$\frac{T_{LC}}{T}-0,4$
M_{WH}	C_{WH}	0	0	0	0	$1,2-\frac{T_{LC}}{T}$	$\frac{T_{LC}}{T}-1,2$	0	0
a_{surge}	C_{XS}	-0.8	0.8	0	0	0	0	0	0
$a_{pitch\ x}$	C_{XP}	1	-1	0	0	0	0	0	0
$g\sin\Phi$	C_{XG}	1	-1	0	0	0	0	0	0
a_{sway}	C_{YS}	0	0	0	0	0	0	1	-1
$a_{roll\ y}$	C_{YR}	0	0	0	0	1	-1	0.3	-0.3
$g\sin\theta$	C_{YG}	0	0	0	0	1	-1	0.3	-0.3
a_{heave}	C_{ZH}	$0,6\frac{T_{LC}}{T}$	$-0,6\frac{T_{LC}}{T}$	0	0	$\frac{\sqrt{L}}{40}$	$-\frac{\sqrt{L}}{40}$	1	-1
$a_{roll\ z}$	C_{ZR}	0	0	0	0	1	-1	0.3	-0.3
$a_{pitch\ z}$	C_{ZP}	1	-1	0	0	0	0	0	0

1) Note * The LCF for C_{QW} is only used for the aft part of midship section. The inverse value of it should be used for the forward part of the midship section.

Chapter 4 – Design loads

Welcome JBP

Section 5 – EXTERNAL PRESSURE

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

λ : Wave length, in m, corresponding to the load case, defined in [1.3.1], [1.4.1], and [1.5.1]

f_p : Coefficient corresponding to the probability, defined in Ch 4, Sec 2

T_{LCi} : Draught in the considered cross section, in m, in the considered loading condition

B_i : Moulded breadth at the waterline, in m, in the considered cross section

x, y, z : X, Y and Z co-ordinates, in m, of the load point with respect to the reference co-ordinate system defined in Ch 1, sec 4.

1. External sea pressures on side shell and bottom

1.1 General

1.1.1

The total pressure p at any point of the hull, in kN/m², to be obtained from the following formula should not be negative:

$p = p_S + p_W$

Where:

p_S : Hydrostatic pressure defined in [1.2]

p_W : Wave pressure equal to the hydrodynamic pressure defined in [1.3], [1.4] or [1.5], as the case may be, and corrected according to [1.6]

1.2 Hydrostatic pressure

1.2.1

The hydrostatic pressure p_S at any point of the hull, in kN/m², corresponding to the draught in still water is obtained, for each loading condition, from the formulae in Tab 1 (see also Fig 1).

Table 1: Hydrostatic pressure p_S

Location	Hydrostatic pressure, p_S, in kN/m²
Points at and below the waterline ($z \le T_{LCi}$)	$\rho\, g\, (T_{LCi} - z)$
Points above the waterline ($z > T_{LCi}$)	0

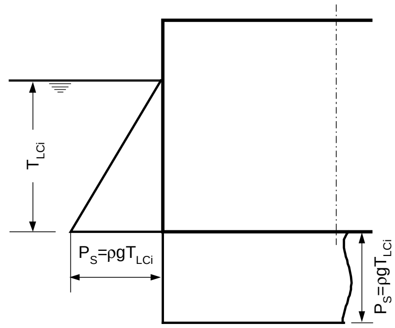


Figure 1: Hydrostatic pressure p_S

1.3 Hydrodynamic pressure – Load cases H1, H2, F1 and F2

1.3.1

The hydrodynamic pressures p_H and p_F, for load cases H1, H2, F1 and F2, at any point of the hull below the waterline are to be obtained, in kN/m^2, from Tab 2.

The distribution of pressure p_{F2} is schematically given in Fig 2.

Table 2: Hydrodynamic pressures for load cases H1 ,H2, F1 and F2

Load case	Hydrodynamic pressure, in kN/m^2
H1	$p_{H1} = - k\ \ k_P\, p_{HF}$
H2	$p_{H2} = k\ \ k_P\, p_{HF}$
F1	$p_{F1} = - p_{HF}$
F2	$p_{F2} = p_{HF}$

where:

$$p_{HF} = 3 f_p f_{nl} C \sqrt{\frac{L+\lambda-125}{L}} \left(\frac{z}{T_{LCi}} + \frac{|2y|}{B_i} + 1 \right); \quad \text{with } \frac{|2y|}{B_i} \le 1.0 \text{ and z is to be taken not greater than } T_{LCi}$$

f_{nl} : Coefficient considering nonlinear effect, taken equal to:

- $f_{nl} = 0,9$, for the probability level of 10^{-8}
- $f_{nl} = 1,0$, for the probability level of 10^{-4}

k_l : Amplitude coefficient in the longitudinal direction of the ship, taken equal to:

- $k \ = 1 + \frac{12}{C_B}\left(1-\sqrt{\frac{|2y|}{B}}\right)\left|\frac{x}{L}-0,5\right|^3$, for $0,0 \le x/L \le 0,5$
- $k \ = 1 + \frac{6}{C_B}\left(3-\frac{|4y|}{B}\right)\left|\frac{x}{L}-0,5\right|^3$, for $0,5 \le x/L \le 1,0$

k_p : Phase coefficient in the longitudinal direction of the ship, taken equal to:

- $k_P = \left(1.25 - \frac{T_{LC}}{T}\right)\cos\left(\frac{2\pi|x-0,5L|}{L}\right) - \frac{T_{LC}}{T} + 0.25$, for direct strength analysis and fatigue strength assessments
- $k_P = 1,0$, for local strength analysis

λ : Wave length, in m, taken equal to:

- $\lambda = 0.6\left(1 + \frac{T_{LC}}{T}\right)L$ for load cases H1 and H2
- $\lambda = 0.6\left(1 + \frac{2}{3}\frac{T_{LC}}{T}\right)L$ for load cases F1 and F2

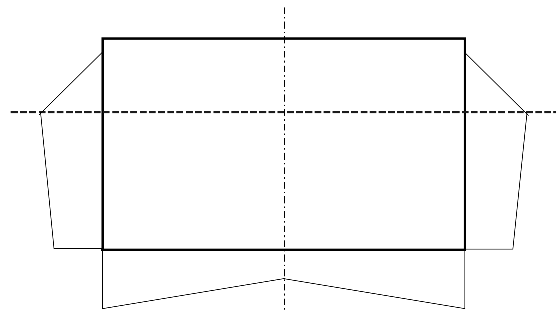


Figure 2: Distribution of hydrodynamic pressure p_{F2} at midship

1.4 Hydrodynamic pressure – Load cases R1 and R2

1.4.1

The hydrodynamic pressures p_R, for load cases R1 and R2, at any point of the hull below the waterline are to be obtained, in kN/m^2, from the following formulae. The distribution of pressure p_{R1} is schematically given in Fig. 3.

$$p_{R1} = f_{nl}\left(10 y \sin\theta + 0.88 f_p C \sqrt{\frac{L + \lambda - 125}{L}}\left(\frac{|2y|}{B} + 1\right)\right)$$

$$p_{R2} = -p_{R1}$$

where:

f_{nl} = Coefficient considering nonlinear effect, taken equal to:

- $f_{nl} = 0,8$, for the probability level of 10^{-8}
- $f_{nl} = 1,0$, for the probability level of 10^{-4}

$$\lambda = \frac{g}{2\pi} T_R^2$$

y = Y co-ordinate of the load point, in m, taken positive on the weather side

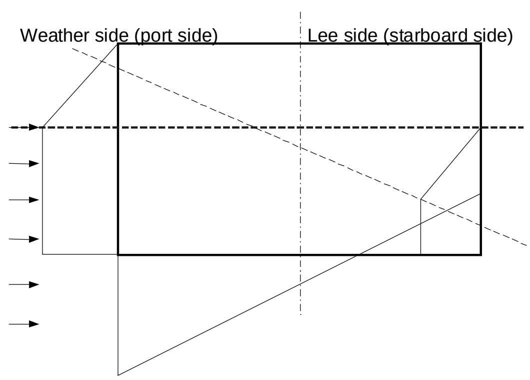


Figure 3: Distribution of hydrodynamic pressure p_{R1} at midship

1.5 Hydrodynamic pressure – Load cases P1 and P2

1.5.1

The hydrodynamic pressures p_P, for the load cases P1 and P2, at any point of the hull below the waterline are to be obtained, in kN/m^2, from Tab 3. The distribution of pressure p_{P1} is schematically given in Fig. 4.

Table 3: Hydrodynamic pressures for load cases P1 and P2

Load case	Hydrodynamic pressure, in kN/m^2	
	weather side (port side)	lee side (starboard side)
P1	$p_{P1} = p_P$	$p_{P1} = p_P / 3$
P2	$p_{P2} = - p_P$	$p_{P1} = - p_P / 3$

where:

$$p_P = 4.5 f_p f_{nl} C \sqrt{\frac{L + \lambda - 125}{L}} \left(2 \frac{|z|}{T_{LCi}} + 3 \frac{|2y|}{B} \right)$$

f_{nl} = Coefficient considering nonlinear effect, taken equal to:

- $f_{nl} = 0,65$, for the probability level of 10^{-8}
- $f_{nl} = 1,0$, for the probability level of 10^{-4}

$$\lambda = \left(0.2 + 0.4 \frac{T_{LC}}{T} \right) L$$

y = Y co-ordinate of the load point, in m, as defined in [1.4.1]

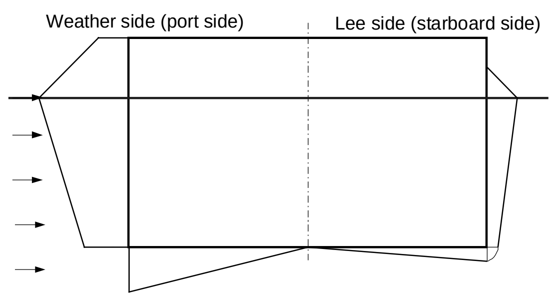


Figure 4: Distribution of hydrodynamic pressure p_{P1} at midship

1.6 Correction to hydrodynamic pressure

1.6.1

The hydrodynamic pressure may be considered to have a uniform distribution in the longitudinal direction of the ship within the range of the hold model.

1.6.2

For the positive hydrodynamic pressure at the waterline [in load cases H1, H2, F1, R1, R2 and P1], the hydrodynamic pressure $P_{W,C}$ at the side above waterline is given (see also Fig. 5), in kN/m^2, by:

- $p_{W,C} = p_{W,WL} + \rho g (T_{LCi} - z)$ for $T_{LCi} \le z \le h_W + T_{LCi}$
- $p_{W,C} = 0$ for $z \ge h_W + T_{LCi}$

where:

$p_{W,WL}$: positive hydrodynamic pressure at the waterline for the considered load case

$$h_W = \frac{p_{W,WL}}{\rho g}$$

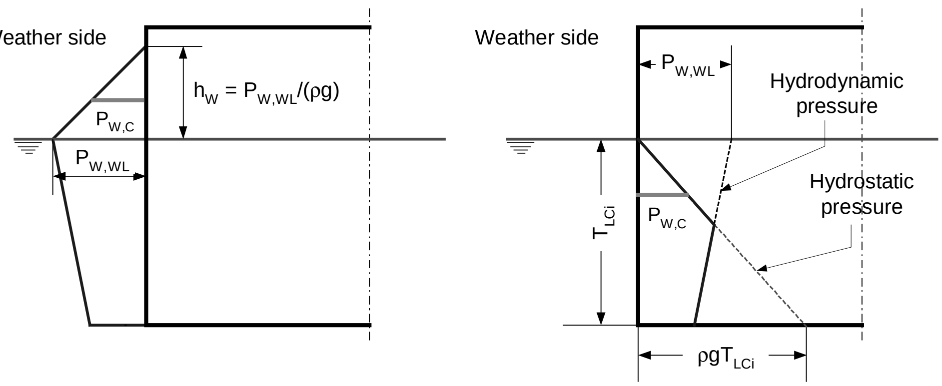
1.6.3

For the negative hydrodynamic pressure at the waterline [in load cases H1, H2, F2, R1, R2, and P2], the hydrodynamic pressure $P_{W,C}$, under the waterline is given (see also Fig. 5), in kN/m^2, by:

$p_{W,C} = p_W$, without being taken less than $\rho g(z-T_{LCi})$

where

p_W : Negative hydrodynamic pressure under the waterline for the considered load case



When hydrodynamic pressure is positive When hydrodynamic pressure is negative

Figure 5: Correction to hydrodynamic pressure

2. External pressures on exposed decks

2.1 General

2.1.1

If a breakwater is fitted on the exposed deck, no reduction in the external pressures defined in [2.2] and [2.3] is allowed for the area of the exposed deck located aft of the breakwater.

2.2 Load cases H1, H2, F1 and F2

2.2.1

The external pressure p_D, for load cases H1, H2, F1 and F2, at any point of an exposed deck is to be obtained, in kN/m^2, from the following formula:

$$p_D = \varphi p_W$$

where:

p_W : Pressure obtained from the formulae in Tab 4

φ : Coefficient defined in Tab 5

Table 4: Pressures on exposed decks for H1 ,H2, F1 and F2

Location	Pressure p_W, in kN/m^2	
	$L_{LL} \geq 100$ m	$L_{LL} < 100$ m
$0 \leq x/L_{LL} \leq 0{,}75$	34,3	$14{,}9 + 0{,}195\ L_{LL}$
$0{,}75 < x/L_{LL} < 1$	$34{,}3 + (14{,}8 + a(L_{LL} - 100))\left(4\frac{x}{L_{LL}} - 3\right)$	$12{,}2 + \frac{L_{LL}}{9}\left(5\frac{x}{L_{LL}} - 2\right) + 3{,}6\frac{x}{L_{LL}}$
Note 1: a : coefficient taken equal to: a = 0,0726 for Type B freeboard ships a = 0,356 for Type B-60 or Type B-100 freeboard ships.		

Table 5: Coefficient for pressure on exposed decks

Exposed deck location	φ
Freeboard deck and forecastle deck	1
Superstructure deck, excluding forecastle deck	0,75
1st tier of deckhouse	0,56
2nd tier of deckhouse	0,42
3rd tier of deckhouse	0,32
4th tier of deckhouse	0,25
5th tier of deckhouse	0,20
6th tier of deckhouse	0,15
7th tier of deckhouse and above	0,10

2.3 Load cases R1, R2, P1 and P2

2.3.1

The external pressure p_D, for load cases R1, R2, P1 and P2, at any point of an exposed deck is to be obtained, in kN/m^2, from the following formula:

$$p_D = 0{,}4 \varphi p_W$$

where:

p_W : Value of p_{R1}, p_{R2}, p_{P1} and p_{P2}, in kN/m^2, as defined in [1.3] and [1.4], determined at the z co-ordinate of the exposed deck for the load case considered

φ : Coefficient defined in Tab 5.

2.4 Load carried on exposed deck

2.4.1

If a specific load is carried on an exposed deck, the static pressure p_S corresponding to this load is to be defined by the Designer and, in general, is not to be taken less than 10 kN/m^2.

The total pressure p due to this load is to be considered not simultaneously to the pressures defined in [2.2] and [2.3], but in addition to them. It is to be taken equal, in kN/m^2, to the greater of the two following formulae:

$p = p_S + p_W$

$p = 0{,}3\ p_D$

where:

p_S : Static pressure due to the load carried, if any, as defined in [2.1.1]

p_W : Wave pressure, in kN/m^2, taken equal to:

$$p_W = \frac{a_Z}{g} p_S$$

a_Z : Vertical acceleration for the load case considered, in m/s^2, defined in Ch 4, Sec 2, [3.2]

p_D : Pressure for the exposed deck, for the load case considered, as defined in [2.2.1] and [2.3.1]

3. External pressures on hatch covers

3.1 General

3.1.1

If a specific load is carried on a hatch cover, the pressure is to be obtained according to [2.4].

3.2 Wave pressure

3.2.1

The pressure at any point of the hatch cover is to be obtained according to [2.2.1], considering φ equal to 1,0.

However, when the hatchway is located at least one superstructure standard height, as defined in Ch 1, Sec 4, [3.14], higher than the freeboard deck, the pressure p_W may be taken equal to 34,3 kN/m^2.

3.3 Conventional pressure

3.3.1

The conventional pressure p_0 is defined in Tab 6 according to the hatch cover location.

Table 6: Conventional pressure on hatch cover

Location	Conventional pressure p_0, in kN/m^2
Position 1	$g\left(\frac{58 + 0,75L}{76}\right)$, without being taken greater than 1,75g
Position 2	$g\left(\frac{43,8 + 0,55L}{76}\right)$, without being taken greater than 1,3g
Note 1: Positions 1 and 2 are defined in Ch 1, Sec 4, [3.16]	

4. External pressures on superstructure and deckhouses

4.1 Exposed decks

4.1.1

External pressures on exposed decks of superstructures and deckhouses are to be obtained according to [2].

4.2 Front, sides and aft bulkhead

4.2.1

External pressures on front, sides and aft bulkhead of superstructures and deckhouses are to be obtained according to Ch 9, Sec 4.

5. Impact pressure in fore part

5.1

Under development

Chapter 4 – Design loads

Welcome JBP

Section 6 – INTERNAL PRESSURES AND FORCES

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

ρ_C : Density of the dry bulk cargo, in t/m^3, taken equal to:

- the value given in Tab 1 for ships having a length of 150 m and above
- the maximum density from the loading manual for ships having a length less than 150 m

Table 1: Density of dry bulk cargo

	BC-A , BC-B	BC-C
Light cargo	max(W/Vc, 1.0)	1.0
Heavy cargo	3.0*	N/A

* except otherwise specified by the designer.

ρ_L : Density of internal liquid, in t/m^3, taken equal to 1.025 when internal liquid is ballast water

W : Mass, in t, of the bulk cargo in the considered hold

V_C : volume, in m^3, of cargo hold excluding the volume enclosed by hatch coaming

K_C : Coefficient taken equal to:

- $K_C = \cos^2\alpha + (1 - \sin\psi)\sin^2\alpha$, for $0° \le \alpha \le 90°$
- $K_C = 0$, for $\alpha > 90°$

α : Angle, in deg, between panel considered and the horizontal plane

ψ : Assumed angle of repose, in deg, of bulk cargo (considered drained and removed); in the absence of more precise evaluation, the following values may be taken:

- $\psi = 30°$, in general
- $\psi = 35°$, for iron ore
- $\psi = 25°$, for cement

h_C : Vertical distance, in m, from the inner bottom to the upper surface of bulk cargo , as defined in [1.1.1]

h_{DB} : Height, in m, of the double bottom in the centreline

h_{LS} : Mean height, in m, of the lower stool, measured from the inner bottomz_{TOP} : Z co-ordinate, in m, of the top of the tank, in upright condition

z_{B0} : Z co-ordinate, in m, of the top of the overflow pipe

a_X : Longitudinal acceleration of the centre of gravity of the hold or tank considered, in m/s^2, defined in Ch 4, Sec 2, [3.2]

a_Y : Transverse acceleration of the centre of gravity of the hold or tank considered, in m/s^2, defined in Ch 4, Sec 2, [3.2]

a_Z : Vertical acceleration of the centre of gravity of the hold or tank considered, in m/s^2, defined in Ch 4, Sec 2, [3.2]

B_H : Breadth of the cargo hold, in m

ℓ_H : Length of the cargo hold, in m

b_{IB} : Breadth of inner bottom, in m

D_1 : Distance, in m, from the base line to the freeboard deck at side amidships

S_1 : Spacing of corrugations, in m; see Ch 3, Sec 6, Fig 27

x, y, z : X, Y and Z co-ordinates, in m, of the load point with respect to the reference co-ordinate system defined in Ch 1, Sec 4. y is to be taken positive on the weather side

x_G, y_G, z_G : X, Y and Z co-ordinates, in m, of the centre of gravity of the hold or tank considered with respect to the reference co-ordinate system defined in Ch 1, Sec 4

d_{AP} : Distance from the top of air pipe to the top of compartment, in m

1. Lateral pressure due to dry bulk cargo

1.1 Dry bulk cargo upper surface

1.1.1

When the dry bulk cargo density is such that the cargo hold is loaded up to the upper deck (i.e. light cargo), the upper surface of the bulk cargo is taken at the distance h_C, in m, from the inner bottom obtained from the following formula (see Fig 1):

$$h_C = h_{HPU} + h_0$$

$$h_0 = \frac{S_0}{B_H}$$

h_{HPU} : vertical distance, in m, between inner bottom and lower intersection of top side tank and inner side, as defined in Fig. 1

S_0 : shaded area, in m^2, as defined in Fig. 1

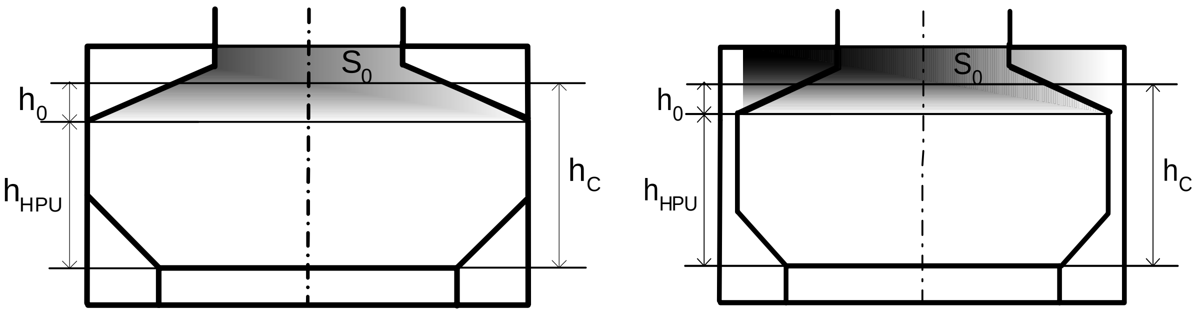


Figure 1: Definitions of h_C, h_0, h_{HPU} and S_0

1.1.2

When the dry bulk cargo density is such that the cargo hold is not loaded up to the upper deck (i.e. heavy cargo), the upper surface of the bulk cargo is taken at the distance h_C, in m, from the inner bottom obtained from the following formula (see Fig 2):

$$h_C = h_{HPL} + h_1 + h_2$$

where:

h_{HPL} : vertical distance, in m, between inner bottom and upper intersection of hopper tank and inner side, as defined in Fig. 2. h_{HPL} is to be taken equal to 0 if there is no hopper tank.

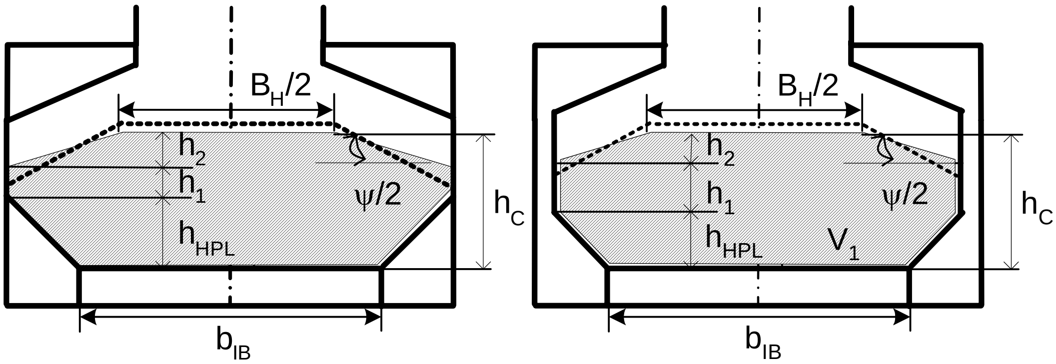
h_1 : the vertical distance obtained from the following formula, see Fig. 2.

$$h_1 = \frac{W}{\rho_C \cdot B_H l_H} - \frac{B_H + b_{IB}}{2B_H} h_{HPL} - \frac{3}{16} B_H \tan\frac{\psi}{2}$$

h_2 : bulk cargo upper surface, depending on y, given by:

$$h_2 = \frac{B_H}{4}\tan\frac{\psi}{2}\text{, if } 0 \le |y| \le \frac{B_H}{4}$$

$$h_2 = \left(\frac{B_H}{2} - |y|\right)\tan\frac{\psi}{2}\text{, if } \frac{B_H}{4} \le |y| \le \frac{B_H}{2}$$



Single hull bulk carrier   Double hull bulk carrier

Figure 2: Definitions of h_C, h_1, h_2 and h_{HPL}

1.2 Dry bulk cargo pressure in still water

1.2.1

The dry bulk cargo pressure in still water p_{CS}, in kN/m^2, is given by:

$$p_{CS} = \rho_C g K_C (h_C + h_{DB} - z)$$

1.3 Inertial pressure due to dry bulk cargo

1.3.1

The inertial pressure induced by dry bulk cargo p_{CW}, in kN/m^2, for each load case is given by the following formulae.

- for load case H: $p_{CW} = \rho_C [0{,}25 a_X (x - x_G) + K_C a_Z (h_C + h_{DB} - z)]$
- for load case F: $p_{CW} = 0$
- for load cases R and P: $p_{CW} = \rho_C [0{,}25 a_Y (y - y_G) + K_C a_Z (h_C + h_{DB} - z)]$

$(x - x_G)$ may be taken as $0.25\ell_H$ for local strength by Ch 6 and fatigue check for longitudinal stiffeners by Ch 8.

1.4 Shear load due to dry bulk cargo

1.4.1

In order to evaluate the total force in the vertical direction, shear load due to dry bulk cargo in way of sloping members is to be considered.

The shear load due to dry bulk cargo in the vertical direction in still water $p_{CS\text{-}S}$ (positive downward), in kN/m^2, is given by:

$$p_{CS-S} = \rho_C g \frac{(1-K_C)(h_C + h_{DB} - z)}{\tan\alpha}$$

The shear load due to dry bulk cargo in the vertical direction in waves $p_{CW\text{-}S}$ (positive downward), in kN/m^2, is given by:

- for load cases H, R and P: $p_{CW-S} = \rho_C a_Z \frac{(1-K_C)(h_C + h_{DB} - z)}{\tan\alpha}$
- for load case F: $p_{CW-S} = 0$

1.4.2

In order to evaluate the total force in the longitudinal and horizontal directions, shear load due to dry bulk cargo in way of inner bottom plating is to be considered.

The shear load due to dry bulk cargo in the longitudinal direction in waves $p_{CW\text{-}S}$ (positive forward), in kN/m^2, is given by:

- for load case H: $p_{CW\text{-}S} = 0.75\rho_C\, a_X\, (h_C + h_{DB} - z)$
- for load cases F, R and P: $p_{CW\text{-}S} = 0$

The shear load due to dry bulk cargo in the transverse direction in waves $p_{CW\text{-}S}$ (positive weather side), in kN/m^2, is given by:

- for load cases R and P: $p_{CW\text{-}S} = 0.75\rho_C\, a_Y\, (h_C + h_{DB} - z)$
- for load cases H and F: $p_{CW\text{-}S} = 0$

2. Lateral pressure due to liquid

2.1 Pressure due to liquid in still water

2.1.1

The liquid pressure in still water p_{BS}, in kN/m^2, is given by:

$p_{BS} = \rho_L\, g(z_{TOP} - z + 0.5d_{AP}) + p_{PV}$

For local strength assessments, the static pressure p_{BS} is to be taken not less than 25 kN/m^2.

The pressure p_{PV} due to safety valveis to be considered, if any, and is given, in kN/m^2, as follows.

$p_{PV} = 100P_{PV}$

where:

P_{PV} : Setting pressure, in bar, of safety valves

2.1.2

If the ship is intended to perform ballast water exchange operations by means of the flow through method, the stationary pressure p_{BS} for local strength assessments and direct strength analysis in harbour condition by Ch 7 is to be not less than:

$p_{BS} = \rho_L\, g\, (z_{TOP} - z + d_{AP}) + 25$

2.2 Inertial pressure due to liquid

2.2.1

The inertial pressure due to liquid p_{BW}, in kN/m^2, for each load case is given as follows.

- for load case H: $p_{BW} = \rho_L \, [a_Z \, (z_{TOP} - z) + a_X \, (x - x_B)]$

$(x-x_B)$ may be taken as $0.75\ell_H$ for local strength by Ch 6 and fatigue check for longitudinal stiffeners by Ch 8

- for load case F: $p_{BW} = 0$
- for load cases R and P: $p_{BW} = \rho_L \, [a_Z \, (z_B - z) + a_Y \, (y - y_B)]$

where:

x_B : X co-ordinate, in m, of the aft end of the tank when the bow side is downward, or of the fore end of the tank when the bow side is upward, as defined in Fig. 3.

y_B : Y co-ordinate, in m, of the tank top located at the most lee-side when the weather side is downward, or of the most weather side when the weather side is upward, as defined in Fig. 3.

z_B : Z co-ordinate of the following point:

- for completely filled spaces: the tank top
    - for the hopper side tank and/or double bottom tank, which are not connected to the topside tank: the highest point between the tank top and a point located at mid-distance between the tank top and the top of the overflow
- for ballast hold: the top of the hatch coaming

The reference point B is defined as the upper most point after rotation by the angle between the vertical axis and the global resulting acceleration vector (a_X & a_Z) or (a_Y & a_Z).

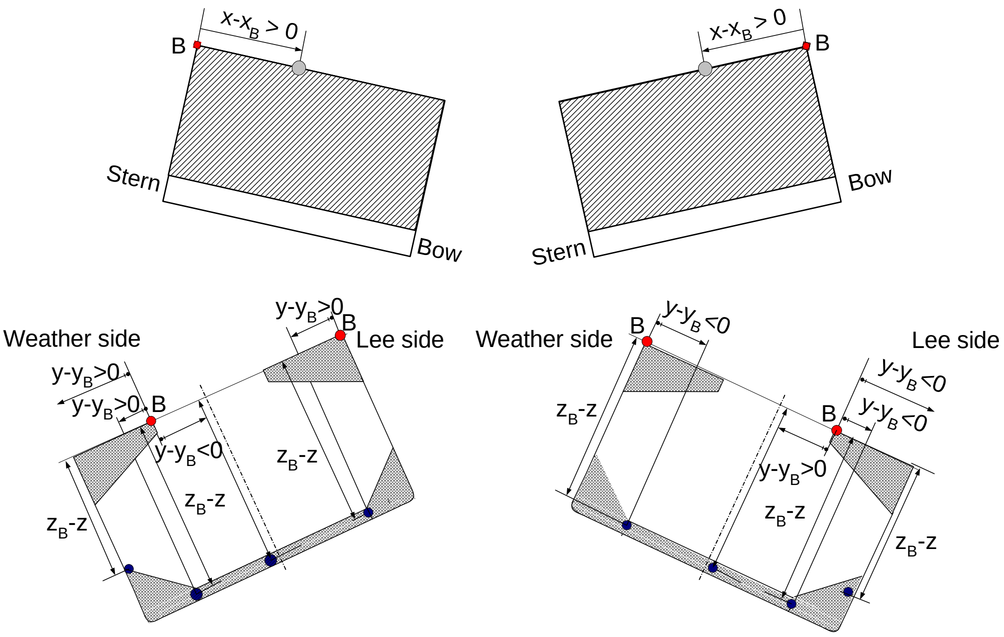


Figure 3: Definition of x_B and y_B

3. Flooding lateral pressures and forces

3.1 Application

3.1.1

The flooding pressures to be considered in flooding condition are indicated in:

- [3.2] in general cases
- [3.3] and [3.4]. for the particular cases of transverse corrugated bulkheads and double bottom of single side skin bulk carriers equal to or greater than 150 m in length, intended for the carriage of bulk cargoes having dry bulk density of 1,0 t/m^3 or above.

3.2 General

3.2.1

The pressure p_F to be considered as acting on plating (excluding bottom and side shell plating) which constitute boundaries of compartments not intended to carry liquids is to be obtained, in kN/m^2, from the following formula:

$p_F = \rho g \left(1 + 0{,}6 \frac{a_Z}{g}\right)(z_F - z)$, without being less than g d_0

where:

z_F : Z co-ordinate, in m, of the freeboard deck at side in way of the transverse section considered. Where the results of damage stability calculations are available, the deepest equilibrium waterline may be considered in lieu of the freeboard deck; in this case, the Society may require transient conditions to be taken into account

d_0 : Distance, in m, to be taken equal to:

- $d_0 = 0{,}02L$, for 90 m $\le L <$ 120 m
- $d_0 = 2{,}4$, for $L \ge$ 120 m

3.3 Transverse vertically corrugated watertight bulkheads of single side skin bulk carriers equal to or greater than 150 m in length

3.3.1 Application

These requirements apply to single side skin bulk carriers equal to or greater than 150 m in length, intended for the carriage of bulk cargoes having dry bulk density of 1,0 t/m^3 or above, with transverse vertically corrugated watertight bulkheads.

Each cargo hold is to be considered individually flooded.

3.3.2 General

The loads to be considered as acting on each bulkhead are those given by the combination of those induced by cargo loads with those induced by the flooding of one hold adjacent to the bulkhead under examination. In any case, the pressure due to the flooding water alone is to be considered.

The most severe combinations of cargo induced loads and flooding loads are to be used for the check of the scantlings of each bulkhead, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions
- non-homogeneous loading conditions,

considering the individual flooding of both loaded and empty holds.

For the purpose of this item, homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for each hold, does not exceed 1,20, to be corrected for different cargo densities.

Non-homogeneous part loading conditions associated with multiport loading and unloading operations for homogeneous loading conditions need not be considered according to these requirements.

The specified design load limits for the cargo holds are to be represented by loading conditions defined by the Designer in the loading manual.

For the purpose of this item, holds carrying packed cargoes are to be considered as empty holds for this application.

Unless the ship is intended to carry, in non-homogeneous conditions, only iron ore or cargo having bulk density equal to or greater than 1,78 t/m^3, the maximum mass of cargo which may be carried in the hold is also to be considered to fill that hold up to the upper deck level at centreline.

3.3.3 Flooding level

The flooding level z_F is the distance, in m, measured vertically from the the base line with the ship in the upright position, and equal to:

- in general:
  - D_1 for the foremost transverse corrugated bulkhead
  - $0,9D_1$ for other bulkheads;

where the ship is to carry cargoes having bulk density less than 1,78 t/m^3 in non-homogeneous loading conditions, the following values may be assumed:

  - $0,95D_1$ for the foremost transverse corrugated bulk-head
  - $0,85D_1$ for other bulkheads
- for ships less than 50000 t deadweight with type B free-board:
  - $0,95D_1$ for the foremost transverse corrugated bulkhead
  - $0,85D_1$ for other bulkheads;

where the ship is to carry cargoes having bulk density less than 1,78 t/m^3 in non-homogeneous loading conditions, the following values may be assumed:

  - $0,9D_1$ for the foremost transverse corrugated bulkhead
  - $0,8D_1$ for other bulkheads.

3.3.4 Pressures and forces on a corrugation in non-flooded bulk cargo loaded holds

At each point of the bulkhead, the pressure is to be obtained, in kN/m^2, from the following formula:

$$p_B = \rho_B g\left(h_C + h_{DB}\right)\tan^2\left(45 - \frac{\varphi}{2}\right)$$

The force acting on a corrugation is to be obtained, in kN, from the following formula:

$$F_B = \rho_B g s_C \frac{(h_C - h_{LS})^2}{2} \tan^2\left(45 - \frac{\varphi}{2}\right)$$

3.3.5 Pressures and forces on a corrugation in flooded bulk cargo loaded holds

Two cases are to be considered, depending on the values of z_F and h_C (see [3.3.3] and [1.1]):

- $z_F \geq h_C + h_{DB}$

At each point of the bulkhead located at a distance between z_F and $h_C + h_{DB}$ from the base line, the pressure, in kN/m², is to be obtained from the following formula:

$$p_{B,F} = \rho\, g\, (z_F - z)$$

At each point of the bulkhead located at a distance lower than $h_C + h_{DB}$ from the base line, the pressure, in kN/m², is to be obtained from the following formula:

$$p_{B,F} = \rho g h_F + [\rho_B - \rho(1 - perm)] g (h_C + h_{DB} - z) \tan^2\left(45 - \frac{\varphi}{2}\right)$$

where perm is the permeability of cargo, to be taken as 0,3 for iron ore, coal cargoes and cement.

The force acting on a corrugation is to be obtained, in kN, from the following formula:

$$F_{B,F} = s_1 \left[\rho g \frac{(z_F - h_C - h_{DB})^2}{2} + \frac{\rho g (Z_F - h_C - h_{DB}) + (p_{B,F})_{LE}}{2} (h_C - h_{LS}) \right]$$

where $(p_{B,F})_{LE}$ is the pressure $p_{B,F}$, in kN/m², calculated at the lower edge of the corrugation.

- $z_F < h_C + h_{DB}$

  At each point of the bulkhead located at a distance between z_F and $h_C + h_{DB}$ from the base line, the pressure is to be obtained, in kN/m², from the following formula:

$$p_{B,F} = \rho_B g (h_C + h_{DB}) \tan^2\left(45 - \frac{\varphi}{2}\right)$$

At each point of the bulkhead located at a distance lower than z_F from the base line, the pressure is to be obtained, in kN/m², from the following formula:

$$p_{B,F} = \rho g h_F + [\rho_B (h_C + h_{DB} - z) - \rho(1 - perm)(z_F - z)] g \tan^2\left(45 - \frac{\varphi}{2}\right)$$

where perm is the permeability of cargo, to be taken as 0,3 for iron ore, coal cargoes and cement.

The force acting on a corrugation is to be obtained, in kN, from the following formula:

$$F_{B,F} = s_1 \left[\rho_B g \frac{(h_C + h_{DB} - Z_F)}{2} \tan^2\left(45 - \frac{\varphi}{2}\right) \right]$$

$$+ s_1 \left[\frac{\rho_B g (h_C + h_{DB} - Z_F) \tan^2\left(45 - \frac{\varphi}{2}\right) + (p_{B,F})_{LE}}{2} (Z_F - h_{DB} - h_{LS}) \right]$$

where $(p_{B,F})_{LE}$ is the pressure $p_{B,F}$, in kN/m², calculated at the lower edge of the corrugation.

3.3.6 Pressures and forces on a corrugation in flooded empty holds

At each point of the bulkhead, the still water pressure induced by the flooding to be considered is to be obtained, in kN/m^2, from the following formula:

$p_F = \rho\, g\, (z_F - z)$

The force acting on a corrugation is to be obtained, in kN, from the following formula:

$$F_F = s_1 \rho g \frac{(Z_F - h_{DB} - h_{LS})^2}{2}$$

3.3.7 Resultant pressures and forces

Resultant pressures and forces to be calculated for homogeneous and non-homogeneous loading conditions are to be obtained according to the following formulae:

- Homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure to be considered for the scantlings of the bulkhead is to be obtained, in kN/m^2, from the following formula:

$p = p_{B,F} - 0{,}8 p_B$

The resultant force acting on a corrugation is to be obtained, in kN, from the following formula:

$F = F_{B,F} - 0{,}8 p_B$

where:

p_B : Pressure in the non-flooded holds, in kN/m^2, to be obtained as specified in [3.3.4]

$p_{B,F}$: Pressure in the flooded holds, in kN/m^2, to be obtained as specified in [3.3.5]

$F_{B,F}$: Force acting on a corrugation in the flooded holds, in kN, to be obtained as specified in [3.3.5].

- Non-homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure to be considered for the scantlings of the bulkhead is to be obtained, in kN/m^2, by the following formula:

$p = p_{B,F}$

The resultant force acting on a corrugation is to be obtained, in kN, by the following formula:

$F = F_{B,F}$

where:

$p_{B,F}$: Pressure in the flooded holds kN/m^2, to be obtained as specified in [3.3.5]

$F_{B,F}$: Force acting on a corrugation in the flooded holds kN/m^2, to be obtained as specified in [3.3.5].

3.4 Double bottom of single side skin bulk carriers equal to or greater than 150 m in length

3.4.1 Application

These requirements apply to single side skin bulk carriers equal to or greater than 150 m in length, intended for the carriage of bulk cargoes having dry bulk density 1,0 t/m^3 or above.

Each cargo hold is to be considered individually flooded.

3.4.2 General

The loads to be considered as acting on the double bottom are those given by the external sea pressures and the combination of the cargo loads with those induced by the flooding of the hold which the double bottom belongs to.

The most severe combinations of cargo induced loads and flooding loads are to be used, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions
- non-homogeneous loading conditions
- packed cargo conditions (such as in the case of steel mill products).

For each loading condition, the maximum dry bulk cargo density to be carried is to be considered in calculating the allowable hold loading.

3.4.3 Flooding level

The flooding level z_F is the distance, in m, defined in [3.3.3]

4. Testing lateral pressure

4.1 Still water pressures

4.1.1

The still water pressure to be considered as acting on plates and stiffeners subject to tank testing is obtained, in kN/m^2, from the formulae in Tab 2.

No inertial pressure is to be considered as acting on plates and stiffeners subject to tank testing.

Table 2: Testing - Still water pressures

Compartment or structure to be tested	Still water pressure p_{ST} , in kN/m^2
Double bottom tanks	The greater of the following: • $p_{ST} = 10 (z_{TOP} - z + d_{AP})$ • $p_{ST} = 10 (z_{ml} - z)$
Hopper side tanks, topside tanks, double side tanks, fore and after peaks used as tank, cofferdams	The greater of the following: • $p_{ST} = 10 (z_{TOP} - z + d_{AP})$ • $p_{ST} = 10 (z_{TOP} - z + 2{,}4)$
Tank bulkheads, deep tanks, fuel oil bunkers	The greater of the following: • $p_{ST} = 10 (z_{TOP} - z + d_{AP})$ • $p_{ST} = 10 (z_{TOP} - z + 2{,}4)$ • $p_{ST} = 10 (z_{TOP} - z + 10\ p_{PV})$
Ballast hold	The greater of the following: • $p_{ST} = 10 (z_{TOP} - z + d_{AP})$ • $p_{ST} = 10 (z_h - z + 0{,}9)$
Fore peak not used as tank	The greater of the following: • $p_{ST} = 10 (z_F - z)$ • $p_{ST} = 10 (z_{ml} - z)$
Watertight doors below freeboard deck	$p_{ST} = 10 (z_{fd} - z)$
Watertight hatch covers of tanks in ships with service notation combination carrier	The greater of the following: • $p_{ST} = 10 (z_h - z + 2{,}4)$ • $p_{ST} = 10 (z_h - z + 10\ p_{PV})$

Compartment or structure to be tested	Still water pressure p_{ST} , in kN/m^2
Chain locker (if aft of collision bulkhead)	$p_{ST} = 10 (z_{TOP} - z)$
Independent tanks	The greater of the following: • $p_{ST} = 10 (z_{TOP} – z + d_{AP})$ • $p_{ST} = 10 (z_{TOP} - z + 0,9)$
Ballast ducts	Ballast pump maximum pressure
z_{ml} : Z co-ordinate, in m, of the margin line. z_h : Z co-ordinate, in m, of the top of hatch. z_{F} , as defined in [3.2.1] z_{fd} : Z co-ordinate, in m, of the freeboard deck. p_{PV} : Setting pressure, in bar, of safety valves	

Chapter 4 – Design Loads

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Section 7 – LOADING CONDITIONS

Symbols

M_H : the actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught, in t

M_{FULL} : the cargo mass in a cargo hold corresponding to cargo with virtual density (homogenous mass / hold cubic capacity = M_H / V_H [= minimum 1.0 t/m^3]) filled to the top of the hatch coaming, in t. M_{FULL} is in no case to be less than M_H

M_{HD} : the maximum cargo mass allowed to be carried in a cargo hold according to design loading condition(s) with specified holds empty at maximum draught, in t

T_S : maximum draught, i.e. scantling draught, in m

T_{HB} : deepest ballast draught, in m

1. Application

1.1 Ships having a length less than 150 m

1.1.1

The severest loading conditions from the loading manual, midship section drawing or otherwise specified by the Designer are to be considered for the longitudinal strength according to Ch 5, Sec.1 and for the local strength check of plating, ordinary stiffeners and primary supporting members according to Ch 6.

1.2 Ships having a length of 150 m and above

1.2.1

The requirements in [2] to [4] are applicable to ships having a length of 150 m and above.

1.2.2

These requirements are not intended to prevent any other loading conditions to be included in the loading manual for which calculations are to be submitted. It is not neither intended to replace in any way the required loading manual/instrument.

1.2.3

The maximum loading condition draught is to be taken as the moulded summer load line draught.

1.2.4

The loading conditions listed in [2] are to be checked for the longitudinal strength as required by Ch 5, Sec.1, local strength by Ch 6, direct strength analysis by Ch 7, capacity and disposition of ballast tanks and stability purposes. The loading conditions listed in [3] are to be checked regarding local strength. The loading conditions listed in [4] are to be applied for direct strength analysis.

1.2.5
In operation, a bulk carrier may be loaded differently from the design loading conditions specified in the loading manual, provided longitudinal and local strength as defined in the loading manual and onboard loading instrument and applicable stability requirements are not exceeded.

2. General

2.1 Design loading conditions - General

2.1.1
For the determination of the maximum cargo mass in cargo holds, the condition corresponding to the ship being loaded at maximum draught with 50 % of consumables is also to be considered.

2.1.2 BC-C
Homogeneous cargo loaded condition where the cargo density corresponds to all cargo holds, including hatchways, being 100 % full at maximum draught with all ballast tanks empty.

2.1.3 BC-B
As required for **BC-C**, plus:

Homogeneous cargo loaded condition with cargo density 3,0 t/m^3, and the same filling ratio (cargo mass/hold cubic capacity) in all cargo holds at maximum draught with all ballast tanks empty.

In cases where the cargo density applied for this design loading condition is less than 3,0 t/m^3, the maximum density of the cargo that the vessel is allowed to carry is to be indicated with the additional Notation **{maximum cargo density x.y t/ m^3}**.

2.1.4 BC-A
As required for **BC-B**, plus:

At least one cargo loaded condition with specified holds empty, with cargo density 3,0 t/m^3 , and the same filling ratio (cargo mass/hold cubic capacity) in all loaded cargo holds at maximum draught with all ballast tanks empty.

The combination of specified empty holds is to be indicated with the additional Notation **{holds a, b, ... may be empty}**.

In such cases where the design cargo density applied is less than 3,0 t/m^3, the maximum density of the cargo that the vessel is allowed to carry is to be indicated within the additional Notation, e.g. **{holds a, b, ... may be empty with maximum cargo density x.y t/m^3}**.

2.2 Ballast conditions applicable to all Notations

2.2.1 Ballast tank capacity and disposition
All bulk carriers are to have ballast tanks of sufficient capacity and so disposed to at least fulfill the following requirements.

Normal ballast condition

Normal ballast condition is a ballast (no cargo) condition where:

- the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in Ch. 4 Sec. 3 are to be complied with
- any cargo hold or holds adapted for the carriage of water ballast at sea are to be empty
- the propeller is to be fully immersed, and
- the trim is to be by the stern and is not to exceed 0,015 L_{BP}.

In the assessment of the propeller immersion and trim, the draughts at the forward and after perpendiculars may be used.

Heavy ballast condition

Heavy ballast condition is a ballast (no cargo) condition where:

- the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in Ch. 4 Sec. 3 are to be complied with
- at least one cargo hold adapted for carriage of water ballast at sea is to be full
- the propeller immersion I/D is to be at least 60 %, where:

  I = Distance from propeller centerline to the waterline

  D = Propeller diameter
- the trim is to be by the stern and is not to exceed 0,015 L_{BP}
- the moulded forward draught in the heavy ballast condition is not to be less than the smaller of 0,03 L or 8 m.

2.2.2 Strength requirements

All bulk carriers are to meet the following strength requirements:

Normal ballast condition:

- the structures of bottom forward are to be strengthened in accordance with the Rules against slamming for the condition of 2.2.1 for normal ballast condition at the lightest forward draught,
- the longitudinal strength requirements according to Ch. 4 Sect.3 are to be met for the condition of [2.2.1] for normal ballast condition, and
- in addition, the longitudinal strength requirements according to Ch. 4 Sect.3are to be met with all ballast tanks 100 % full.

Heavy ballast condition:

- the longitudinal strength requirements according to Ch. 4 Sect.3 are to be met for the condition of [2.2.1] for heavy ballast condition
- in addition, the longitudinal strength requirements according to Ch. 4 Sect.3 are to be met with all ballast tanks 100 % full and one cargo hold adapted and designated for the carriage of water ballast at sea, where provided, 100 % full, and

- where more than one hold is adapted and designated for the carriage of water ballast at sea, it will not be required that two or more holds be assumed 100 % full simultaneously in the longitudinal strength assessment, unless such conditions are expected in the heavy ballast condition. Unless each hold is individually investigated, the designated heavy ballast hold and any/all restrictions for the use of other ballast hold(s) are to be indicated in the loading manual.

2.3 Departure and arrival conditions

2.3.1

Unless otherwise specified, each of the design loading conditions defined in [2.1] and [2.2] is to be investigated for the arrival and departure conditions as defined below.

Departure condition: with bunker tanks not less than 95 % full and other consumables 100 %

Arrival condition: with 10% of consumables

3. Design loading conditions for local strength

3.1 Definitions

3.1.1

The maximum allowable or minimum required cargo mass in a cargo hold, or in two adjacently loaded holds, is related to the net load on the double bottom. The net load on the double bottom is a function of draft, cargo mass in the cargo hold, as well as the mass of fuel oil and ballast water contained in double bottom tanks.

3.2 General conditions applicable for all Notations

3.2.1

Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100 % full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught.

3.2.2

Any cargo hold is to be capable of carrying minimum 50 % of M_H, with all double bottom tanks in way of the cargo hold being empty, at maximum draught.

3.2.3

Any cargo hold is to be capable of being empty, with all double bottom tanks in way of the cargo hold being empty, at the deepest ballast draught.

3.3 Conditions applicable for all Notations except when Notation {no MP} is assigned

3.3.1

Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100 % full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67 % of maximum draught.

3.3.2

Any cargo hold is to be capable of being empty with all double bottom tanks in way of the cargo hold being empty, at 83 % of maximum draught.

3.3.3

Any two adjacent cargo holds are to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100 % full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67 % of the maximum draught. This requirement to the mass of cargo and fuel oil in double bottom tanks in way of the cargo hold applies also to the condition where the adjacent hold is fitted with ballast, if applicable.

3.3.4

Any two adjacent cargo holds are to be capable of being empty, with all double bottom tanks in way of the cargo hold being empty, at 75 % of maximum draught.

3.4 Additional Notations applicable for BC-A Notation only

3.4.1

Cargo holds, which are intended to be empty at maximum draught, are to be capable of being empty with all double bottom tanks in way of the cargo hold also being empty.

3.4.2

Cargo holds, which are intended to be loaded with high density cargo, are to be capable of carrying M_{HD} plus 10 % of M_H, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100 % full and ballast water tanks in the double bottom being empty in way of the cargo hold, at maximum draught.
In operation the maximum allowable cargo mass shall be limited to M_{HD}.

3.4.3

Any two adjacent cargo holds which according to a design loading condition may be loaded with the next holds being empty, are to be capable of carrying 10 % of M_H in each hold in addition to the maximum cargo load according to that design loading condition, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100 % full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught.
In operation the maximum allowable mass shall be limited to the maximum cargo load according to the design loading conditions.

3.5 Additional conditions applicable for ballast hold(s) only

3.5.1

Cargo holds, which are designed as ballast water holds, are to be capable of being 100 % full of ballast water including hatchways, with all double bottom tanks in way of the cargo hold being 100 % full, at any heavy ballast draught. For ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty.

3.6 Additional conditions applicable during loading and unloading in harbour only

3.6.1

Any single cargo hold is to be capable of holding the maximum allowable seagoing mass at 67 % of maximum draught, in harbour condition.

3.6.2

Any two adjacent cargo holds are to be capable of carrying M_{Full} , with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100 % full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67 % of maximum draught, in harbour condition.

3.6.3

At reduced draught during loading and unloading in harbour, the maximum allowable mass in a cargo hold may be increased by 15 % of the maximum mass allowed at the maximum draught in sea-going condition, but shall not exceed the mass allowed at maximum draught in the sea-going condition. The minimum required mass may be reduced by the same amount.

3.7 Hold mass curves

3.7.1

Based on the design loading criteria for local strength, as given in [3.2] to [3.6] (except [3.5.1]), hold mass curves are to be included in the loading manual and the loading instrument, showing maximum allowable and minimum required mass as a function of draught in sea-going condition as well as during loading and unloading in harbour.

3.7.2

At other draughts than those specified in the design loading conditions, the maximum allowable and minimum required mass is to be adjusted for the change in buoyancy acting on the bottom. Change in buoyancy is to be calculated using water plane area at each draught.

Hold mass curves for each single hold, as well as for any two adjacent holds, are to be included in the loading manual and the loading instrument.

4. Design loading conditions for direct strength analysis

4.1 Application

4.1.1

The following describes the loading conditions that are to be applied for the strength assessment of cargo hold models by means of the Finite Element Analysis method.

4.1.2

The loading conditions are in general to be considered according to [2] and [3]. The loading conditions to be applied for each Additional service feature are to be taken from Tab 1.

4.1.3

The loading conditions shown in Tab 2 are to be applied at minimum. In column “Description” of Tab 2, a direct reference to the loading conditions described in [3.2.1] to [3.6.3] is placed under the description of each loading condition. Load cases to be applied for each loading condition are shown in the same table. Other loading conditions from the loading manual, which are not covered in Tab 2, if any, are also to be considered.

4.2 Loads

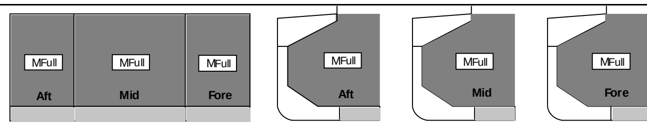
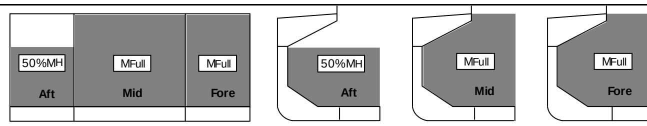
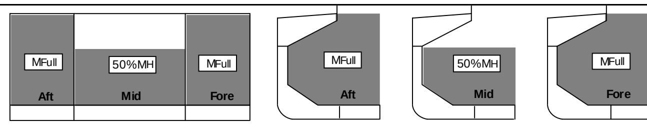
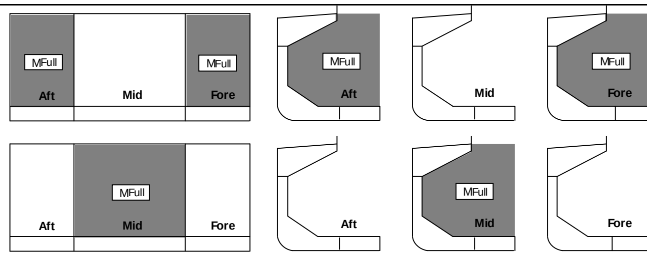
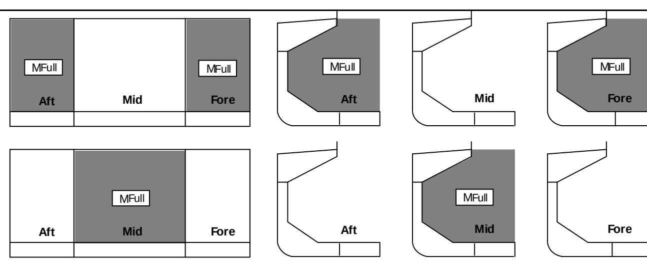
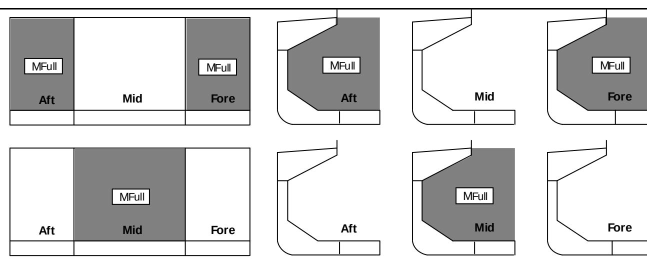
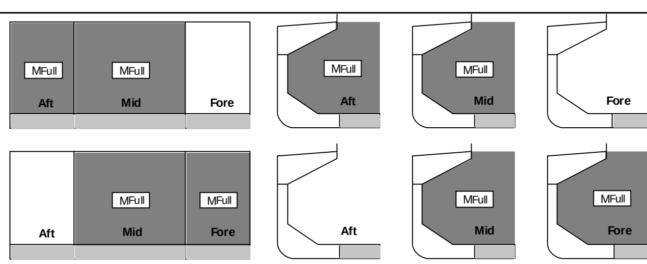
4.2.1 Stillwater Bending Moment

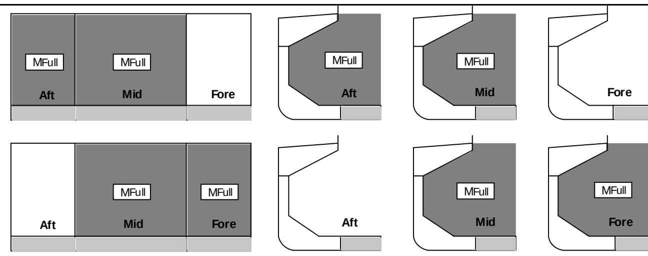
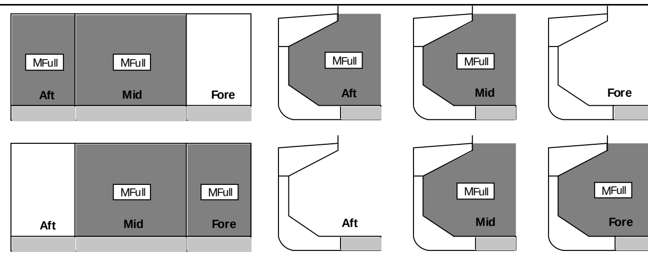
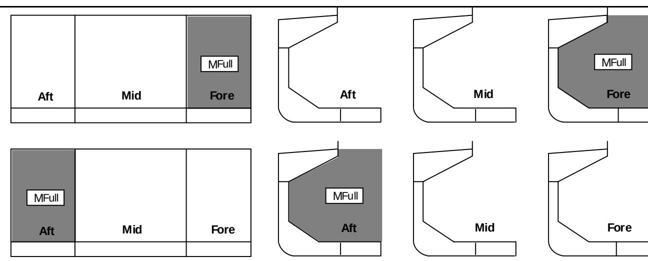
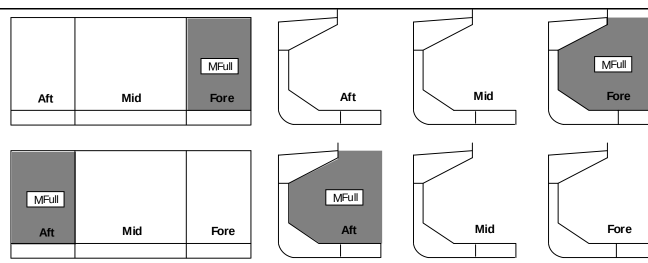
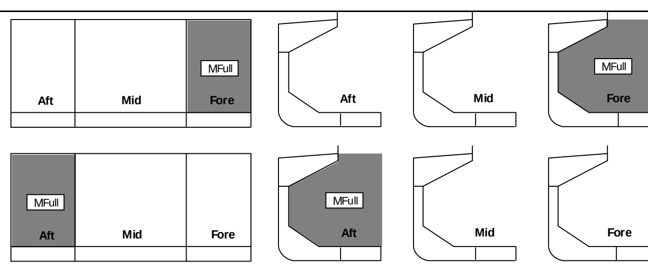
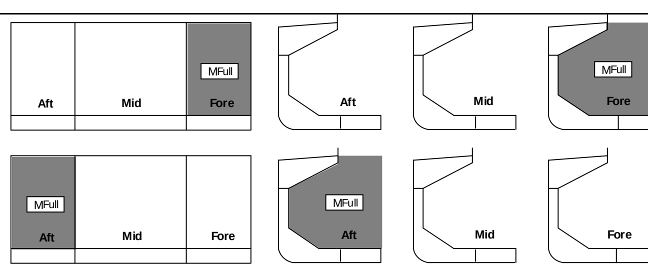
When considering hull girder bending moment in still water in each loading condition, the maximum allowable still water vertical bending moment of the ship is in general to be considered unless otherwise specified according to each loading condition in the loading manual. Standard still water bending moments for the respective loading conditions are shown in Tab 2.

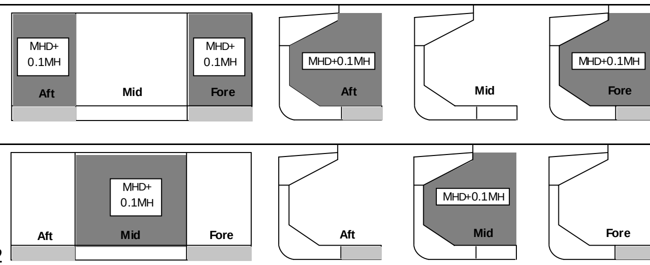
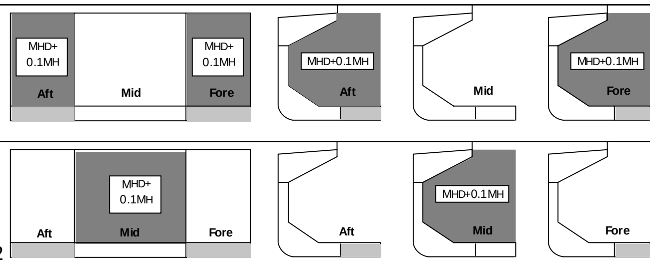
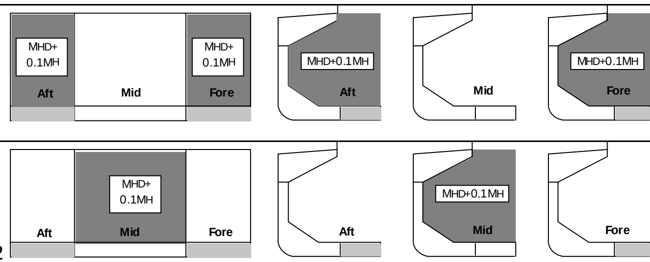
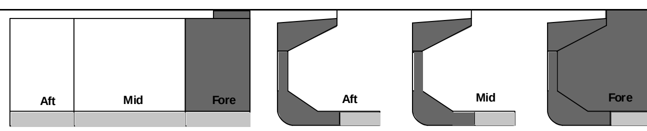
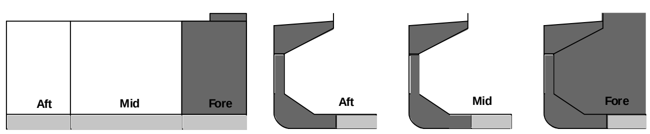
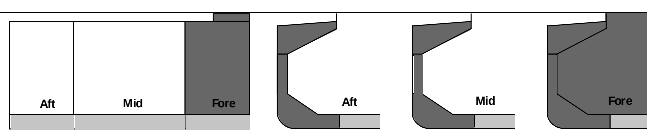
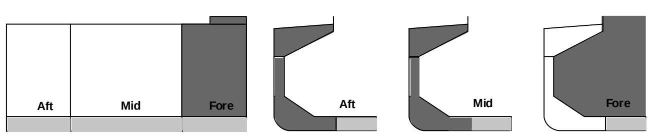
Table 1: Applicable loading conditions for Additional service feature notations

No.	Description	ref.				no MP		
			A	B	C	A	B	C
1	Full Loaded	3.2.1	x	x	x	x	x	x
2	Slack Load 1	3.2.2	x	x	x	x	x	x
3	Slack Load 2	3.2.2	x	x	x	x	x	x
4	Normal Ballast	3.2.3	x	x	x	x	x	x
5	Multi Port 1	3.3.1	x	x	x			
6	Multi Port 2	3.3.2	x	x	x			
7	Multi Port 3a Block Loading	3.3.3	x	x	x			
8	Multi Port 3b Block Loading	3.3.3	x	x	x			
9	Multi Port 3c Block Loading	3.3.3	x	x	x			
10	Multi Port 3d Block Loading	3.3.3	x	x	x			
11	Multi Port 4a Block Loading	3.3.4	x	x	x			
12	Multi Port 4b Block Loading	3.3.4	x	x	x			
13	Alter. 1	3.4.1	x			x		
14	Alter. 2	3.4.2	x			x		
15	Alter. 3a Block Loading	3.4.3	x					
16	Alter. 3b Block Loading	3.4.3	x					
17	Heavy Ballast	3.5.1	x	x	x	x	x	x
18	Harbour 1a	3.6.1		x	x		x	x
19	Harbour 1b	3.6.1	x			x		
20	Harbour 2a Block Loading	3.6.2	x	x	x	x	x	x
21	Harbour 2b Block Loading	3.6.2	x	x	x	x	x	x

Table 2: Applicable loading conditions for standard class notations

No	Description	Draught	**Load Pattern** Case 1: The fore hold is a ballast/loaded hold, the mid hold an empty hold and the aft hold is a loaded hold. The ballast hold is deemed as loaded hold. Case 2: The fore hold is a ballast/empty hold, the mid hold a loaded hold and the aft hold is an empty hold. The ballast hold is deemed as empty hold.	Load Case	Still water vertical bending moment
1	Full Loaded [3.2.1]	T_S		P1	0.5 M_S(-)
2	Slack Load [3.2.2]	T_S		P1	0
3	Slack Load [3.2.2]	T_S		P1	0
4	Multi Port [3.3.2] Except when notation {no MP} is assigned	0.83 T_S		H1	M_S(-)
5	Multi Port [3.3.2] Except when notation {no MP} is assigned	0.83 T_S		F2	M_S(+)
6	Multi Port [3.3.2] Except when notation {no MP} is assigned	0.83 T_S		P1	M_S(-)
7	Multi Port [3.3.3] Except when notation {no MP} is assigned	0.67 T_S		H1	M_S(-)

No	Description	Draught	**Load Pattern** Case 1: The fore hold is a ballast/loaded hold, the mid hold an empty hold and the aft hold is a loaded hold. The ballast hold is deemed as loaded hold. Case 2: The fore hold is a ballast/empty hold, the mid hold a loaded hold and the aft hold is an empty hold. The ballast hold is deemed as empty hold.	Load Case	Still water vertical bending moment
8	Multi Port [3.3.3] Except when notation {no MP} is assigned	0.67 T_S		F2	$M_S(+)$
9	Multi Port [3.3.3] Except when notation {no MP} is assigned	0.67 T_S		P1	$M_S(-)$
10	Multi Port [3.3.4] Except when notation {no MP} is assigned	0.75 T_S		H1	$M_S(-)$
11	Multi Port [3.3.4] Except when notation {no MP} is assigned	0.75 T_S		F2	$M_S(+)$
12	Multi Port [3.3.4] Except when notation {no MP} is assigned	0.75 T_S		R1	$M_S(+)$, $M_S(-)$
13	Multi Port [3.3.4] Except when notation {no MP} is assigned	0.75 T_S		P1	$M_S(-)$

No	Description	Draught	Load Pattern Case 1: The fore hold is a ballast/loaded hold, the mid hold an empty hold and the aft hold is a loaded hold. The ballast hold is deemed as loaded hold. Case 2: The fore hold is a ballast/empty hold, the mid hold a loaded hold and the aft hold is an empty hold. The ballast hold is deemed as empty hold.	Load Case	Still water vertical bending moment
14	Alt. Load [3.4.2]	T_S	case1 case 2 	H1	0
15	Alt. Load [3.4.2]	T_S	case1 case 2 	F2	$M_S(+)$
16	Alt. Load [3.4.2]	T_S	case1 case 2 	P1	0
17	Heavy Ballast [3.5.1]	T_{HB}		H1	$M_S(-)$
18	Heavy Ballast [3.5.1]	T_{HB}		R1	+: ballast. hold 0; empty hold $M_S(+)$ -: $M_S(-)$
19	Heavy Ballast [3.5.1]	T_{HB}		P1	$M_S(-)$
20	Heavy Ballast [3.5.1]	T_{HB}		R1	+: ballast. hold 0; empty hold $M_S(+)$ -: $M_S(-)$

1) $M_S(+)$: Allowable still water vertical bending moment in hogging

2) $M_S(-)$: Allowable still water vertical bending moment in sagging

Chapter 4 – Design loads

Welcome JBP

Section 8 - LOADING MANUAL AND LOADING INSTRUMENT

1. General

1.1 All ships

An approved loading manual is to be supplied for all ships

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

The loading instrument is ship specific onboard equipment and the results of the calculations are only applicable to the ship for which it has been approved.

An approved loading instrument may not replace an approved loading manual.

1.2 Ships equal to or greater than 150 m in length

BC-A, BC-B, and BC-C ships are to be provided with an approved loading manual and an approved computer-based loading instrument, in accordance with the applicable requirements of this Section.

A guidance for loading and unloading sequences is given in [5].

2. Loading manual

2.1 Definitions

2.1.1 All ships

A loading manual is a document which describes:

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

2.1.2 Ships equal to or greater than 150 m in length

In addition to [2.1.1], for BC-A, BC-B, and BC-C ships, the loading manual is also to describe:

- the loading conditions on which the design of the ship has been based, including permissible limits of still water bending moments and shear forces
- the results of the calculations of still water bending moments, shear forces
- envelope results and permissible limits of still water bending moments and shear forces in the hold flooded condition according to Ch 5, Sec 1
- the cargo hold(s) or combination of cargo holds that might be empty at full draught. If no cargo hold is allowed to be empty at full draught, this is to be clearly stated in the loading manual
- maximum allowable and minimum required mass of cargo and double bottom contents of each hold as a function of the draught at mid-hold position
- maximum allowable and minimum required mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds. This mean draught may be calculated by averaging the draught of the two mid-hold positions

- maximum allowable tank top loading together with specification of the nature of the cargo for cargoes other than bulk cargoes
- maximum allowable load on deck and hatch covers. If the ship is not approved to carry load on deck or hatch covers, this is to be clearly stated in the loading manual
- maximum rate of ballast change together with the advice that a load plan is to be agreed with the terminal on the basis of the achievable rates of change of ballast.

2.2 Conditions of approval

2.2.1 All ships

The approved loading manual is to be based on the final data of the ship. The manual is to include the design (cargo and ballast) loading conditions, subdivided into departure and arrival conditions as appropriate, upon which the approval of the hull scantlings is based.

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

2.2.2 Ships equal to or greater than 150 m in length

In addition to [2.2.1], for BC-A, BC-B, and BC-C ships, the following loading conditions, subdivided into departure and arrival conditions as appropriate, are also to be included in the loading manual:

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

2.3 Language

2.3.1

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

3. Loading Instrument

3.1 Definitions

3.1.1 All ships

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

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

Single point loading instruments are not acceptable.

3.1.2 Ships equal to or greater than 150 m in length

For BC-A, BC-B, and BC-C ships, the loading instrument is an approved digital system as defined in [3.1.1]. In addition to [3.1.1], it is also to ascertain as applicable that:

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

do not exceed the specified permissible values.

3.2 Conditions of approval

3.2.1 All ships

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

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

3.2.2 Ships equal to or greater than 150 m in length

In addition, for BC-A, BC-B, and BC-C ships, the approval is also to include, as applicable:

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

3.2.3

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

3.2.4
The operation manual and the instrument output are to be prepared in a language understood by the users. If this is not English, a translation into English is to be included.

3.2.5
The operation of the loading instrument is to be verified upon installation under the agreed test conditions. It is to be checked that the agreed test conditions and the operation manual for the instrument are available on board.

4. Annual and Special Survey

4.1 General

4.1.1
At each Annual and Special Survey, it is to be checked that the approved loading manual is available on board.

4.1.2
The loading instrument is to be checked for accuracy at regular intervals by the ship's Master by applying test loading conditions.

4.1.3 3.3
At each Special Survey this checking is to be done in the presence of the Surveyor.

5. Guidance for Loading/Unloading Sequences

5.1 General

5.1.1
The typical unloading sequences shall be developed paying due attention to the loading rate, the deballasting capacity and the applicable strength limitations.

5.1.2
The shipbuilder will be required to prepare and submit for approval typical loading and unloading sequences.

5.1.3
The typical loading sequences as relevant should include:

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

5.1.4
The loading / unloading sequences may be port specific or typical.

5.1.5

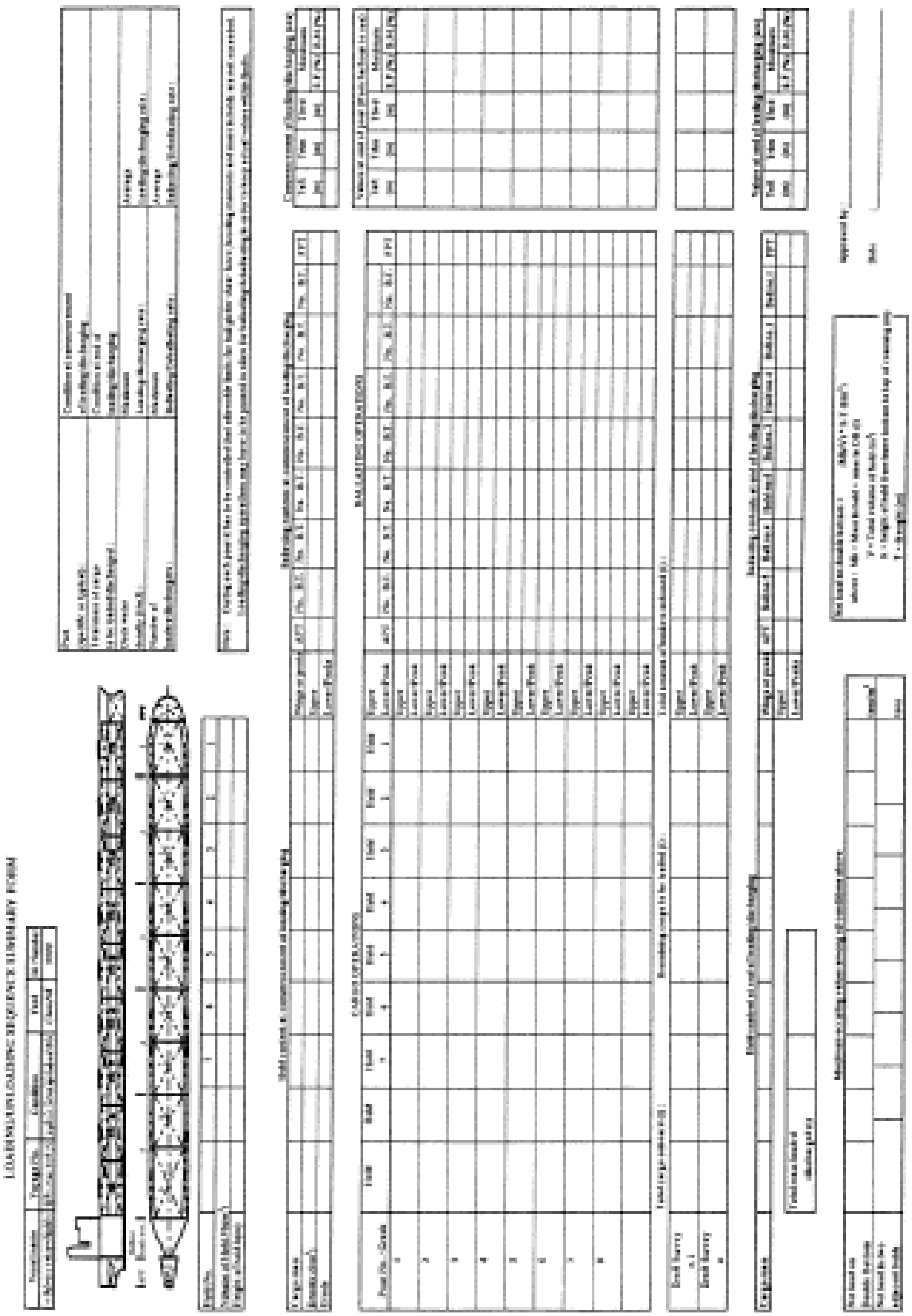
The sequence is to be built up step by step from commencement of cargo loading to reaching full deadweight capacity. Each time the loading equipment changes position to a new hold defines a step. Each step is to be documented and submitted to the Society. In addition to longitudinal strength, the local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

5.1.6

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

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

Table 1: Guidance on Typical Loading Sequence Summary Form



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Appendix 1 - HULL GIRDER ULTIMATE STRENGTH

Symbols

For symbols not defined in this Appendix, refer to Ch 1, Sec 4..

I_y: Moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Ch 5, Sec 11.4]

Z_{AB},Z_{AD}: Section moduli, in cm^3, at bottom and deck, respectively, defined in Ch 5, Sec 1, [1.4.2].

1. Hull girder ultimate strength check

1.1 Introduction

1.1.1

This Appendix provides the criteria for obtaining the curve M-χ and the ultimate longitudinal bending moment capacity M_U that are to be calculated according to one of the following methods:

- Simplified method based on a incremental-iterative approach, specified in [2.1], or
- Nonlinear finite element analysis, specified in [2.2].

1.1.2

Where materials other than steel are used, the use of such materials and corresponding scantlings are to be considered by the Society on a case-by-case basis.

2. Criteria for the calculation of the curve M-χ

2.1 Simplified method based on a incremental-iterative approach

2.1.1 Procedure

The curve M-χ is to be obtained by means of an incremental-iterative approach, summarised in the flow chart in Fig 1.

In this approach, the ultimate hull girder bending moment capacity M_U is defined as the peak value of the curve with vertical bending moment M versus the curvature χ of the ship cross section as shown in Fig 1**.** The curve is to be obtained through an incremental-iterative approach.

Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i.

For each step, the value χ_i is to be obtained by summing an increment of curvature $\Delta\chi$ to the value relevant to the previous step χ_{i-1}.This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.

This rotation increment induces axial strains ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened. Vice-versa in sagging condition.

The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve σ-ε of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.

The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position, since the relationship σ-ε is non-linear. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements.

Once the position of the neutral axis is known and the relevant stress distribution in the section structural elements is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress.

The main steps of the incremental-iterative approach described above are summarised as follows (see also Fig 1):

Step 1 Divide the transverse section of hull into stiffened plate elements.

Step 2 Define stress-strain relationships for all elements as shown in Tab 1.

Step 3 Initialize curvature and neutral axis for the first incremental step with the value of incremental curvature as:

$\chi = \chi_0 = 0,01\ \varepsilon_{Yi}$ (ε_{Yi} = yield strain of element)

Step 4 Calculate for each element the corresponding strain $\varepsilon_i = \chi\ z_i$ and the corresponding stress σ_i.

Step 5 Determine the neutral axis z_{NA_cur} at each incremental step by establishing force equilibrium over the whole transverse section as:

$\Sigma A_i\ \sigma_i = \Sigma A_j\ \sigma_j$ (i-th element is under compression, j-th element under tension)

Step 6 Calculate the corresponding moment by summing the contributions of all elements as:

$$M_U = \sum \sigma_{Ui} A_i \left| (z_i - z_{NA\_cur}) \right|$$

Step 7 Compare the moment in the current incremental step with the moment in the previous incremental step. If the slope in M-χ relationship is less than a negative fixed value, terminate the process and define the peak value of M_U. Otherwise, increase the curvature by the amount of χ_0 and go to **Step 4**.

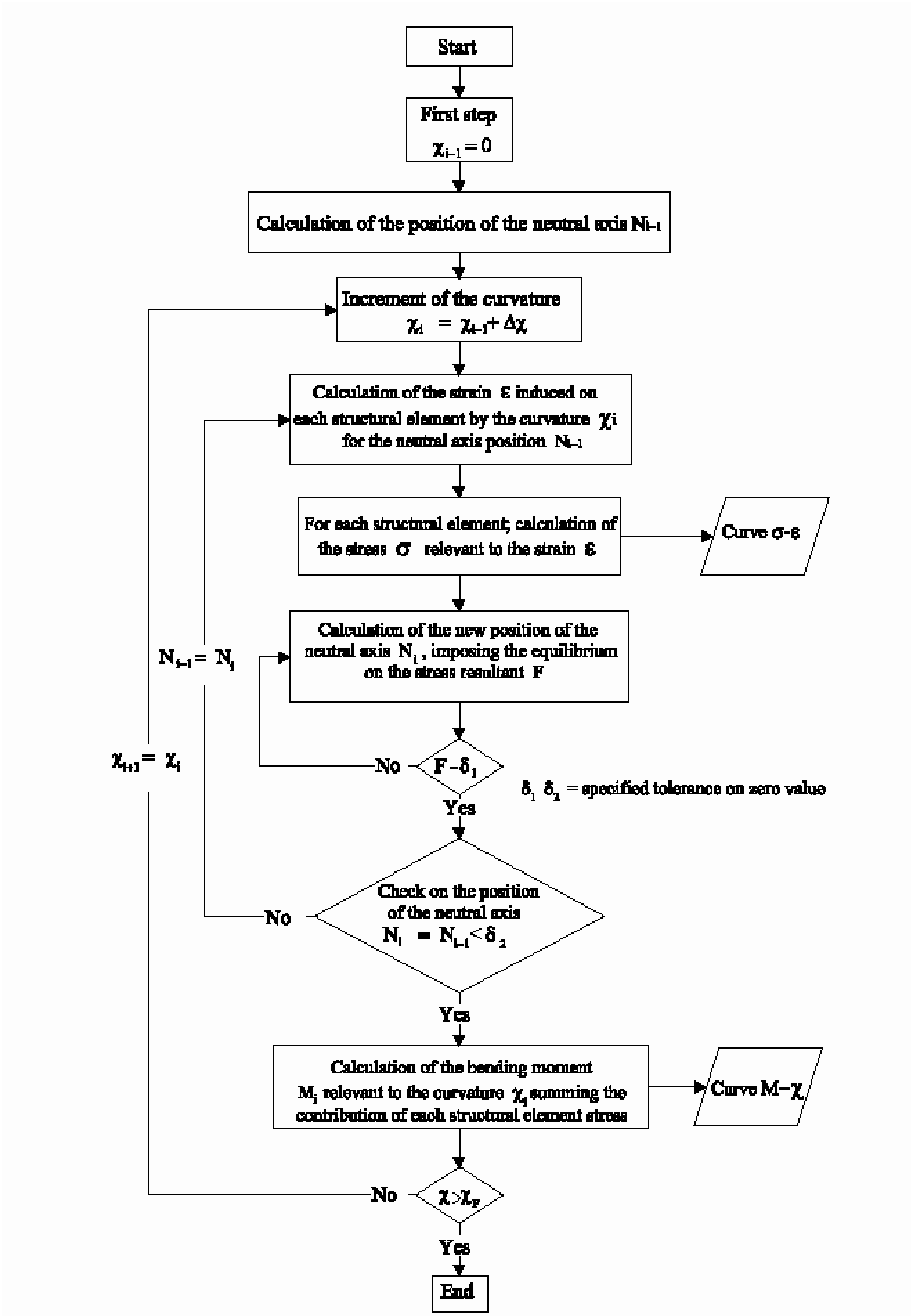


Figure 1: **Flow chart of the procedure for the evaluation of the curve M χ**

2.1.2 Assumption

In applying the procedure described in [2.1.1], the following assumptions are generally to be made:

- The ultimate strength is calculated at hull transverse sections between two adjacent transverse webs.
- The hull girder transverse section remains plane during each curvature increment.
- The hull material has an elasto-plastic behaviour.
- The hull girder transverse section is divided into a set of elements, which are considered to act independently.

  These elements are:
  - transversely framed plating panels and/or ordinary stiffeners with attached plating, whose structural behaviour is described in [2.2.1]
  - hard corners, constituted by plating crossing, whose structural behaviour is described in [2.2.2].
- According to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χi is obtained by summing the contribution given by the stress σ acting on each element. The stress σ, corresponding to the element strain ε, is to be obtained for each curvature increment from the non-linear load-end shortening curves σ - of the element.

  These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in [2.2]. The stress σ is selected as the lowest among the values obtained from each of the considered load-end shortening curves σ- ε.
- The procedure is to be repeated for each step, until the value of the imposed curvature reaches the value χ F, in m -1 , in hogging and sagging condition, obtained from the following formula:

$$\chi_F = \pm 0{,}003 \frac{M_Y}{EI_Y}$$

where:

M_Y: the lesser of the values M_{Y1} and M_{Y2}, in kN.m:

$M_{Y1} = 10^{-3}\, R_{eH}\, Z_{AB}$

$M_{Y2} = 10^{-3}\, R_{eH}\, Z_{AD}$

If the value χ F is not sufficient to evaluate the peaks of the curve M-χ, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

2.2 Load-end shortening curves σ-ε

2.2.1 Plating panels and ordinary stiffeners

Plating panels and ordinary stiffeners composing the hull girder transverse sections may collapse following one of the modes of failure specified in Tab 1.

2.2.2 Hard corners

Hard corners are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure. The relevant load-end shortening curve σ-ε is to be obtained for lengthened and shortened hard corners according to [2.2.3].

Table 1: Modes of failure of plating panel and ordinary stiffeners

Element	Mode of failure	Curve σ–ε defined in
Lengthened transversely framed plating panel or ordinary stiffeners	Elasto-plastic collapse	[2.2.3]
Shortened ordinary stiffeners	Beam column buckling Torsional buckling Web local buckling of flanged profiles Web local buckling of flat bars	[2.2.4] [2.2.5] [2.2.6] [2.2.7]
Shortened transversely framed plating panel	Plate buckling	[2.2.8]

2.2.3 Elasto-plastic collapse of structural elements

The equation describing the load-end shortening curve σ-ε or the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula, valid for both positive (shortening) and negative (lengthening) strains (see Fig 2):

$\sigma = \Phi R_{eH}$

where:

Φ: Edge function:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 < \varepsilon < 1$

$\Phi = 1$ for $\varepsilon > 1$

ε: Relative strain:

$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E: Element strain

ε_Y: Strain including yield stress in the element:

$$\varepsilon_Y = \frac{R_{eH}}{E}$$

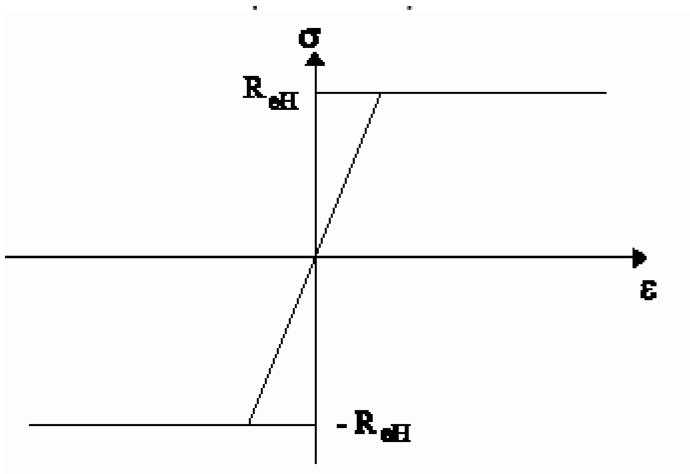


Figure 2: Load-end curve σ-ε for elasto plastic collapse

2.2.4 Beam column buckling

The equation describing the load-end shortening curve σ_{CR1}-ε for the beam column buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see Fig 3):

$$\sigma_{CR1} = \Phi\sigma_{C1}\frac{A_S + 10b_E t_P}{A_S + 10st_P}$$

where:

Φ: Edge function defined in [2.2.3]

σ_{C1}: Critical stress, in N/mm^2:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \qquad \text{for} \qquad \sigma_{E1} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{C1} = R_{eH}\left(1 - \frac{\Phi R_{eH}\varepsilon}{4\sigma_{E1}}\right) \qquad \text{for} \qquad \sigma_{E1} > \frac{R_{eH}}{2}\varepsilon$$

ε Relative strain defined in [2.2.3]

σ_{E1}: Euler column buckling stress, in N/mm^2:

$$\sigma_{E1} = \pi^2 E \frac{I_E}{A_E l^2}10^4$$

I_E Net moment of inertia of ordinary stiffeners, in cm^4, with attached shell plating of width b_{E1}

b_{E1} Width, in m, of the attached shell plating:

$$b_{E1} = \frac{s}{\beta_E} \qquad \text{for} \qquad \beta_E > 1{,}0$$

$$b_{E1} = s \qquad \text{for} \qquad \beta_E \le 1{,}0$$

$$\beta_E = 10^3\frac{s}{t_P}\sqrt{\frac{\varepsilon R_{eH}}{E}}$$

A_E: Net sectional area, in cm^2, of ordinary stiffeners with attached shell plating of width b_E

b_E Width, in m, of the attached shell plating:

$$b_E = \left(\frac{2{,}25}{\beta_E} - \frac{1{,}25}{\beta_E^2}\right)s \qquad \text{for} \qquad \beta_E > 1{,}25$$

$$b_E = s \qquad \text{for} \qquad \beta_E \le 1{,}25$$

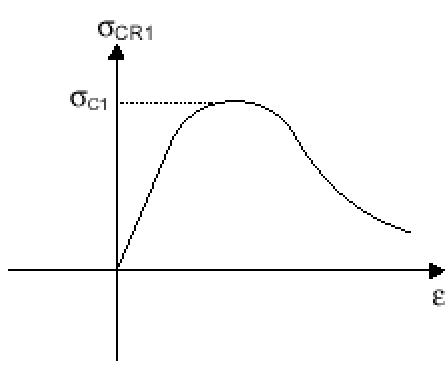


Figure 3: Load-end shortening curve σ_{CR1}-ε for beam column buckling

2.2.5 Torsional buckling

The equation describing the load-end shortening curve σ_{CR2}-ε for the lateral-flexural buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained according to the following formula (see Fig 4).

$$\sigma_{CR2} = \Phi \frac{A_S \sigma_{C2} + 10 s t_P \sigma_{CP}}{A_S + 10 s t_P}$$

where:

Φ: Edge function defined in [2.2.3]

σ_{C2}: Critical stress, in N/mm^2:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \quad \text{for} \quad \sigma_{E2} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{C2} = R_{eH}\left(1 - \frac{\Phi R_{eH} \varepsilon}{4\sigma_{E2}}\right) \quad \text{for} \quad \sigma_{E2} > \frac{R_{eH}}{2}\varepsilon$$

σ_{E2}: Euler torsional buckling stress, in N/mm^2, defined in Ch 6, Sec 3

ε: Relative strain defined in [2.2.3]

σ_{CP}: Buckling stress of the attached plating, in N/mm^2:

$$\sigma_{CP} = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right) R_{eH} \quad \text{for} \quad \beta_E > 1,25$$

$$\sigma_{CP} = R_{eH} \quad \text{for} \quad \beta_E \le 1,25$$

β_E: Coefficient defined in [2.2.4]

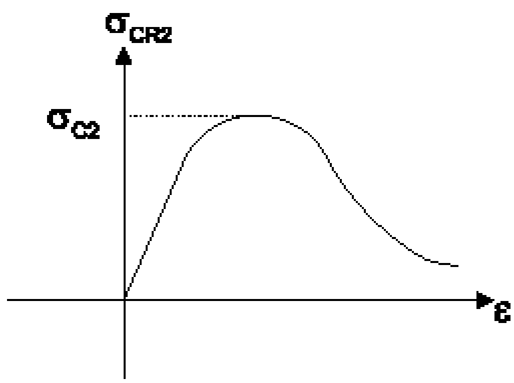


Figure 4: Load-end shortening curve σ_{CR2}-ε for flexural-torsional buckling

2.2.6 Web local buckling of ordinary stiffeners made of flanged profiles

The equation describing the load-end shortening curve σ_{CR1}-ε for the web local buckling of flanged ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi R_{eH} \frac{10^3 b_E t_P + h_{WE} t_W + b_F t_F}{10^3 s t_P + h_W t_W + b_F t_F}$$

where

Φ: Edge function defined in [2.2.3]

b_E: Width, in m, of the attached shell plating, defined in [2.2.4]

h_{WE}: Effective height, in mm, of the web:

$$h_{WE} = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right) h_W \quad \text{for} \quad \beta_W > 1,25$$

$$h_{WE} = h_W \quad \text{for} \quad \beta_W \le 1,25$$

β_E: Coefficient defined in [2.2.4]

$$\beta_W = 10^3 \frac{h_W}{t_W}\sqrt{\frac{\varepsilon R_{eH}}{E}}$$

ε: Relative strain defined in [2.2.3]

2.2.7 Web local buckling of ordinary stiffeners made of flat bars

The equation describing the load-end shortening curve σ_{CR4}-ε for the web local buckling of flat bar ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see Fig 5):

$$\sigma_{CR4} = \Phi \frac{10st_p\sigma_{CP} + A_s\sigma_{C4}}{A_s + 10st_p}$$

where:

Φ: Edge function defined in [2.2.3]

σ_{CP}: Buckling stress of the attached plating, in N/mm^2, defined in [2.2.5]

σ_{C4}: Critical stress, in N/mm^2:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \quad \text{for} \quad \sigma_{E4} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{C4} = R_{eH}\left(1 - \frac{\Phi R_{eH}\varepsilon}{4\sigma_{E4}}\right) \quad \text{for} \quad \sigma_{E4} > \frac{R_{eH}}{2}\varepsilon$$

σ_{E4}: Local Euler buckling stress, in N/mm^2:

$$\sigma_{E4} = 160000\left(\frac{t_W}{h_W}\right)^2$$

ε: Relative strain defined in [2.2.3].

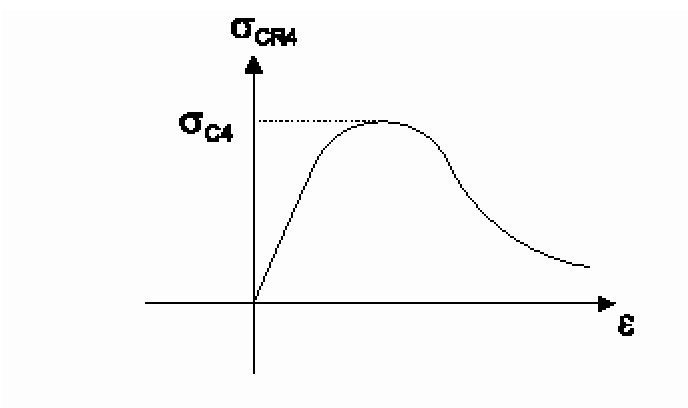


Figure 5: Load-end shortening curve σ_{CR4}-ε for web local buckling

2.2.8 Plate buckling

The equation describing the load-end shortening curve σ_{CR5}-ε for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = R_{eH}\left[\frac{s}{l}\left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right) + 0,1\left(1 - \frac{s}{l}\right)\left(1 + \frac{1}{\beta_E^2}\right)^2\right]$$

where:

β_E: Coefficient defined in [2.2.4].

2.3 Nonlinear finite element analysis

2.3.1 General

The requirements in [2.3] provide a procedure for the direct calculation of the ultimate hull girder bending moment capacity M_U using non-linear finite element programs.

2.3.2 Procedure

The non-linear finite element program is to be capable of adopting the effects of the geometrical non-linearity and the material non-linearity through the incremental load analysis.

This approach assumes that the stress-strain relationship is elasto-perfect plastic and the von-Mises criterion is applied to yield condition.

The methods for calculating ultimate longitudinal bending moment is as follows:

a) The hull girder transverse sections composed of the longitudinal members only are to be fine-meshed model, as specified in [2.3.3].

b) For considering the effect of lateral pressure, linear static analysis is to be carried out for the hydrostatic pressure and cargo load with specific boundary constraint, as specified in [2.3.4].

c) Initial deflections for the nonlinear static analysis are to be taken equal to the deflections due to the lateral pressure obtained according to the above point b), multiplied by the factor $(1+\alpha)$, where:

α : / (750 δ_M)

: *s*pan, in m, of ordinary stiffeners

δ_M : maximum deflection, in m, obtained according to the above point b).

d) The yield stress due to the effect of residual stress may be taken equal to 0,9 R_{eH} for each material.

e) Both end transverse sections of the structural model in longitudinal direction are assumed as rigid planes, as specified in [2.3.5].

f) Increment of loading or increment of enforced rotational displacement is to be applied for the incremental analysis.

g) The incremental step continues until the resulting hull girder bending moment is no longer increased.

2.3.3 Structural Model

In order to obtain the hull girder ultimate bending moment capacity, the extent of the finite element model is to be as follows:

- longitudinal extension: structural members within one transverse frame spacing,
- transverse extension: the full hull breadth,
- vertical extension: the full hull depth.

The web or flange of secondary stiffeners is also to be fine-meshed. The transverse members are not included in the model.

In this approach, 4-node shell element is to be used for all structural members, including buckling stiffener sniped at both-end. The size of the mesh elements is to be as follows:

- longitudinally, 10 or more elements between web frames,
- transversely, 3 or more elements between longitudinal stiffener spacing,

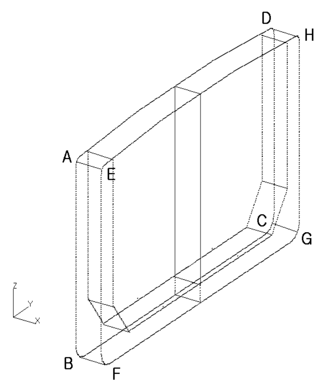
- vertically, 9 or more elements over the depth of double bottom girders.

2.3.4 Boundary constraints and loading for the lateral pressure

The boundary condition for lateral pressure is to be applied to the structural model as follows, as shown in Fig 6.

- both end transverse sections of the structural model in longitudinal direction are to be fixed,
- lateral loads due to hydrostatic pressures and cargo loads are to be applied to the structural model.

The vertical unbalanced forces of the model caused by the difference between the internal loads and the external hydrostatic pressure may be not considered in this approach.



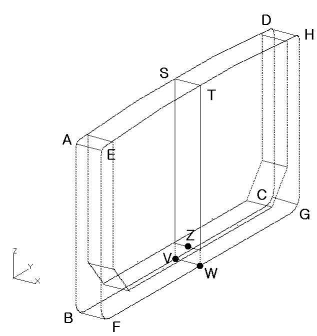
Plane ABCD	Fixed in all degrees of freedom
Plane EFGH	Fixed in all degrees of freedom

Figure 6: Boundary constraints for lateral pressure

2.3.5 Boundary constraints and loading for the hull girder bending moment

The boundary condition and loading are to be appied to the structural model as shown in Fig 7.

The nodal coordinates of original model are to be modified by the assumed initial deflection, to be obtained as specified in [2.3.2] c).



Plane ABCD	Rigid plane : Independent point V constrained in δ_X, θ_X, θ_Y, θ_Z
Plane EFGH	Rigid plane : Independent point W constrained in δ_X, θ_X, θ_Y, θ_Z

Mid-plane between Plane ABCD and EFGH	δ_X, θ_X, θ_Y, θ_Z
Plane STVW	δ_Y, θ_X, θ_Z
Point Z	δ_Z
Point V, W	(±) M_Y

Figure 7: Boundary constraints for bending moments

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Chapter 5 – Hull girder strength

Section 1 - YIELDING CHECK

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

M_{SW} : Design still water bending moment in intact condition, in kN.m, at the hull transverse section considered, defined in Ch 4, Sec 3, [2.2]:

- In hogging conditions: $M_{SW} = M_{SW,H}$
- In sagging conditions: $M_{SW} = M_{SW,S}$

M_{WV} : Vertical wave bending moment in intact condition, in kN.m, at the hull transverse section considered, defined in Ch 4, Sec 3, [3.1]

$M_{SW,F}$: Still water bending moment, in kN.m, in flooded conditions, at the hull transverse section under consideration, to be calculated according to Ch 4, Sec 3

$M_{WV,F}$: Vertical wave bending moment, in kN.m, in flooded conditions, at the hull transverse section under consideration, , to be calculated according to Ch 4, Sec 3

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in harbour conditions, at the hull transverse section under consideration, , to be calculated according to Ch 4, Sec 3

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 4, Sec 3, [3.3]

Q_{SW} : Design still water shear force in intact condition, in kN, at the hull transverse section considered, defined in Ch 4, Sec 3, [2.2]

Q_{WV} : Vertical wave shear force in intact condition, in kN, at the hull transverse section considered, defined in Ch 4, Sec 3, [3.2]:

- if $Q_{SW} \geq 0$, Q_{WV} is the positive wave shear force
- if $Q_{SW} < 0$, Q_{WV} is the negative wave shear force

$Q_{SW,F}$: Still water shear force, in kN, in flooded conditions, at the hull transverse section under consideration, to be calculated according to Ch 4, Sec 3

$Q_{WV,F}$: Vertical wave shear force, in kN, in flooded conditions, at the hull transverse section under consideration, to be calculated according to Ch 4, Sec 3

$Q_{WV,H}$: Vertical wave shear force, in kN, in harbour conditions, at the hull transverse section under consideration, to be calculated according to Ch 4, Sec 3

k : Material factor, as defined in Ch 1, Sec 4, [2.2.1]

x : X co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4]

I_Y : Moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to [1.5]

I_Z : Moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to [1.5]

S : First moment, in m^3, of the hull transverse section, to be calculated according to [1.6]

Z_A : Gross section modulus, in m^3, at any point of the hull transverse section, to be calculated according [1.4.1]

Z_{AB},Z_{AD} : Gross section moduli, in m^3, at bottom and deck, respectively, to be calculated according to [1.4.2]

C : Wave parameter defined in Ch 1, Sec 4, [2.3.1]

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm^2, defined in [3.1.1]

$\tau_{1,ALL}$: Allowable shear stress, in N/mm^2, defined in [3.2.1]

ρ : Sea water density, taken equal to 1,025 t/m^3.

1. Strength characteristics of the hull girder transverse sections

1.1 General

1.1.1

This Article specifies the criteria for calculating the hull girder strength characteristics to be used for the checks in [2] to [5], in association with the hull girder loads specified in Ch 4, Sec 3.

1.2 Hull girder transverse sections

1.2.1 General

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder longitudinal strength, i.e. all continuous longitudinal members below the strength deck defined in [1.3], taking into account the requirements in [1.2.2] to [1.2.9].

These members are to be considered as having (see also Ch 3, Sec 2):

- offered gross scantlings, when the hull girder strength characteristics are used for the hull girder yielding check according to [2] to [5]
- offered net scantlings based on offered gross thickness reduced by 0.5 t_C, when the hull girder strength characteristics are used for the ultimate strength check in Ch 5, Sec 2 and for calculating the hull girder stresses for the strength checks of plating, ordinary stiffeners and primary supporting members according to Ch 6.

1.2.2 Continuous trunks and continuous longitudinal hatch coamings

Continuous trunks and continuous longitudinal hatch coamings may be included in the hull girder transverse sections, provided they are effectively supported by longitudinal bulkheads or primary supporting members.

1.2.3 Longitudinal ordinary stiffeners or girders welded above the decks

Longitudinal ordinary stiffeners or girders welded above the decks (including the deck of any trunk fitted as specified in [1.22]) may be included in the hull girder transverse sections.

1.2.4 Longitudinal girders between hatchways, supported by longitudinal bulkheads

Where longitudinal girders, effectively supported by longitudinal bulkheads, are fitted between hatchways, the sectional area of these longitudinal girders are to be included in the hull girder transverse.

1.2.5 Longitudinal bulkheads with vertical corrugations

Longitudinal bulkheads with vertical corrugations may not be included in the hull girder transverse sections.

1.2.6 Members in materials other than steel

Where a member contributing to the longitudinal strength is made in material other than steel with a Young's modulus E equal to 2,06 10^5 N/mm^2, the steel equivalent sectional area that may be included in the hull girder transverse sections is obtained, in m^2, from the following formula:

$$A_{SE} = \frac{E}{2{,}06{,}10^5} A_M$$

where:

A_M : Sectional area, in m^2, of the member under consideration.

1.2.7 Large openings

Large openings are:

- elliptical openings exceeding 2,5 m in length or 1,2 m in breadth
- circular openings exceeding 0,9 m in diameter.

Large openings and scallops, where scallop welding is applied, are always to be deducted from the sectional areas included in the hull girder transverse sections.

1.2.8 Small openings

Smaller openings than those in [1.2.7] in one transverse section in the strength deck or bottom area need not be deducted from the sectional areas included in the hull girder transverse sections, provided that:

$\Sigma b_S \leq 0{,}06\ (B - \Sigma b)$

where:

Σb_S : Total breadth of small openings, in m, in the strength deck or bottom area at the transverse section considered, determined as indicated in Fig 1

Σb : Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Fig 1

Where the total breadth of small openings Σb_S does not fulfil the above criteria, only the excess of breadth is to be deducted from the sectional areas included in the hull girder transverse sections.

1.2.9 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than 0,25 h_W, without being greater than 75 mm, where h_W is the web height, in mm.

Otherwise, the excess is to be deducted from the sectional area or compensated.

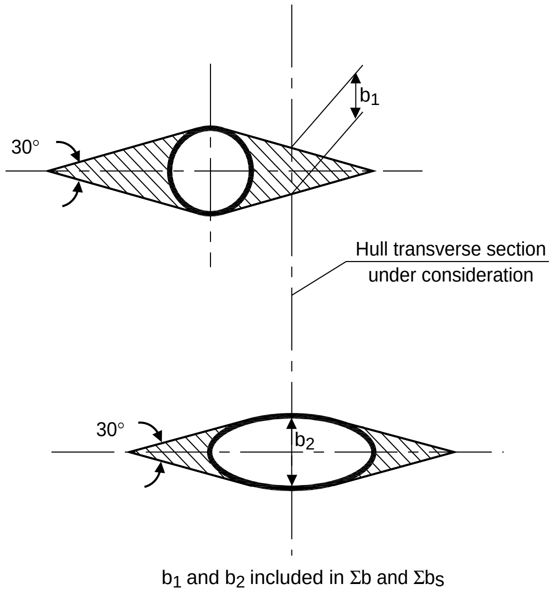


Figure 1: Calculation of Σb and Σb$_S$

1.3 Strength deck

1.3.1

The strength deck is, in general, the uppermost continuous deck.

In the case of a superstructure or deckhouses contributing to the longitudinal strength, the strength deck is the deck of the superstructure or the deck of the uppermost deckhouse.

1.3.2

A superstructure extending at least 0,15 L within 0,4 L amidships may generally be considered as contributing to the longitudinal strength.

For other superstructures and for deckhouses, their contribution to the longitudinal strength is to be assessed on a case by case basis, to evaluate their percentage of participation to the longitudinal strength.

1.4 Section modulus

1.4.1

The section modulus at any point of a hull transverse section is obtained, in m^3, from the following formula:

$$Z_A = \frac{I_Y}{|z - N|}$$

where:

I_Y : Moment of inertia, in m^4, of the hull transverse section defined in [1.2], about its horizontal neutral axis

Z : Z co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section defined in [1.2], with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4].

1.4.2

The section moduli at bottom and at deck are obtained, in m^3, from the following formulae:

- at bottom:

$$Z_{AB} = \frac{I_Y}{N}$$

- at deck:

$$Z_{AD} = \frac{I_Y}{V_D}$$

where:

I_Y, N : Defined in [1.4.1]

V_D : Vertical distance, in m, taken equal to:

- in general:

  $V_D = z_D - N$

  where:

  z_D : Z co-ordinate, in m, of strength deck defined in [1.3], with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4]

- if continuous trunks or hatch coamings are taken into account in the calculation of I_Y, as specified in [1.2.2]:

  $$V_D = (z_T - N)\left(0{,}9 + 0{,}2\frac{y_T}{B}\right) \geq z_D - N$$

  where:

  y_T, z_T : Y and Z co-ordinates, in m, of the top of continuous trunk or hatch coaming with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4]; y_T and z_T are to be measured for the point which maximises the value of V_D

- if longitudinal ordinary stiffeners or girders welded above the strength deck are taken into account in the calculation of I_Y, as specified in [1.2.3], V_D is to be obtained from the formula given above for continuous trunks and hatch coamings. In this case, y_T and z_T are the Y and Z co-ordinates, in m, of the top of the longitudinal stiffeners or girders with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4].

1.5 Moments of inertia

1.5.1

The moments of inertia I_Y and I_Z, in m^4, are those, calculated about the horizontal and vertical neutral axes, respectively, of the hull transverse sections defined in [1.2].

1.6 First moment

1.6.1

The first moment S, in m^3, at a level z above the baseline is that, calculated with respect to the horizontal neutral axis, of the portion of the hull transverse sections defined in [1.2] located above the z level.

2. Hull girder stresses

2.1 Normal stresses

2.1.1 General

The normal stresses in a member made in material other than steel with a Young's modulus E equal to 2,06 10^5 N/mm^2, included in the hull girder transverse sections as specified in [1.2.6], are obtained from the following formula:

$$\sigma_1 = \frac{E}{2{,}06 \cdot 10^5}\sigma_{1S}$$

where:

σ_{1S} : Normal stress, in N/mm^2, in the member under consideration, calculated according to [2.1.2] and [2.1.3] considering this member as having the steel equivalent sectional area A_{SE} defined in [1.2.6].

2.1.2 Normal stresses induced by vertical bending moments

The normal stresses induced by vertical bending moments are obtained, in N/mm^2, from the following formulae:

- at any point of the hull transverse section:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_A}10^3$$

- at bottom:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AB}}10^3$$

- at deck:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AD}}10^3$$

2.1.3 Normal stresses in flooded conditions of BC-A or BC-B ships

This requirement applies to BC-A or BC-B ships, in addition to [2.1.2].

The normal stresses, in the flooded conditions specified in Ch 4, Sec 3, are to be obtained at any point, in N/mm^2, from the following formula:

$$\sigma_1 = \frac{M_{SW,F} + M_{WV,F}}{Z_A}10^3$$

2.2 Shear stresses

2.2.1 General

The shear stresses induced by shear forces Q_{SW} and Q_{WV} are normally to be obtained through direct analyses.

The shear force corrections ΔQ_C and ΔQ are to be taken into account, in accordance with [2.2.2].

As an alternative to this procedure, the shear stresses induced by the vertical shear forces Q_{SW} and Q_{WV} may be obtained through the simplified procedure in [2.2.2].

2.2.2 Simplified calculation of shear stresses induced by vertical shear forces

In this context, effective longitudinal bulkhead means a bulkhead extending from the bottom to the strength deck.

The shear stresses induced by the vertical shear forces in the calculation point are obtained, in N/mm², from the following formula:

a) For ships without effective longitudinal bulkhead or with one effective longitudinal bulkhead:

$$\tau_1 = (Q_{SW} + Q_{WV} - \varepsilon \Delta Q_C)\frac{S}{I_Y t}\delta$$

where:

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable according to Tab 2

δ : Shear distribution coefficient defined in Tab 1

$\varepsilon = \mathrm{sgn}(Q_{SW})$

ΔQ_C : Shear force correction (see Fig 2), which takes into account, when applicable, the portion of loads transmitted by the double bottom girders to the transverse bulkheads:

- for ships with double bottom in alternate loading conditions:

$$\Delta Q_C = \alpha \left| \frac{P}{B_H \ell_C} - \rho T_1 \right|$$

- for other ships:

$$\Delta Q_C = 0$$

$$\varphi = 1{,}38 + 1{,}55\frac{\ell_0}{b_0} \le 3{,}7$$

$$\alpha = g\frac{\ell_0 b_0}{2 + \varphi\frac{\ell_0}{b_0}}$$

ℓ_0, b_0 : Length and breadth, respectively, in m, of the flat portion of the double bottom in way of the hold considered; b_0 is to be measured on the hull transverse section at the middle of the hold

ℓ_C : Length, in m, of the hold considered, measured between transverse bulkheads

B_H : Ship's breadth, in m, measured on the hull transverse section at the middle of the hold considered

P : Total mass of cargo, in t, in the transversely adjacent hold in the section considered

T_1 : Draught, in m, measured vertically on the hull transverse section at the middle of the hold considered, from the moulded baseline to the waterline in the loading condition considered.

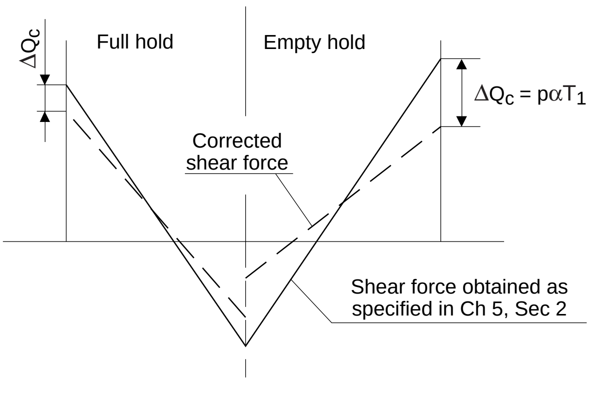


Figure 2: Shear force correction ΔQ_C

b) For ships with two effective longitudinal bulkheads:

$$\tau_1 = [(Q_{SW} + Q_{WV})\delta + \varepsilon_Q \Delta Q]\frac{S}{I_Y t}$$

where:

t : Minimum thickness, in mm, of side and longitudinal bulkhead plating, as applicable, according to Tab 1

δ : Shear distribution coefficient defined in Tab 1

$$\varepsilon_Q = \text{sgn}\left(\frac{Q_F - Q_A}{\ell_C}\right)$$

Q_F, Q_A : Value of Q_{SW}, in kN, in way of the forward and aft transverse bulkhead, respectively, of the hold considered

ΔQ : Shear force correction, in kN, which takes into account the redistribution of shear force between sides and longitudinal bulkheads due to possible transverse non-uniform distribution of cargo:

- in sides:

$$\Delta Q = \frac{g\varepsilon(P_C - P_W)\ell_C b_C}{4}\left[\frac{n}{3(n+1)} - (1-\phi)\right]$$

- in longitudinal bulkheads:

$$\Delta Q = \frac{g\varepsilon(P_C - P_W)\ell_C b_C}{4}\left[\frac{2n}{3(n+1)} - \phi\right]$$

$\varepsilon = \text{sgn}(Q_{SW})$

p_C : Pressure, in kN/m^2, acting on the inner bottom in way of the centre hold in the loading condition considered

p_W : Pressure, in kN/m^2, acting on the inner bottom in way of the wing hold in the loading condition considered, to be taken not greater than p_C

ℓ_C : Length, in m, of the hold considered, measured between transverse bulkheads

b_C : Breadth, in m, of the centre hold, measured between longitudinal bulkheads

n : Number of floors in way of the centre hold

Φ : Coefficient defined in Tab 1.

Table 1: Shear stresses induced by vertical shear forces

Ship typology	Location	t, in mm	δ	Meaning of symbols used in the definition of δ
Single side ships without effective longitudinal bulkheads See Fig 3 (a)	Sides	t_S	0,5	
Double side ships without effective longitudinal bulkheads See Fig 3 (b)	Sides	t_S	(1 – Φ) / 2	Φ = 0,275 + 0,25 α
	Inner sides	t_{IS}	Φ / 2	$\alpha = t_{ISM} / t_{SM}$

Ship typology	Location	t, in mm	δ	Meaning of symbols used in the definition of δ
Double side ships with one effective longitudinal bulkhead	Sides	t_S	$(1 - \Phi)\Psi / 2$	$\Phi = 0{,}275 + 0{,}25\,\alpha$
	Inner sides	t_{IS}	$\Phi\Psi / 2$	
	Longitudinal bulkhead	t_B	$1 - \chi$	
Single side ships with two effective longitudinal bulkheads - see Fig 3 (d)	Sides	t_S	$(1 - \Phi) / 2$	$\Phi = 0{,}3 + 0{,}21\,\alpha$
	Longitudinal bulkheads	t_B	$\Phi / 2$	$\alpha = t_{BM} / t_{SM}$
Note 1: t_S, t_{IS}, t_B : Minimum thicknesses, in mm, of side, inner side and longitudinal bulkhead plating, respectively t_{SM}, t_{ISM}, t_{BM} : Mean thicknesses, in mm, over all the strakes of side, inner side and longitudinal bulkhead plating, respectively. They are calculated as $\Sigma(\ell_i\, t_i) / \Sigma\ell_i$, where ℓ_i and t_i are the length, in m, and the thickness, in mm, of the i^{th} strake of side, inner side and longitudinal bulkhead.				

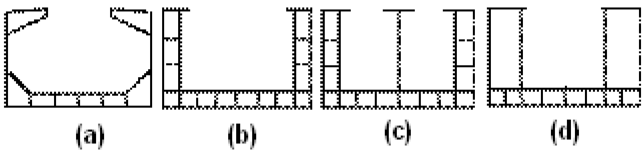


Figure 3: Ship typologies

2.2.3 Shear stresses in flooded conditions of BC-A or BC-B ships

This requirement applies to BC-A or BC-B ships, in addition to [2.2.1] and [2.2.2].

The shear stresses, in the flooded conditions specified in Ch 4, Sec 3, are to be obtained at any point, in N/mm^2, from the following formula:

$$\tau_1 = 0{,}5\left(Q_{SW,F} + Q_{WV,F} - \varepsilon\Delta Q_C\right)\frac{S}{I_Y t}$$

$\varepsilon = \mathrm{sgn}(Q_{SW,F})$

ΔQ_C : Shear force correction, to be calculated according to [2.2.2], where the mass P is to include the mass of the ingressed water in the hold considered and the draught T_1 is to be measured up to the equilibrium waterline

I_Y : Moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to [1.5]

S : First moment, in m^3, of the hull transverse section around its horizontal neutral axis, to be calculated according to [1.6]

t : Thickness, in mm, of the side plating.

3. Checking criteria

3.1 Normal stresses

3.1.1

It is to be checked that the normal stresses σ_1 calculated according to [2.1.2] and, when applicable, [2.1.3] are in compliance with the following formula:

$\sigma_1 \le \sigma_{1,ALL}$

where:

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm², obtained from the following formulae:

$$\sigma_{1,ALL} = \frac{119}{k} \quad \text{for } \frac{x}{L} \le 0,1$$

$$\sigma_{1,ALL} = \frac{175}{k} - \frac{1400}{k}\left(\frac{x}{L} - 0,3\right)^2 \quad \text{for } 0,1 < \frac{x}{L} < 0,3$$

$$\sigma_{1,ALL} = \frac{175}{k} \quad \text{for } 0,3 \le \frac{x}{L} \le 0,7$$

$$\sigma_{1,ALL} = \frac{175}{k} - \frac{1400}{k}\left(\frac{x}{L} - 0,7\right)^2 \quad \text{for } 0,7 < \frac{x}{L} < 0,9$$

$$\sigma_{1,ALL} = \frac{119}{k} \quad \text{for } \frac{x}{L} \ge 0,9$$

3.2 Shear stresses

3.2.1

It is to be checked that the shear stresses τ_1 calculated according to [2.2.1] or [2.2.2] and, when applicable, [2.2.3] are in compliance with the following formula:

$\tau_1 \le \tau_{1,ALL}$

where:

$\tau_{1,ALL}$: Allowable shear stress, in N/mm²:

$\tau_{1,ALL} = 110/k$

4. Section modulus and moment of inertia

4.1 General

4.1.1

The requirements in [4.2] to [4.5] provide the minimum hull girder section modulus, complying with the checking criteria indicated in [3], and the midship section moment of inertia required to ensure sufficient hull girder rigidity.

4.1.2

The k material factors are to be defined with respect to the materials used for the bottom and deck members contributing to the longitudinal strength according to [1]. When material factors for higher strength steels are used, the requirements in [4.5] apply.

4.2 Section modulus within 0,4L amidships

4.2.1

For ships with C_B greater than 0,8, the gross section moduli Z_{AB} and Z_{AD} within 0,4L amidships are to be not less than the greater value obtained, in m^3, from the following formulae:

- $Z_{R,MIN} = n_1\, C\, L^2\, B\, (C_B + 0,7)\, k\, 10^{-6}$
- $Z_R = \dfrac{M_{SW} + M_{WV}}{\sigma_{1,ALL}} 10^{-3}$
- in addition, for BC-A and BC-B ships: $Z_R = \dfrac{M_{SW,F} + M_{WV,F}}{\sigma_{1,ALL}} 10^{-3}$

4.2.2

For ships with C_B less than or equal to 0,8, the gross section moduli Z_{AB} and Z_{AD} at the midship section are to be not less than the value obtained, in m^3, from the following formula:

$Z_{R,MIN} = n_1\, C\, L^2\, B\, (C_B + 0,7)\, k\, 10^{-6}$

In addition, the gross section moduli Z_{AB} and Z_{AD} within 0,4L amidships are to be not less than the value obtained, in m^3, from the following formula:

- $Z_R = \dfrac{M_{SW} + M_{WV}}{\sigma_{1,ALL}} 10^{-3}$
- in addition, for BC-A and BC-B ships: $Z_R = \dfrac{M_{SW,F} + M_{WV,F}}{\sigma_{1,ALL}} 10^{-3}$

4.2.3

Where the total breadth Σb_S of small openings, as defined in [1.2.8], is deducted from the sectional areas included in the hull girder transverse sections, the values Z_R and $Z_{R,MIN}$ defined in [4.2.1] or [4.2.2] may be reduced by 3%.

4.2.4

Scantlings of members contributing to the longitudinal strength (see [1]) are to be maintained within 0,4 L amidships.

4.3 Section modulus outside 0,4L amidships

4.3.1

The gross section moduli Z_{AB} and Z_{AD} outside 0,4 L amidships are to be not less than the value obtained, in m^3, from the following formula:

- $Z_R = \dfrac{M_{SW} + M_{WV}}{\sigma_{1,ALL}} 10^{-3}$
- in addition, for BC-A and BC-B ships: $Z_R = \dfrac{M_{SW,F} + M_{WV,F}}{\sigma_{1,ALL}} 10^{-3}$

4.3.2

Scantlings of members contributing to the hull girder longitudinal strength (see [1]) may be gradually reduced, outside 0,4L amidships, to the minimum required for local strength purposes at fore and aft parts, as specified in Ch 9, Sec 1 or Ch 9, Sec 2, respectively.

4.4 Midship section moment of inertia

4.4.1

The gross midship section moment of inertia about its horizontal neutral axis is to be not less than the value obtained, in m^4, from the following formula:

$$I_{YR} = 3\, Z'_{R,MIN}\, L\, 10^{-2}$$

where $Z'_{R,MIN}$ is the required midship section modulus $Z_{R,MIN}$, in m^3, calculated as specified in [4.2.1] or [4.2.2], but assuming k = 1.

4.5 Extent of higher strength steel

4.5.1

When a material factor for higher strength steel is used in calculating the required section modulus at bottom or deck according to [4.2] or [4.3], the relevant higher strength steel is to be adopted for all members contributing to the longitudinal strength (see [1]), at least up to a vertical distance, in m, obtained from the following formulae:

- above the baseline (for section modulus at bottom):

$$V_{HB} = \frac{\sigma_{1B} - k\sigma_{1,ALL}}{\sigma_{1B} + \sigma_{1D}} z_D$$

- below a horizontal line located at a distance V_D (see [1.4.2]) above the neutral axis of the hull transverse section (for section modulus at deck):

$$V_{HD} = \frac{\sigma_{1D} - k\sigma_{1,ALL}}{\sigma_{1B} + \sigma_{1D}} (N + V_D)$$

where:

σ_{1B}, σ_{1D} : Normal stresses, in N/mm^2, at bottom and deck, respectively, calculated according to [2.1.2]

z_D : Z co-ordinate, in m, of the strength deck defined in [1.3], with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section, defined in [1.4.1], with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4]

V_D : Vertical distance, in m, defined in [1.4.2].

4.5.2

The higher strength steel is to extend in length at least throughout 0,4 L amidships where it is required for strength purposes according to the provision of the present Rules.

5. Permissible still water bending moment and shear force

5.1 Permissible still water bending moment in intact condition

5.1.1 Permissible still water bending moment

The permissible still water bending moment at any hull transverse section in intact condition, in hogging or sagging conditions, is the value M_{SW} considered in the hull girder section modulus calculation according to [4.2] and [4.3].

In the case of structural discontinuities in the hull transverse sections, the distribution of permissible still water bending moments is considered on a case by case basis.

5.1.2 Permissible still water shear force - Direct calculation

Where the shear stresses are obtained through calculation analyses according to [2.2.1], the permissible positive or negative still water shear force in intact condition at any hull transverse section is obtained, in kN, from the following formula:

$Q_P = \varepsilon\,|Q_T| - Q_{WV}$

where:

$\varepsilon = \mathrm{sgn}(Q_{SW})$

Q_T : Shear force, in kN, which produces a shear stress τ = 110/k N/mm^2 in the most stressed point of the hull transverse section, taking into account the shear force correction ΔQ_C and ΔQ in accordance with [2.2.2].

5.1.3 Permissible still water shear force - Simplified calculation

Where the shear stresses are obtained through the simplified procedure in [2.2.2], the permissible positive or negative still water shear force in intact condition at any hull transverse section is obtained, in kN, from the following formula:

a) For ships without effective longitudinal bulkhead or with one effective longitudinal bulkhead:

$$Q_P = \varepsilon\left(\frac{110}{k\delta}\frac{I_Y t}{S} - \Delta Q_C\right) - Q_{WV}$$

b) For ships with two effective longitudinal bulkheads:

$$Q_P = \frac{1}{\delta}\left(\varepsilon\frac{110}{k}\frac{I_Y t}{S} - \varepsilon_Q \Delta Q\right) - Q_{WV}$$

where:

$\varepsilon = \mathrm{sgn}(Q_{SW})$

δ : Shear distribution coefficient defined in Tab 1

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable according to Tab 1

ΔQ_C , ΔQ : Shear force corrections defined in [2.2.2].

ε_Q : Defined in [2.2.2]

5.2 Permissible still water bending moment in harbour conditions

5.2.1 Permissible still water bending moment

The permissible still water bending moment at any hull transverse section in harbour conditions, in hogging or sagging conditions, is obtained, in kN.m, from the following formula:

$$M_{P,H} = M_{SW} + M_{WV} - M_{WV,H}$$

5.2.2 Permissible still water shear force

The permissible positive or negative still water shear force at any hull transverse section, in harbour conditions, is obtained, in kN, from the following formula:

$$Q_{P,H} = \varepsilon Q_P + Q_{WV} - Q_{WV,H}$$

where:

$\varepsilon = \text{sgn}(Q_{SW})$

Q_P : Permissible still water shear force during navigation, in kN, to be calculated according to [5.1.3].

5.3 Permissible still water bending moment and shear force in flooded condition

5.3.1 Permissible still water bending moment

The permissible still water bending moment at any hull transverse section in flooded condition, in hogging or sagging conditions, is the value $M_{SW,F}$ considered in the hull girder section modulus calculation according to [4.2] and [4.3].

In the case of structural discontinuities in the hull transverse sections, the distribution of permissible still water bending moments is considered on a case by case basis.

5.3.2 Permissible still water shear force - Direct calculation

Where the shear stresses are obtained through calculation analyses according to [2.2.1], the permissible positive or negative still water shear force in flooded condition at any hull transverse section is obtained, in kN, from the following formula:

$Q_{P,F} = \varepsilon \, |Q_T| - Q_{WV,F}$

where:

$\varepsilon = \text{sgn}(Q_{SW,F})$

Q_T : Shear force, in kN, which produces a shear stress $\tau = 110/k$ N/mm^2 in the most stressed point of the hull transverse section, taking into account the shear force correction ΔQ_C and ΔQ in accordance with [2.2.2].

5.3.3 Permissible still water shear force - Simplified calculation

Where the shear stresses are obtained through the simplified procedure in [2.2.2], the permissible positive or negative still water shear force in flooded condition at any hull transverse section is obtained, in kN, from the following formula:

c) For ships without effective longitudinal bulkhead or with one effective longitudinal bulkhead:

$$Q_{P,F} = \varepsilon \left(\frac{110}{k\delta} \frac{I_Y t}{S} - \Delta Q_C \right) - Q_{WV,F}$$

d) For ships with two effective longitudinal bulkheads:

$$Q_{P,F} = \frac{1}{\delta}\left(\varepsilon \frac{110}{k} \frac{\mathrm{I}_Y t}{S} - \varepsilon_Q \Delta Q \right) - Q_{WV,F}$$

where:

$\varepsilon = \mathrm{sgn}(Q_{SW})$

δ : Shear distribution coefficient defined in Tab 1

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable according to Tab 1

ΔQ_C, ΔQ : Shear force corrections defined in [2.2.2].

ε_Q : Defined in [2.2.2]

Chapter 5 – Hull girders strength

Welcome JBP

Section 2 - ULTIMATE STRENGTH CHECK

1. Application

1.1

1.1.1

The requirements of this Section apply to ships equal to or greater than 150 m in length.

2. Hull girder ultimate strength check

2.1 Hull girder loads

2.1.1 Bending moment

The bending moment M in sagging and hogging conditions, to be considered in the ultimate strength check of the hull girder, is to be obtained, in kN.m, in intact, flooded and harbour conditions, from the following formula:

$$M = M_{SW} + \gamma_W M_{WV}$$

where:

M_{SW} , $M_{SW,F}$, $M_{SW,H}$: Design still water bending moment, in kN.m, in sagging and hogging conditions at the hull transverse section considered, to be calculated respectively in intact, flooded and harbour conditions

M_{WV}, $M_{WV,F}$, $M_{WV,H}$: Vertical wave bending moment, in kN.m, in sagging and hogging conditions at the hull transverse section considered, defined in Ch 4, Sec 3, respectively in intact, flooded and harbour conditions

γ_W : Safety factor on wave hull girder bending moments, taken equal to:

γ_W = [1,15]

2.2 Hull girder bending moment

2.2.1 Curve M- χ

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment capacity M versus the curvature χ of the transverse section considered (see Fig 1).

The curvature χ is positive for hogging condition and negative for sagging condition.

The curve M-χ is to be obtained either through an incremental-iterative procedure, or through a nonlinear finite element analysis, according to the criteria specified in App 1.

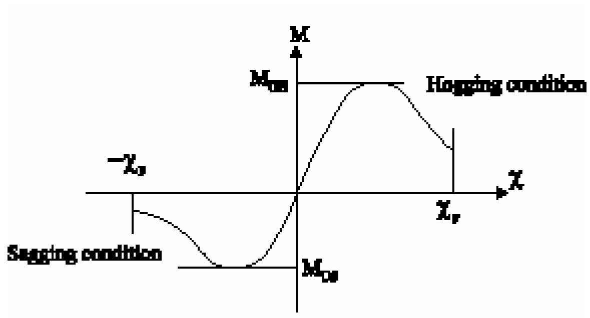


Figure 1: Curve bending moment capacity M versus curvature χ

2.2.2 Hull girder transverse sections

The hull girder transverse sections are constituted by the elements contributing to the hull girder longitudinal strength, considered with their net offered scantlings based on offered gross thickness reduced by 0.5 t_C, according to Ch 5, Sec 1, [1].

2.3 Checking criteria

2.3.1

It is to be checked that the hull girder ultimate bending capacity at any hull transverse section is in compliance with the following formula:

$$M \le \frac{M_U}{\gamma_R}$$

where:

M_U : Ultimate bending moment capacity of the hull transverse section considered, calculated with offered net scantlings based on offered gross thickness reduced by 0.5 t_C, in kN.m:

in hogging conditions:

$M_U = M_{UH}$

in sagging conditions:

$M_U = M_{US}$

M_{UH} : Ultimate bending moment capacity in hogging conditions, defined in [2.2.1]

M_{US} : Ultimate bending moment capacity in sagging conditions, defined in [2.2.1]

M : Bending moment, in kN.m, defined in [2.1.1] for the ship in intact, flooded and harbour conditions

γ_R : Safety factor, taken equal to [1.10]

Chapter 6 – Hull scantlings

Welcome JBP

Section 1 - PLATING

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

I_Y : Net moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to Ch 5, Sec 1, [1.5], on offered gross thickness reduced by $0,5t_C$ for all structural members

I_Z : Net moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to Ch 5, Sec 1, [1.5], on offered gross thickness reduced by $0,5t_C$ for all structural members

N : Z co-ordinate with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4], in m, of the centre of gravity of the hull net transverse section, defined in Ch 5, Sec 1, [1.2], considering offered gross thickness reduced by $0,5t_C$ for all structural members

t : Net thickness, in mm, of a plate panel.

p_S, p_W : Still water and wave pressure, in kN/m^2, in intact conditions, defined in [3.1.2]

p_F : pressure, in kN/m^2, in flooding conditions, defined in [3.1.3]

p_T : Pressure, in kN/m^2, in testing conditions, defined in [3.1.4]

σ_X : Normal stress, in N/mm^2, defined in [3.1.5]

ℓ : Length, in m, of the longer side of the elementary plate panel

s : Length, in m, of the shorter side of the elementary plate panel

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1{,}21\sqrt{1 + 0{,}33\left(\frac{s}{\ell}\right)^2} - 0{,}69\frac{s}{\ell}$$, to be taken not greater than 1,0

c_r : Coefficient of curvature of the panel, equal to:

$$c_r = 1 - 0{,}5\frac{s}{r}$$, to be taken not less than 0,5

r : Radius of curvature, in m

1. General

1.1 Application

1.1.1

The requirements of this Section apply for the strength check of plating subjected to lateral pressure and, for plating contributing to the longitudinal strength, to in-plane hull girder normal stress.

In addition, the buckling check of platings and stiffened panels is to be carried out according to Ch 6, Sec 3.

1.2 Net thicknesses

1.2.1

As specified in Ch 3, Sec 2, all thicknesses referred to in this Section are net, i.e. they do not include any corrosion addition.

The gross thicknesses are obtained as specified in Ch 3, Sec 2, [3].

1.2.2

The net thickness, in mm, of each plating is given by the greatest of the net thicknesses calculated for each load calculation point, as defined in [1.4.1], representative of the considered plating (see Tab 1). The geometry to be considered is that of the elementary plate panel related to the load calculation point.

1.3 Elementary plate panel

1.3.1

The elementary plate panel (EPP) is the smallest unstiffened part of plating between stiffeners.

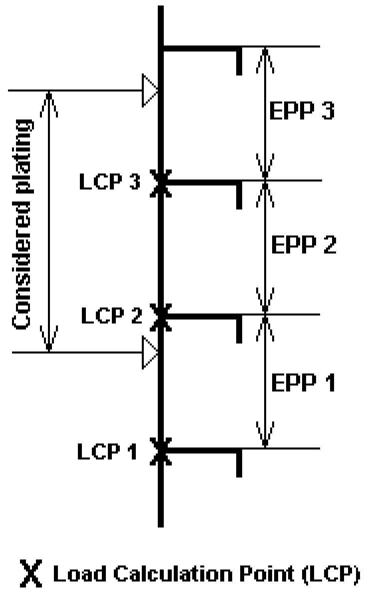
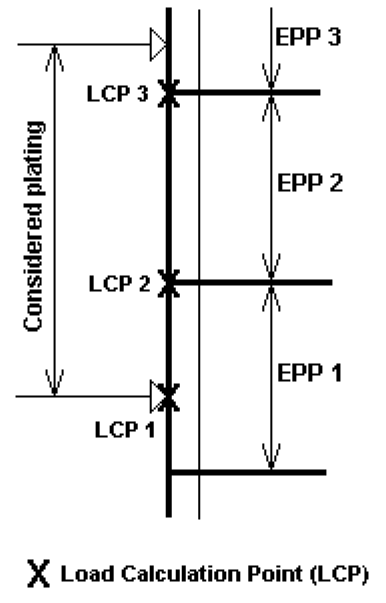
1.4 Load calculation point

1.4.1

Unless otherwise specified, lateral pressure and hull girder stresses are to be calculated:

- for longitudinal framing, at the lower edge of the elementary plate panel (see Tab 1) or, in the case of horizontal plating, at the point of minimum y-value among those of the elementary plate panel considered, as the case may be
- for transverse framing, at the lower edge of the elementary plate panel or at the lower edge of the strake (see Tab 1) or, in the case of horizontal plating, at the point of minimum y-value among those of the elementary plate panel considered, as the case may be.

Table 1: Load calculation points

Longitudinally stiffened plating	Transversely stiffened plating
	

2. General requirements

2.1 Corrugated bulkhead

2.1.1

Unless otherwise specified, the net plating thickness of a corrugated bulkhead is to be not less than that obtained for a plate panel with s equal to the greater of A and c, where A and c are defined in Fig 1.

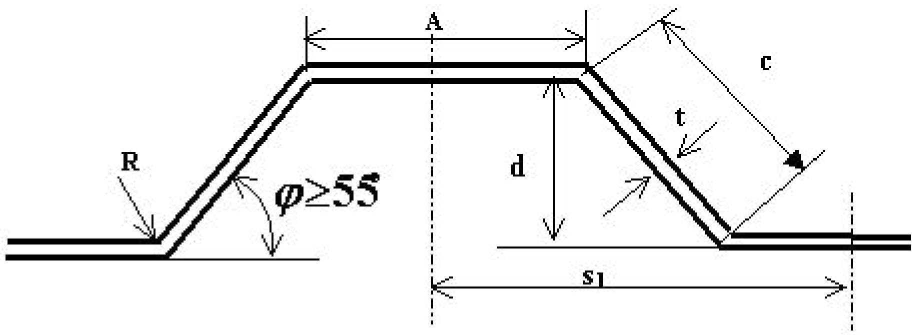


Figure 1: Corrugated bulkhead

2.2 Minimum net thicknesses

2.2.1

The net thickness of plating is to be not less than the values given in Tab 2.

In addition, in the cargo area, the net thickness of side shell plating, from the normal ballast draught to 0,25T (minimum 2,2 m) above T, is to be not less than the value obtained, in mm, from the following formula:

$$t = 28(s + 0{,}7)\frac{(BT)^{0{,}25}}{\sqrt{R_{eH}}}$$

Table 2: Minimum net thickness of plating (in mm)

Plating	Minimum net thickness
Keel	$3{,}8 + 0{,}040\ L\ k^{1/2} + 4{,}5\ s$
Bottom • longitudinal framing • transverse framing	 $1{,}9 + 0{,}032\ L\ k^{1/2} + 4{,}5\ s$ $2{,}8 + 0{,}032\ L\ k^{1/2} + 4{,}5\ s$
Inner bottom • outside the engine room • engine room	 $1{,}9 + 0{,}024\ L\ k^{1/2} + 4{,}5\ s$ $3{,}0 + 0{,}024\ L\ k^{1/2} + 4{,}5\ s$
Side	$0{,}85\ L^{1/2}$
Inner side	$0{,}85\ L^{1/2}$
Weather strength deck and trunk deck, if any • area within 0,4 L amidships •- longitudinal framing •- transverse framing • area outside 0,4 L amidships • between hatchways • at fore and aft part	 $1{,}6 + 0{,}032\ L\ k^{1/2} + 4{,}5\ s$ $1{,}6 + 0{,}040\ L\ k^{1/2} + 4{,}5\ s$ **(1)** $2{,}1 + 0{,}013\ L\ k^{1/2} + 4{,}5\ s$ $2{,}1 + 0{,}013\ L\ k^{1/2} + 4{,}5\ s$

Plating	Minimum net thickness
Cargo deck	$8\ s\ k^{1/2}$
Accommodation deck	$2,1 + 2,20\ k^{1/2} + s$
Platform in engine room	$3,6 + 2,20\ k^{1/2} + s$
Transverse watertight bulkhead	$0,6\ L^{1/2}$
Longitud. Watertight bulkhead	$3,6 + 2,20\ k^{1/2} + s$
Tank and wash bulkheads	$3,6 + 2,20\ k^{1/2} + s$
(1) The minimum net thickness is to be obtained by linearly interpolating between that required for the area within 0,4 L amidships and that at the fore and aft part.	

2.3 Bilge plating

2.3.1

The net thickness of the longitudinally framed bilge plating, in mm, is to be not less than the value obtained from [3.2]

2.3.2

The net thickness of the transversely framed bilge plating, in mm, is to be not less than the value obtained from the following formula:

$$t = 0,76\left[(p_S + p_W)s_b\right]^{0,4} R^{0,6} k^{0,5}$$

where :

R : Bilge radius, in m

s_b : Spacing of floors or transverse bilge brackets, in m

2.3.3

The net thickness bilge plating is to be not less than the actual thicknesses of the adjacent 2 m width bottom or side plating, whichever is the greater.

2.4 Sheerstrake

2.4.1 Welded sheerstrake

The net thickness of a welded sheerstrake is to be not less than the actual thicknesses of the adjacent 2 m width side plating, taking into account higher strength steel corrections if needed.

2.4.2 Rounded sheerstrake

The net thickness of a rounded sheerstrake is to be not less than the actual net thickness of the adjacent deck plating.

2.4.3 Net thickness of the sheerstrake in way of breaks of long superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of long superstructures occurring within 0,5L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 40%, but need not exceed 4,5 mm.

Where the breaks of superstructures occur outside 0,5L amidships, the increase in net thickness may be reduced to 30%, but need not exceed 2,5 mm.

2.4.4 Net thickness of the sheerstrake in way of breaks of short superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of short superstructures occurring within 0,6L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15%, but need not exceed 4,5 mm.

2.5 Stringer plate

2.5.1 General

The net thickness of the stringer plate is to be not less than the actual net thickness of the adjacent deck plating.

2.5.2 Net thickness of the stringer plate in way of breaks of long superstructures

The net thickness of the stringer plate is to be increased in way of breaks of long superstructures occurring within 0,5L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 40%, but need not exceed 4,5 mm.

Where the breaks of superstructures occur outside 0,5L amidships, the increase in net thickness may be reduced to 30%, but need not exceed 2,5 mm.

2.5.3 Net thickness of the stringer plate in way of breaks of short superstructures

The net thickness of the stringer plate is to be increased in way of breaks of short superstructures occurring within 0,6L amidships, over a length of about one sixth of the ship breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15%, but need not exceed 4,5 mm.

3. Strength check of plating subjected to lateral pressure

3.1 Load model

3.1.1 General

The still water and wave lateral pressures induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the plating under consideration and the type of the compartments adjacent to it.

The plating which constitute the boundary of compartments not intended to carry liquid (excluding bottom and side shell platings) is to be subjected to lateral pressure in flooding conditions.

The wave lateral pressures and hull girder loads are to be calculated, for the probability level of 10^{-8}, in the mutually exclusive load cases H1, H2, F1, F2, R1, R2, P1 and P2, as defined in Ch 4, Sec 4.

3.1.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_s) includes:

- the hydrostatic pressure, defined in Ch 4, Sec 5, [1]
- the still water internal pressure, defined in Ch 4, Sec 6 for the various types of cargoes and for ballast.

Wave pressure (p_w) includes for each load case H1, H2, F1, F2, R1, R2, P1 and P2:

- the hydrodynamic pressure, defined in Ch 4, Sec 5, [1]

- the inertial pressure, defined in Ch 4, Sec 6 for the various types of cargoes and for ballast.

3.1.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions p_F is defined in Ch 4, Sec 6, [3].

3.1.4 Lateral pressure in testing conditions

The lateral pressure p_T in testing conditions is taken equal to:

- $p_T = p_{ST} - p_S$ for bottom shell plating and side shell plating
- $p_T = p_{ST}$ otherwise,

where:

p_{ST}: Testing pressure defined in Ch 4, Sec 6, [4]

p_S : Pressure taken equal to:

- If the testing is carried out afloat: hydrostatic pressure defined in Ch 4, Sec 5, [1] for the draught T_1, defined by the Designer, at which the testing is carried out. If T_1 is not defined, the testing is considered as being not carried out afloat
- If the testing is not carried out afloat: $p_S = 0$

3.1.5 Normal stresses

The normal stress to be considered for the strength check of plating contributing to the hull girder longitudinal strength is the maximum value of σ_X between sagging and hogging conditions, when applicable, obtained, in N/mm², from the following formula:

$$\sigma_X = C_\ell \left[C_{SW} \left| \frac{M_{SW}}{I_Y} \right| (z - N) + C_{WV} \left| \frac{M_{WV}}{I_Y} \right| (z - N) - C_{WH} \left| \frac{M_{WH}}{I_Z} \right| y \right] 10^{-3}$$

where:

C_ℓ : Coefficient defined in Tab 3

M_{SW} : Permissible still water bending moments, in kNm, in hogging or sagging as the case may be

M_{WV} : Vertical wave bending moment, in kNm, in hogging or sagging as the case may be, as defined in Ch 4, Sec 3

M_{WH} : Horizontal wave bending moment, in kNm, as defined in Ch 4, Sec 3

C_{SW} : Combination factor for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and defined in the Table 4

C_{WV}, C_{WH} : Combination factors defined in Ch 4, Sec 4, [2.4] for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and given in the Tab 4

Table 3: Coefficient C_ℓ

C_ℓ	
Within 0.4L amidships	At ends(x/L = 0 and x/L = 1)
1	0
(1) C_ℓ is to be linearly interpolated between the specified values of x/L.	

Table 4: Combination factors C_{SW}, C_{WV} and C_{WH}

LC	Hogging			Sagging		
	C_{SW}	C_{WV}	C_{WH}	C_{SW}	C_{WV}	C_{WH}
H1	Not Applicable			-1	-1	0
H2	1	1	0	Not Applicable		
F1	Not Applicable			-1	-1	0
F2	1	1	0	Not Applicable		
R1	1	0	$+1.2- T_{LC}/T$	-1	0	$+1.2- T_{LC}/T$
R2	1	0	$-1.2 +T_{LC}/T$	-1	0	$-1.2 +T_{LC}/T$
P1	1	$0.4-T_{LC}/T$	0	-1	$0.4-T_{LC}/T$	0
P2	1	$-0.4 +T_{LC}/T$	0	-1	$-0.4 +T_{LC}/T$	0

3.2 Plating thickness

3.2.1 Intact conditions

The net thickness of laterally loaded plate panels is to be not less than the value obtained, in mm, from the following formula:

$$t = 15{,}8 c_a c_r s \sqrt{\frac{p_S + p_W}{\lambda_P R_Y}}$$

where:

λ_P : Coefficient defined in Tab 5

Table 5: Coefficient λ_P

Plating		Coefficient λ_P
Contributing to the hull girder longitudinal strength	Longitudinally framed plating	$0{,}95 - 0{,}45\left\lvert\frac{\sigma_X}{R_Y}\right\rvert$ without being taken greater than 0,7
	Transversely framed plating	$0{,}95 - 0{,}90\left\lvert\frac{\sigma_X}{R_Y}\right\rvert$, without being taken greater than 0,7
Not contributing to the hull girder longitudinal strength		0,7

3.2.2 Flooding conditions

The plating which constitute the boundary of compartments not intended to carry liquids (excluding bottom plating and side shell plating) is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 15{,}8 c_a c_r s \sqrt{\frac{p_F}{\alpha \lambda_P R_Y}}$$

where:

λ_P : Coefficient defined in Tab 5

α : Coefficient taken equal to:

- 0,95 for the plating of collision bulkhead
- 1,15 for the plating of other watertight boundaries of compartments.

3.2.3 Additional requirement for flooding conditions for BC-A and BC-B ships

The net plate thickness t, in mm, of transverse vertically corrugated watertight bulkheads of BC-A and BC-B ships is to be not less than that obtained from the following formula:

$$t = 14{,}9s\sqrt{\frac{1.05p}{R_{eH}}}$$

p : Resultant pressure, in kN/m^2, as defined in Ch 4, Sec 6, [3.3.7]

For built-up corrugation bulkheads, when the thicknesses of the flange and web are different:

- the net thickness of the narrower plating is to be not less than that obtained, in mm, from the following formula:

$$t_N = 14{,}9s\sqrt{\frac{1.05p}{R_{eH}}}$$

- the net thickness of the wider plating is not to be less than the greater of those obtained, in mm, from the following formulae:

$$t_W = 14{,}9s\sqrt{\frac{1.05p}{R_{eH}}}$$

$$t_W = \sqrt{\frac{462s^2 p}{R_{eH}} - t_{NP}^2}$$

where:

t_{NP}: Actual net thickness of the narrower plating, in mm, to be not taken greater than:

$$t_{NP} = 14{,}9s\sqrt{\frac{1.05p}{R_{eH}}}$$

3.2.4 Testing conditions

The plating of compartments or structures as defined in Ch 4, Sec 6, [4] is to be checked in testing conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 15{,}8c_a c_r s\sqrt{\frac{p_T}{1{,}05R_Y}}$$

Chapter 6- Hull scantlings

Welcome JBP

Section 2 - ORDINARY STIFFENERS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

I_Y : Net moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to Ch 5, Sec 1, [1.5], on offered gross thickness reduced by $0,5t_C$ for all structural members

I_Z : Net moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to Ch 5, Sec 1, [1.5], on offered gross thickness reduced by $0,5t_C$ for all structural members

N : Z co-ordinate with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4], in m, of the centre of gravity of the hull net transverse section defined in Ch 5, Sec 1, [1.2], considering offered gross thickness reduced by $0,5t_C$ for all structural members

p_S, p_W : Still water and wave pressure, in kN/m^2, in intact conditions, defined in [3.1.2]

p_F : Pressure, in kN/m^2, in flooding conditions, defined in [3.1.3]

p_T : Pressure, in kN/m^2, in testing conditions, defined in [3.1.4]

σ_X : Normal stress, in N/mm^2, defined in [3.1.5]

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 3, Sec 6, [4.2]

h_w : Web height, in mm

t_w : Net web thickness, in mm

b_f : Face plate width, in mm

t_f : Net face plate thickness, in mm

b_p : Width, in m, of the plating attached to the stiffener, for the yielding check, defined in Ch 3, Sec 6, [4.3]

w : Net section modulus, in cm^3, of the stiffener, with an attached plating of width b_p, to be calculated as specified in Ch 3, Sec 6, [4.4]

A_{Sh} : Net shear sectional area, in cm^2, of the stiffener, to be calculated as specified in Ch 3, Sec 6, [4.4]

m : Coefficient taken equal to:

- m = 10 for vertical stiffeners
- m = 12 for other stiffeners

τ_a : Allowable shear stress, in N/mm^2, taken equal to:

- $\tau_a = 0,4\ R_Y$

1. General

1.1 Application

1.1.1

The requirements of this Section apply for the yielding check of ordinary stiffeners subjected to lateral pressure and, for ordinary stiffeners contributing to the hull girder longitudinal strength, to hull girder normal stresses.

The yielding check is also to be carried out for ordinary stiffeners subjected to specific loads, such as concentrated loads.

In addition, the buckling check of ordinary stiffeners is to be carried out according to Ch 6, Sec 3.

1.2 Net scantlings

1.2.1

As specified in Ch 3, Sec 2, all scantlings referred to in this Section are net, i.e. they do not include any corrosion addition.

The gross scantlings are obtained as specified in Ch 3, Sec 2, [3].

1.3 Load calculation point

1.3.1 Horizontal stiffeners

Unless otherwise specified, lateral pressure and hull girder stress, if any, are to be calculated at mid-span of the ordinary stiffener considered.

1.3.2 Vertical stiffeners

The lateral pressure p is to be calculated as the maximum between the value obtained at mid-span and the pressure obtained from the following formula:

- $p = \dfrac{p_U + p_L}{2}$, when the upper end of the vertical stiffener is below the lowest zero pressure level
- $p = \dfrac{\ell_1}{\ell}\dfrac{p_L}{2}$, when the upper end of the vertical stiffener is at or above the lowest zero pressure level (see Fig 1)

where:

ℓ_1 : Distance, in m, between the lower end of vertical stiffener and the lowest zero pressure level

p_U, p_L : Lateral pressures at the upper and lower end of the vertical stiffener span ℓ, respectively

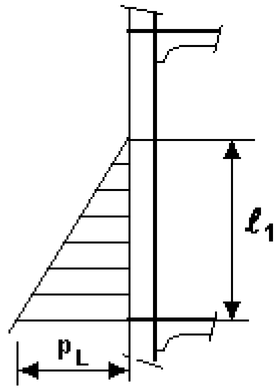


Figure 1: Definition of pressure for vertical stiffeners

1.4 Net dimensions of ordinary stiffeners

1.4.1 Flat bar

The net dimensions of a flat bar ordinary stiffener (see Fig 2) are to comply with the following requirement:

$$\frac{h_w}{t_w} \leq 20\sqrt{k}$$

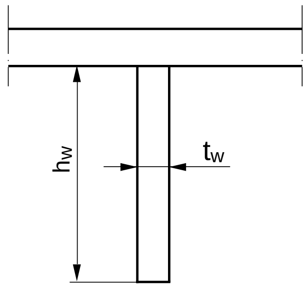


Figure 2: Net dimensions of a flat bar

1.4.2 T-section

The net dimensions of a T-section ordinary stiffener (see Fig 3) are to comply with the following two requirements:

$$\frac{h_W}{t_W} \leq 65\sqrt{k}$$

$$\frac{b_f}{t_f} \leq 33\sqrt{k}$$

$$b_f t_f \geq \frac{h_w t_w}{6}$$

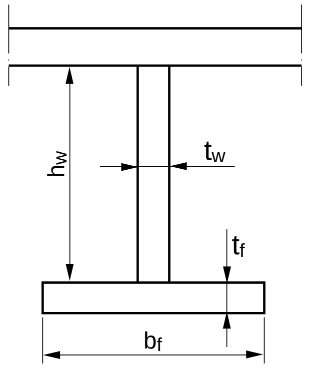


Figure 3: Net dimensions of a T-section

1.4.3 Angle

The net dimensions of an angle ordinary stiffener (see Fig 4) are to comply with the following two requirements:

$$\frac{h_w}{t_w} \le 55\sqrt{k}$$

$$\frac{b_f}{t_f} \le 16{,}5\sqrt{k}$$

$$b_f t_f \ge \frac{h_w t_w}{6}$$

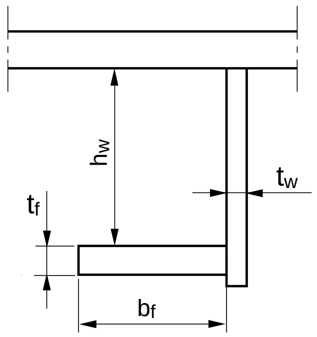


Figure 4: Net dimensions of an angle

2. General requirements

2.1 Corrugated bulkhead

2.1.1

Unless otherwise specified, the net section modulus and the net shear sectional area of a corrugation are to be not less than those obtained for an ordinary stiffener with s equal s_1, as defined in Fig 5.

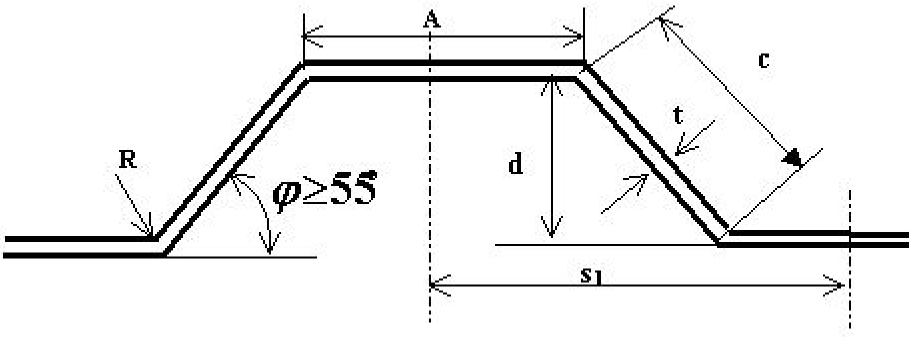


Figure 5: Corrugated bulkhead

2.2 Minimum net thicknesses of webs of ordinary stiffeners

2.2.1 Ordinary stiffeners other than side frames of single side bulk carriers

The net thickness of the web of ordinary stiffeners, in mm, is to be not less than the greater of:

- $t_{MIN} = 1,6 + 2,2\ k^{1/2} + s$
- 50% of the net offered thickness of the attached plating.

2.2.2 Side frames of single side bulk carriers

The net thickness of side frame webs within the cargo area, in mm, is to be not less than the value obtained from the following formula:

$t_{MIN} = 0,75\ \alpha\ (7 + 0,03\ L)$

where:

α : Coefficient taken equal to:

- $\alpha = 1,15$ for the frame webs in way of the foremost hold
- $\alpha = 1,0$ for the frame webs in way of other holds

2.3 Struts connecting ordinary stiffeners

2.3.1

The sectional area A_{SR}, in cm², and the moment of inertia I_{SR} about the main axes, in cm⁴, of struts connecting ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$A_{SR} = \frac{p_{SR} s \ell}{20}$$

$$I_{SR} = \frac{0,75 s \ell (p_{SR1} + p_{SR2}) A_{ASR} \ell_{SR}^2}{47,2 A_{ASR} - s\ell (p_{SR1} + p_{SR2})}$$

where:

p_{SR} : Pressure to be taken equal to the greater of the values obtained, in kN/m², from the following formulae:

$p_{SR} = 0,5\ (p_{SR1} + p_{SR2})$

$p_{SR} = p_{SR3}$

p_{SR1} : External pressure in way of the strut, in kN/m², acting on one side, outside the compartment in which the strut is located

p_{SR2} : External pressure in way of the strut, in kN/m², acting on the opposite side, outside the compartment in which the strut is located

p_{SR3} : Internal pressure at mid-span of the strut, in kN/m², in the compartment in which the strut is located

ℓ : Span, in m, of ordinary stiffeners connected by the strut (see Ch 3, Sec 6, [4.2.3])

ℓ_{SR} : Length, in m, of the strut

A_{ASR} : Actual net sectional area, in cm², of the strut.

2.4 Deck ordinary stiffeners in way of launching appliances used for survival craft or rescue boat

2.4.1

The scantlings of deck ordinary stiffeners are to be determined by direct calculations.

2.4.2

The loads exerted by launching appliance are to correspond to the SWL of the launching appliance.

2.4.3

The combined stress, in N/mm², is not to exceed the smaller of:

$$\frac{100}{235}R_{eH} \text{ and } \frac{54}{235}R_m$$

where R_m is the ultimate tensile strength of the stiffener material, in N/mm².

3. Yielding check

3.1 Load model

3.1.1 General

The still water and wave lateral loads induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the ordinary stiffener under consideration and the type of the compartments adjacent to it.

Ordinary stiffeners located on platings which constitute the boundary of compartments not intended to carry liquids (excluding those on bottom and side shell platings) are to be subjected to the lateral pressure in flooding conditions.

The wave lateral loads and hull girder loads are to be calculated, for the probability level of 10^{-8}, in the mutually exclusive load cases H1, H2, F1, F2, R1, R2, P1 and P2, as defined in Ch 4, Sec 4 .

3.1.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

- the hydrostatic pressure, defined in Ch 4, Sec 5, [1]
- the still water internal pressure, defined in Ch 4, Sec 6 for the various types of cargoes and for ballast.

Wave pressure (p_W) includes for each load case H1, H2, F1, F2, R1, R2, P1 and P2:

- the hydrodynamic pressure, defined in Ch 4, Sec 5, [1]
- the inertial pressure, defined in Ch 4, Sec 6 for the various types of cargoes and for ballast.

3.1.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions p_F is defined in Ch 4, Sec 6, [3].

3.1.4 Lateral pressure in testing conditions

The lateral pressure p_T in testing conditions is taken equal to:

- $p_T = p_{ST} - p_S$ for bottom shell plating and side shell plating
- $p_T = p_{ST}$ otherwise,

where:

p_{ST}: Testing pressure defined in Ch 4, Sec 6, [4]

p_S : Pressure taken equal to:

- If the testing is carried out afloat: hydrostatic pressure defined in Ch 4, Sec 5, [1] for the draught T_1, defined by the Designer, at which the testing is carried out. If T_1 is not defined, the testing is considered as being not carried out afloat
- If the testing is not carried out afloat: $p_S = 0$

3.1.5 Normal stresses

The normal stress to be considered for the strength check of ordinary stiffeners contributing to the hull girder longitudinal strength is the maximum value of σ_X between sagging and hogging conditions, when applicable, obtained , in N/mm², from the following formula:

$$\sigma_X = C_\ell \left[C_{SW} \left| \frac{M_{SW}}{I_Y} \right| (z - N) + C_{WV} \left| \frac{M_{WV}}{I_Y} \right| (z - N) - C_{WH} \left| \frac{M_{WH}}{I_Z} \right| y \right] 10^{-3}$$

where:

C_ℓ : Coefficient defined in Tab 1

M_{SW} : Permissible still water bending moments, in kNm, in hogging or sagging as the case may be

M_{WV} : Vertical wave bending moment, in kNm, in hogging or sagging as the case may be, as defined in Ch 4, Sec 3

M_{WH} : Horizontal wave bending moment, in kNm, as defined in Ch 4, Sec 3

C_{SW} : Combination factor for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and defined in the Tab 2

C_{WV}, C_{WH} : Combination factors defined in Ch 4, Sec 4, [2.4] for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and given in the Tab 2

Table 1: Coefficient C_ℓ

C_ℓ	
Within 0.4L amidships	At ends(x/L = 0 and x/L = 1)
1	0
(1) C_ℓ is to be linearly interpolated between the specified values of x/L.	

Table 2: Combination factors C_{SW}, C_{WV} and C_{WH}

LC	Hogging			Sagging		
	C_{SW}	C_{WV}	C_{WH}	C_{SW}	C_{WV}	C_{WH}
H1	Not Applicable			-1	-1	0
H2	1	1	0	Not Applicable		
F1	Not Applicable			-1	-1	0
F2	1	1	0	Not Applicable		
R1	1	0	$+1.2- T_{LC}/T$	-1	0	$+1.2- T_{LC}/T$
R2	1	0	$-1.2 +T_{LC}/T$	-1	0	$-1.2 +T_{LC}/T$
P1	1	$0.4-T_{LC}/T$	0	-1	$0.4-T_{LC}/T$	0
P2	1	$-0.4 +T_{LC}/T$	0	-1	$-0.4 +T_{LC}/T$	0

3.2 Strength criteria for single span ordinary stiffeners other than side frames of single side bulk carriers

3.2.1 Boundary conditions

The requirements of this sub-article apply to ordinary stiffeners considered as clamped at both ends.

For other boundary conditions, the yielding check is to be considered on a case by case basis.

3.2.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.2.3] to [3.2.5] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.2.3 Net section modulus and net shear sectional area of single span ordinary stiffeners under intact conditions

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of single span ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \frac{(p_S + p_W) s \ell^2}{m \lambda_S R_Y} 10^3$$

$$A_{sh} = \frac{5 (p_S + p_W) s \ell}{\tau_a \sin \phi}$$

where:

λ_S : Coefficient defined in Tab 3.

ϕ : Angle, in deg, between the stiffener web and the shell plate, measured at the middle of the stiffener span; the correction is to be applied when ϕ is less than 75 deg.

Table 3: Coefficient λ_S

Ordinary stiffener	Coefficient λ_S (1)
Longitudinal stiffener contributing to the hull girder longitudinal strength	$\left[1{,}2\left(1{,}0-0{,}85\left\|\frac{\sigma_X}{R_Y}\right\|\right)\right]$, without being taken greater than [0,9]
Other stiffeners	[0,9]

3.2.4 Net section modulus and net shear sectional area of single span ordinary stiffeners under flooding conditions

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of single span ordinary stiffeners subjected to flooding are to be not less than the values obtained from the following formulae:

$$w = \frac{p_F s \ell^2}{m \alpha \lambda_S R_Y} 10^3$$

$$A_{sh} = \frac{5 p_F s \ell}{\alpha \tau_a \sin\phi}$$

where:

λ_s, ϕ : Coefficient and angle defined in [3.2.3]

α : Coefficient taken equal to:

- 0,95 for the ordinary stiffeners of collision bulkhead
- 1,15 for the ordinary stiffeners of other watertight boundaries of compartments.

3.2.5 Additional requirement for flooding conditions for BC-A and BC-B ships

The bending capacity of the corrugations of transverse vertically corrugated watertight bulkheads of BC-A and BC-B ships is to comply with the following formula:

$$10^3 \frac{M}{(0{,}5 W_{LE} + W_M) R_{eH}} \le 0{,}95$$

where:

M : Bending moment in a corrugation, to be obtained, in kN.m, from the following formula:

$$M = F \ell_C / 8$$

F : Resultant force, in kN, to be calculated according to Ch4, Sec 6, [3.3.7]

W_{LE} : Net section modulus, in cm³, of one half pitch corrugation, to be calculated at the lower end of the corrugations according to [1.1.9], without being taken greater than the value obtained from the following formula:

$$W_{LE,M} = W_G + 10^3 \left(\frac{Q h_G - 0{,}5 h_G^2 s_C p_G}{R_{eH}} \right)$$

W_G : Net section modulus, in cm³, of one half pitch corrugation, to be calculated in way of the upper end of shedder or gusset plates, as applicable, according to Ch 3, Sec 6, [10.4.13]

Q : Shear force in a corrugation, to be obtained, in kN, from the following formula:

$$Q = 0{,}8 F$$

h_G : Height, in m, of shedders or gusset plates, as applicable (see Ch 3, Sec 6, Fig 30 to Fig 34)

p_G : Resultant pressure, in kN/m^2, to be calculated in way of the middle of the shedders or gusset plates, as applicable, according to Ch 4, Sec 6, [3.3.7]

W_M : Net section modulus, in cm^3, of one half pitch corrugation, to be calculated at the mid-span of corrugations according to Ch 3, Sec 6, [10.4.14], without being taken greater than $1,15W_{LE}$.

In addition, The shear stress τ, is to comply with the following formula:

$$\tau \le \frac{R_{eH}}{2}$$

where the shear stress τ in the corrugation is to be obtained, in N/mm^2, from the following formula:

$$\tau = 10\frac{Q}{A_{SH}}$$ A_{SH} being the shear area, in cm^2, calculated according to Ch 3, Sec 6, [10.4.15].

3.2.6 Net section modulus and net shear sectional area of single span ordinary stiffeners under testing conditions

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of single span ordinary stiffeners subjected to testing are to be not less than the values obtained from the following formulae:

$$w = \frac{p_T s \ell^2}{1,05 m R_Y} 10^3$$

$$A_{sh} = \frac{5 p_T s \ell}{1,05 \tau_a \sin\phi}$$

where:

ϕ : Angle defined in [3.2.3].

3.3 Strength criteria for side frames of single side bulk carriers

3.3.1 Net section modulus and net shear sectional area of side frames

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of side frames subjected to lateral pressure are to be not less, in the mid-span area, than the values obtained from the following formulae:

$$w = [1.125]\alpha_m \frac{(p_S + p_W)s\ell^2}{m\lambda_S R_Y} 10^3$$

$$A_{sh} = 0,9\alpha_S \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}\left[\frac{\ell - 2\ell_B}{\ell}\right]$$

where:

α_m : Coefficient taken equal to:

- $\alpha_m = 0,42$ for BC-A ships
- $\alpha_m = 0,36$ for other ships

λ_S : Coefficient taken equal to 0,9

ℓ : Side frame span, in m, defined in Ch 3, Sec 6, Fig 17, to be taken not less than 0,25 D

α_S : Coefficient taken equal to:

- $\alpha_S = 1,1$ for side frames of holds specified to be empty in BC-A ships
- $\alpha_S = 1,0$ for other side frames

ℓ_B = Lower bracket length, in m, defined in Ch 3, Sec 6, Fig 17.

3.3.2 Supplementary strength requirements

In addition to [3.3.1], the net moment of inertia, in cm^4, of the 3 side frames located immediately abaft the collision bulkhead is to be not less than the value obtained from the following formula:

$$I = 0{,}18 \frac{(p_S + p_W)\ell^4}{n}$$

where:

ℓ : Side frame span, in m

n : Number of frames from the bulkhead to the frame in question, taken equal to 1,2 or 3

s : frame spacing, in m

As an alternative, supporting structures, such as horizontal stringers, are to be fitted between the collision bulkhead and a side frame which is in line with transverse webs fitted in both the topside tank and hopper tank, maintaining the continuity of forepeak stringers within the foremost hold.

3.3.3 Lower bracket of side frame

In addition, at the level of lower bracket as shown in Ch 3, Sec 6, Fig 17, the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is to be not less than twice the net section modulus w required for the frame mid-span area obtained from [3.3.1].

The net thickness t_{LB} of the frame lower bracket, in mm, is to be not less than the net thickness of the side frame web plus 1,5 mm.

Moreover, the net thickness t_{LB} of the frame lower bracket is to comply with the following formula:

- for symmetrically flanged frames: $\dfrac{h_{LB}}{t_{LB}} \le 87\sqrt{k}$
- for asymmetrically flanged frames : $\dfrac{h_{LB}}{t_{LB}} \le 73\sqrt{k}$

The web depth h_{LB} of lower bracket may be measured from the intersection between the sloped bulkhead of the hopper tank and the side shell plate, perpendicularly to the face plate of the lower bracket (see Ch 3, Sec 6, Fig 21).

For the 3 side frames located immediately abaft the collision bulkhead, whose scantlings are increased according to [3.3.2], when t_{LB} is greater than $1{,}73 t_W$, the thickness t_{LB} may be taken as the value t'_{LB} obtained from the following formula:

$$t'_{LB} = \left(\frac{t_{LB}^2}{t_W} \right)^{1/3}$$

where t_W is the net thickness corresponding to A_{sh} determined in accordance to [3.3.1].

The flange outstand is not to exceed $12k^{0,5}$ times the net flange thickness.

3.3.4 Upper bracket of side frame

In addition, at the level of upper bracket as shown in Ch 3, Sec 6, Fig 17, the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is to be not less than twice the net section modulus w required for the frame mid-span area obtained from [3.3.1].

The net thickness t_{UB} of the frame upper bracket, in mm, is to be not less than the net thickness of the side frame web.

3.4 Upper and lower connections of side frames of single side bulk carriers

3.4.1

The section moduli of the:

- side shell and hopper tank longitudinals that support the lower connecting brackets,
- side shell and topside tank longitudinals that support the upper connecting brackets

are to be such that the following relationship is separately satisfied for each lower and upper connecting bracket (see also Ch 3, Sec 6, Fig 21):

$$\sum_n w_i d_i \geq \alpha_T \frac{(p_S + p_W)\ell^2 \ell_1^2}{16 R_Y}$$

where:

n : number of the longitudinal stiffeners of side shell and hopper / topside tank that support the lower / upper end connecting bracket of the side frame, as applicable

w_i : net section modulus, in cm^3, of the i-th longitudinal stiffener of the side shell or hopper / topside tank that support the lower / upper end connecting bracket of the side frame, as applicable

d_i : distance, in m, of the above i-th longitudinal stiffener from the intersection point of the side shell and hopper /topside tank

ℓ_1 : spacing, in m, of transverse supporting webs in hopper / topside tank, as applicable

R_y : Lowest value of equivalent yield stress, in N/mm^2, among the materials of the longitudinal stiffeners of side shell and hopper / topside tanks that support the lower / upper end connecting bracket of the side frame

α_T : Coefficient taken equal to:

- $\alpha_T = 150$ for the longitudinal stiffeners supporting the lower connecting brackets
- $\alpha_T = 75$ for the longitudinal stiffeners supporting the upper connecting brackets

ℓ : Side frame span, in m, as defined in [3.3.1].

3.4.2

The net connection area, Ai, in cm^2, of the bracket to the i-th longitudinal stiffener supporting the bracket is to be obtained from the following formula:

$$A_i = 0{,}4 \frac{w_i s}{\ell_1^2} \frac{k_{bkt}}{k_{\lg,i}}$$

where:

w_i : net section modulus, in cm^3, of the i-th longitudinal stiffener of the side or sloped bulkheads that support the lower or the upper end connecting bracket of the side frame, as applicable

ℓ_1 : as defined in [3.4.1]

k_{bkt} : material factor for the bracket

$k_{lg,i}$: material factor for the i-th longitudinal st.

3.5 Strength criteria for multi-span ordinary stiffeners

3.5.1 Checking criteria

The maximum normal stress σ and shear stress τ in a multi-span ordinary stiffener, calculated according to [3.3.2], are to comply with the formulae in Tab 5.

Table 4: Checking criteria for multi-span ordinary stiffeners

Condition	Intact	Flooding	Testing
Normal stress	$\sigma \le \lambda_S R_Y$	$\sigma \le \alpha\lambda_S R_Y$	$\sigma \le 1{,}05 R_Y$
Shear stress	$\tau \le \tau_a$	$\tau \le \alpha\tau_a$	$\tau \le 1{,}05\tau_a$

Note 1:
λ_s : Coefficient defined in [3.2.3]
α : Coefficient defined in [3.2.4]

3.5.2 Multi-span ordinary stiffeners

The maximum normal stress σ and shear stress τ in a multi-span ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water and wave pressure and forces, if any
- the number and position of intermediate supports (decks, girders, etc.)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

4. Web stiffeners of primary supporting members

4.1

4.1.1

Where primary supporting member web stiffeners are welded to ordinary stiffener face plates, their net sectional area at the web stiffener mid-height is to be not less than the value obtained, in cm2, from the following formula:

$A = 0.1\, k_1\, p\, s\, \ell$

where:

k_1: Coefficient depending on the web connection with the ordinary stiffener, to be taken as:

- k_1 = 0,30 for connections without collar plate (see Ch 3, Sec 6, Fig 8)
- k_1 = 0,225 for connections with a collar plate (see Ch 3, Sec 6, Fig 9)
- k_1 = 0,20 for connections with one or two large collar plates (see Ch 3, Sec 6, Fig 10 and 11)

p : pressure, in kN/m^2, acting on the ordinary stiffener

4.1.2

The net section modulus of web stiffeners of non-watertight primary supporting members is to be not less than the value obtained, in cm3, from the following formula:

$w = 2{,}5\ s^2\ t\ S_s^2$

where:

s: Length, in m, of web stiffeners

t: Web net thickness, in mm, of the primary supporting member

S_s: Spacing, in m, of web stiffeners.

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Section 3 - BUCKLING & ULTIMATE STRENGTH OF ORDINARY STIFFENERS AND STIFFENED PANELS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

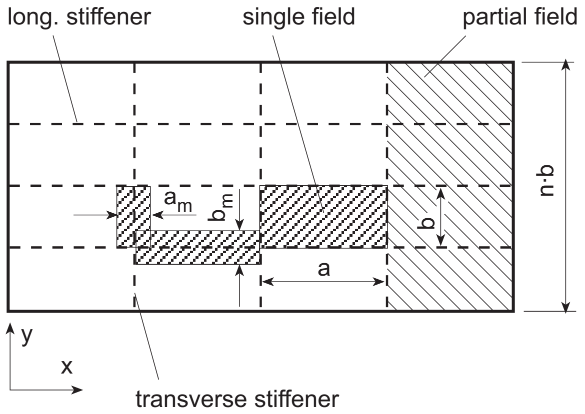
a : Length of single or partial plate field, in mm

b : Breadth of single plate field, in mm

α : Aspect ratio of single plate field, taken equal to:

$\alpha = a / b$

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



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

Figure 1:

t : Nominal plate thickness, in mm

$t = t_a - t_c$

t_a : Plate thickness as built, in mm

t_c : Corrosion addition according to Ch 3 Sec 3, in mm

σ x : Membrane stress in x-direction, in N/mm^2

σ y : Membrane stress in y-direction, in N/mm^2

τ : Shear stress in the x-y plane, in N/mm^2

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

Note: If the stresses in the x- and y-direction contain already the Poisson - effect, the following modified stress values may be used:

$$\sigma_x = (\sigma_x^* - 0{,}3 \cdot \sigma_y^*) / 0{,}91$$

$$\sigma_y = (\sigma_y^* - 0{,}3 \cdot \sigma_x^*) / 0{,}91$$

σ_x^*, σ_y^* : stresses containing the Poisson-effect

Ψ : Edge stress ratio according to Tab 2.

F_1 : Correction factor for boundary condition at the long. stiffeners according to Tab 1

Table 1: Correction factor F_1

1,0 for stiffeners sniped at both ends		
Guidance values *: where both ends are effectively connected to adjacent structures	1,05 1,10 1,20 1,30	for flat bars for bulb sections for angle and tee-sections for girders of high rigidity (e.g. bottom transverses)
* Exact values may be determined by direct calculations.		

σ_e : Reference stress

$$= 0{,}9 \cdot E \left(\frac{t}{b} \right)^2$$

S : Safety factor, taken equal to:

- S = 1,0 in general
- S = 1,2 for structures which are exclusively exposed to local loads
- S = 1,05 for combinations of statistically independent loads

For constructions of aluminium alloys the safety factors are to be increased in each case by 0,1.

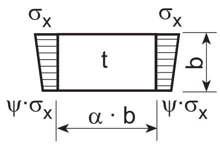
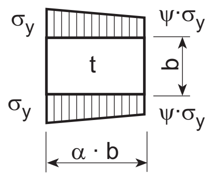
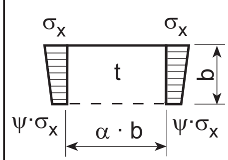
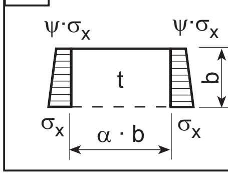
λ = Reference degree of slenderness

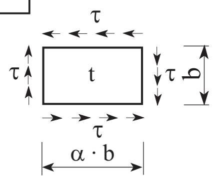
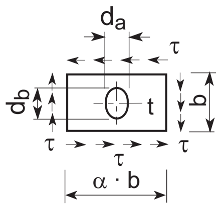
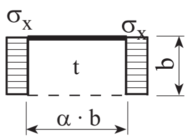
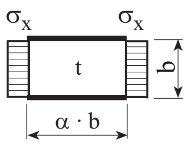
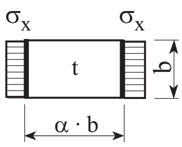
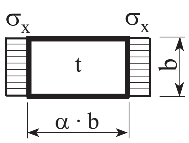
$$= \sqrt{\frac{R_{eH}}{K \cdot \sigma_e}}$$

K = Buckling factor according to Tab 2 and Tab 3

In general, the ratio plate field breadth to plate thickness shall not exceed b/t = 100.

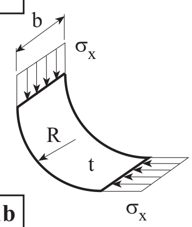
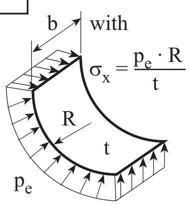
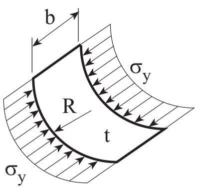
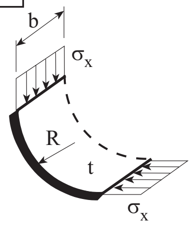
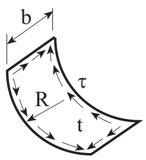
Table 2: Plane plate fields

<table>
<tr><th>Load case</th><th>Edge stress ratio ψ</th><th>Aspect ratio α</th><th>Buckling factor K</th><th>Reductions factor κ</th></tr>
<tr><td rowspan="3">1
</td><td>$1 \geq \psi \geq 0$</td><td rowspan="3">$\alpha > 1$</td><td>$K = \frac{8,4}{\psi + 1,1}$</td><td rowspan="3">$\kappa_x = 1$ for $\lambda \leq \lambda_c$
$\kappa_x = c\left(\frac{1}{\lambda} - \frac{0,22}{\lambda^2}\right)$ for $\lambda > \lambda_c$
$c = (1,25 - 0,12\psi) \leq 1,25$
$\lambda_c = \frac{c}{2}\left(1 + \sqrt{1 - \frac{0,88}{c}}\right)$</td></tr>
<tr><td>$0 > \psi > -1$</td><td>$K = 7,63 - \psi\,(6,26 - 10\,\psi)$</td></tr>
<tr><td>$\psi \leq -1$</td><td>$K = (1 - \psi)^2 \cdot 5,975$</td></tr>
<tr><td rowspan="5">2
</td><td>$1 \geq \psi \geq 0$</td><td>$\alpha \geq 1$</td><td>$K = F_1\left(1 + \frac{1}{\alpha^2}\right)^2 \frac{2,1}{(\psi + 1,1)}$</td><td rowspan="5">$\kappa_y = c\left(\frac{1}{\lambda} - \frac{R + F^2\,(H - R)}{\lambda^2}\right)$
$c = (1,25 - 0,12\psi) \leq 1,25$
$R = \lambda\left(1 - \frac{\lambda}{c}\right)$ for $\lambda < \lambda_c$
$R = 0,22$ for $\lambda \geq \lambda_c$
$\lambda_c = \frac{c}{2}\left(1 + \sqrt{1 - \frac{0,88}{c}}\right)$
$F = \left(1 - \frac{\frac{K}{0,91} - 1}{\lambda_p^2}\right) c_1 \geq 0$
$\lambda_p^2 = \lambda^2 - 0,5 \qquad 1 \leq \lambda_p^2 \leq 3$
$c_1 = 1$ for σ_y due to direct loads
$c_1 = \left(1 - \frac{F_1}{\alpha}\right) \geq 0$ for σ_y due to bending (in general)
$c_1 = 0$ for σ_y due to bending in extreme load cases (e. g. w. t. bulkheads)
$H = \lambda - \frac{2\lambda}{c\,(T + \sqrt{T^2 - 4})} \geq R$
$T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$</td></tr>
<tr><td rowspan="2">$0 > \psi > -1$</td><td>$1 \leq \alpha \leq 1,5$</td><td>$K = F_1\left[\left(1 + \frac{1}{\alpha^2}\right)^2 \frac{2,1\,(1+\psi)}{1,1} - \frac{\psi}{\alpha^2}\,(13,9 - 10\,\psi)\right]$</td></tr>
<tr><td>$\alpha > 1,5$</td><td>$K = F_1\left[\left(1 + \frac{1}{\alpha^2}\right)^2 \frac{2,1\,(1+\psi)}{1,1} - \frac{\psi}{\alpha^2}\,(5,87 + 1,87\,\alpha^2 + \frac{8,6}{\alpha^2} - 10\,\psi)\right]$</td></tr>
<tr><td rowspan="2">$\psi \leq -1$</td><td>$1 \leq \alpha \leq \frac{3\,(1-\psi)}{4}$</td><td>$K = F_1\left(\frac{1 - \psi}{\alpha}\right)^2 5,975$</td></tr>
<tr><td>$\alpha > \frac{3\,(1-\psi)}{4}$</td><td>$K = F_1\left[\left(\frac{1 - \psi}{\alpha}\right)^2 3,9675 + 0,5375\left(\frac{1 - \psi}{\alpha}\right)^4 + 1,87\right]$</td></tr>
<tr><td rowspan="2">3
</td><td>$1 \geq \psi \geq 0$</td><td rowspan="2">$\alpha > 0$</td><td>$K = \frac{4\,(0,425 + 1/\alpha^2)}{3\,\psi + 1}$</td><td rowspan="3">$\kappa_x = 1$ for $\lambda \leq 0,7$
$\kappa_x = \frac{1}{\lambda^2 + 0,51}$ for $\lambda > 0,7$</td></tr>
<tr><td>$0 > \psi \geq -1$</td><td>$K = 4\left(0,425 + \frac{1}{\alpha^2}\right)(1 + \psi) - 5 \cdot \psi\,(1 - 3,42\,\psi)$</td></tr>
<tr><td>4
</td><td>$1 \geq \psi \geq -1$</td><td>$\alpha > 0$</td><td>$K = \left(0,425 + \frac{1}{\alpha^2}\right)\frac{3 - \psi}{2}$</td></tr>
</table>

Load case	Edge stress ratio ψ	Aspect ratio α	Buckling factor K	Reductions factor κ
5 	—	$\alpha \geq 1$	$K = K_\tau \cdot \sqrt{3}$ $K_\tau = \left[5{,}34 + \frac{4}{\alpha^2}\right]$	$\kappa_\tau = 1$ for $\lambda \leq 0{,}84$ $\kappa_\tau = \frac{0{,}84}{\lambda}$ for $\lambda > 0{,}84$
		$0 < \alpha < 1$	$K_\tau = \left[4 + \frac{5{,}34}{\alpha^2}\right]$	
6 	—		$K = K' \cdot r$ K' = K according to load case 5 r = Reductions factor $r = (1 - \frac{d_a}{a})(1 - \frac{d_b}{b})$ with $\frac{d_a}{a} \leq 0{,}7$ and $\frac{d_b}{b} \leq 0{,}7$	
7 	—	$\alpha \geq 1{,}64$	$K = 1{,}28$	$\kappa_x = 1$ for $\lambda \leq 0{,}7$
		$\alpha < 1{,}64$	$K = \frac{1}{\alpha^2} + 0{,}56 + 0{,}13\,\alpha^2$	$\kappa_x = \frac{1}{\lambda^2 + 0{,}51}$ for $\lambda > 0{,}7$
8 	—	$\alpha \geq \frac{2}{3}$	$K = 6{,}97$	$\kappa_x = 1$ for $\lambda \leq 0{,}83$ $\kappa_x = 1{,}13\left[\frac{1}{\lambda} - \frac{0{,}22}{\lambda^2}\right]$ for $\lambda > 0{,}83$
		$\alpha < \frac{2}{3}$	$K = \frac{1}{\alpha^2} + 2{,}5 + 5\,\alpha^2$	
9 	—	$\alpha \geq 4$	$K = 4$	
		$4 > \alpha > 1$	$K = 4 + \left[\frac{4-\alpha}{3}\right]^4 2{,}74$	
		$\alpha \leq 1$	$K = \frac{4}{\alpha^2} + 2{,}07 + 0{,}67\,\alpha^2$	
10 	—	$\alpha \geq 4$	$K = 6{,}97$	
		$4 > \alpha > 1$	$K = 6{,}97 + \left[\frac{4-\alpha}{3}\right]^4 3{,}1$	
		$\alpha \leq 1$	$K = \frac{4}{\alpha^2} + 2{,}07 + 4\,\alpha^2$	

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

Table 3: Curved plate field $R/t \le 2500$ [1]

Load case	Aspect ratio b / R	Buckling factor K	Reductions factor κ
1a 	$\frac{b}{R} \le 1{,}63\sqrt{\frac{R}{t}}$	$K = \frac{b}{\sqrt{R \cdot t}} + 3\,\frac{(R \cdot t)^{0,175}}{b^{0,35}}$	$\kappa_x = 1$ [2] for $\lambda \le 0{,}4$ $\kappa_x = 1{,}274 - 0{,}686\,\lambda$ for $0{,}4 < \lambda \le 1{,}2$ $\kappa_x = \frac{0{,}65}{\lambda^2}$ for $\lambda > 1{,}2$
1b  p_e = external pressure in [N/mm²]	$\frac{b}{R} > 1{,}63\sqrt{\frac{R}{t}}$	$K = 0{,}3\,\frac{b^2}{R^2} + 2{,}25\left(\frac{R^2}{b \cdot t}\right)^2$	
2 	$\frac{b}{R} \le 0{,}5\sqrt{\frac{R}{t}}$	$K = 1 + \frac{2}{3}\,\frac{b^2}{R \cdot t}$	$\kappa_y = 1$ [2] for $\lambda \le 0{,}25$ $\kappa_y = 1{,}233 - 0{,}933\,\lambda$ for $0{,}25 < \lambda \le 1$ $\kappa_y = 0{,}3 / \lambda^3$ for $1 < \lambda \le 1{,}5$ $\kappa_y = 0{,}2 / \lambda^2$ for $\lambda > 1{,}5$
	$\frac{b}{R} > 0{,}5\sqrt{\frac{R}{t}}$	$K = 0{,}267\,\frac{b^2}{R \cdot t}\left[3 - \frac{b}{R}\sqrt{\frac{t}{R}}\right] \ge 0{,}4\,\frac{b^2}{R \cdot t}$	
3 	$\frac{b}{R} \le \sqrt{\frac{R}{t}}$	$K = \frac{0{,}6 \cdot b}{\sqrt{R \cdot t}} + \frac{\sqrt{R \cdot t}}{b} - 0{,}3\,\frac{R \cdot t}{b^2}$	as in load case 1a
	$\frac{b}{R} > \sqrt{\frac{R}{t}}$	$K = 0{,}3\,\frac{b^2}{R^2} + 0{,}291\left(\frac{R^2}{b \cdot t}\right)^2$	
4 	$\frac{b}{R} \le 8{,}7\sqrt{\frac{R}{t}}$	$K = K_\tau \cdot \sqrt{3}$ $K_\tau = \left[28{,}3 + \frac{0{,}67 \cdot b^3}{R^{1,5} \cdot t^{1,5}}\right]^{0,5}$	$\kappa_\tau = 1$ for $\lambda \le 0{,}4$ $\kappa_\tau = 1{,}274 - 0{,}686\,\lambda$ for $0{,}4 < \lambda \le 1{,}2$ $\kappa_\tau = \frac{0{,}65}{\lambda^2}$ for $\lambda > 1{,}2$
	$\frac{b}{R} > 8{,}7\sqrt{\frac{R}{t}}$	$K_\tau = 0{,}28\,\frac{b^2}{R\sqrt{R \cdot t}}$	

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

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

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

Load case 1b: $\kappa_x = 0{,}8/\lambda^2 \le 1{,}0$: load case 2: $\kappa_y = 0{,}65/\lambda^2 \le 1{,}0$

1. Proof of single plate fields

1.1

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

$$\left(\frac{|\sigma_x| \cdot S}{\kappa_x \cdot R_{eH}}\right)^{e1} + \left(\frac{|\sigma_y| \cdot S}{\kappa_y \cdot R_{eH}}\right)^{e2} - B\left(\frac{\sigma_x \cdot \sigma_y \cdot S^2}{R_{eH}^2}\right) + \left(\frac{|\tau| \cdot S \cdot \sqrt{3}}{\kappa_\tau \cdot R_{eH}}\right) \leq 1{,}0$$

Each term of the above condition must be less than 1,0.

The reduction factors, κ_x , κ_y and κ_τ are given in Tab 2 and/or Tab 3.

- Where $\sigma_x \leq 0$ (tension stress), $\kappa_x = 1{,}0$.
- Where $\sigma_Y \leq 0$ (tension stress), $\kappa_Y = 1{,}0$.

The exponents e_1 , e_2 and e_3 as well as the factor B are calculated or set respectively, according to Tab 4.

Table 4:

Exponents $e_1 - e_3$ and factor B	**plate field**	
	plane	**curved**
e_1	$1 + \kappa_x^4$	1,25
e_2	$1 + \kappa_y^4$	1,25
e_3	$1 + \kappa_x \cdot \kappa_y \cdot \kappa_\tau^2$	2,0
B σ_x and σ_y positive (compression stress)	$(\kappa_x \cdot \kappa_y)^5$	0
B σ_x or σ_y negative (tension stress)	1	—

1.2 Effective width of plating under compressive load

The effective width of plating may be determined by the following formulae (see also Fig. 1):

- $b_m = \kappa_x \cdot b$ for longitudinal stiffeners
- $a_m = \kappa_y \cdot a$ for transverse stiffeners

The effective width of plating is not to be taken greater than the value obtained from [1.1].

Note: The effective width e_m' of stiffened flange plates of girders may be determined as follows:

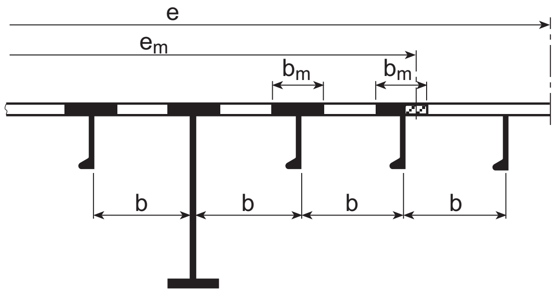


Figure 2: Stiffening parallel to web of girder.

$b \quad < \quad e_m$

$e'_m \quad = \quad n \cdot b_m$

n : Integral number of the stiffener spacing b inside the effective width e_m according to Tab 6.

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

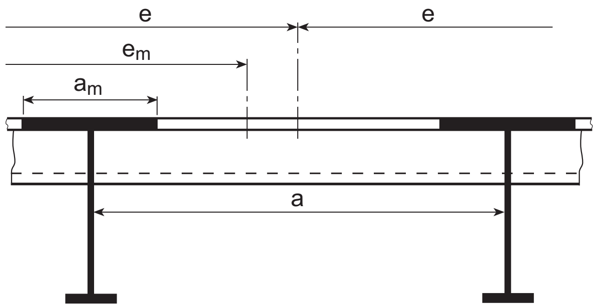


Figure 3: Stiffening vertical to web of girder:

$a \quad \geq \quad e_m$

$e'_m \quad = \quad n \cdot a_m < e_m$

$n \quad = \quad 2{,}7 \cdot \frac{e_m}{a} \leq 1$

e : Width of plating supported according to Tab 6

For $b \geq e_m$ or $a < e_m$ respectively, b and a must be exchanged.

1.3 Webs and flanges

For non-stiffened webs and flanges of sections and girders proof of sufficient buckling strength as for single plate fields is to be provided according to [1.1].

Note:

Within 0,6 L amidships the following guidance values are recommended for the ratio web depth to web thickness and/or flange breadth to flange thickness:

flat bars: $\frac{h_w}{t_w} \leq 19{,}5\sqrt{k}$

angle-, tee and bulb sections:

web: $\frac{h_w}{t_w} \leq 60{,}0\sqrt{k}$

flange: $\frac{b_i}{t_f} \leq 19{,}5\sqrt{k}$

b_i = b_1 or b_2 *according to Fig.4, the larger value is to be taken.*

2. Proof of partial and total fields

2.1 Longitudinal and transverse stiffeners

Proof is to be provided that the continuous longitudinal and transverse stiffeners of partial and total plate fields comply with the conditions set out in [2.2] and [2.3].

2.2 Lateral buckling

$$\frac{\sigma_a + \sigma_b}{R_{eH}} S \leq 1$$

σ_a : Uniformly distributed compressive stress, in N/mm^2 in the direction of the stiffener axis

= σ_x for longitudinal stiffeners

= σ_y for transverse stiffeners

σ_b : Bending stress, in N/mm^2, in the stiffeners

$$= \frac{M_0 + M_1}{W_{st} \cdot 10^3}$$

M_0 : Bending moment, in N/mm^2, due to deformation w of stiffener

$$= F_{Ki} \frac{p_z \cdot w}{c_f - p_z}$$

$$(c_f - p_z) > 0$$

M_1 : Bending moment, in N.mm, due to the lateral load p

for continuous longitudinal stiffeners:

$$= \frac{p \cdot b \cdot a^2}{24 \cdot 10^3}$$

for transverse stiffeners:

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

p : Lateral load, in kN/m^2,according to Ch 4, Sec5 & Sec 6

F_{Ki} : Ideal buckling force, in N, of the stiffener

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

$F_{Kiy} \quad = \dfrac{p^2}{(n \cdot b)^2} \cdot E \cdot I_y \cdot 10^4$ for transverse stiffeners

I_x, I_y : Moments of inertia, in cm⁴, of the longitudinal or transverse stiffener including effective width of plating according to [1.2]

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

$$I_y \geq \frac{a \cdot t^3}{12 \cdot 10^4}$$

p_z : Nominal lateral load, in N/mm², of the stiffener due to σ_x, σ_y and τ

for longitudinal stiffeners:

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

for transverse stiffeners:

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

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

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

$= 0{,}5 \cdot (1 + \Psi)$ for $0 \leq \Psi \leq 1$

$= \dfrac{0{,}5}{1 - \Psi}$ for $\Psi < 0$

ψ : Edge stress ratio according to Table 3

A_x, A_y : Sectional area, in mm², of the longitudinal or transverse stiffener respectively

$$\tau_1 = \left[\tau - t\sqrt{R_{eH} \cdot E\left(\frac{m_1}{a^2} + \frac{m_2}{b^2}\right)}\right] \geq 0$$

for longitudinal stiffeners:

$\dfrac{a}{b} \geq 2{,}0$: $m_1 = 1{,}47$ $m_2 = 0{,}49$

$\dfrac{a}{b} < 2{,}0$: $m_1 = 1{,}96$ $m_2 = 0{,}37$

for transverse stiffeners:

$$\frac{a}{n \cdot b} \geq 0,5 \quad : \quad m_1 = 0,37 \quad m_2 = \frac{1,96}{n^2}$$

$$\frac{a}{n \cdot b} < 0,5 \quad : \quad m_1 = 0,49 \quad m_2 = \frac{1,47}{n^2}$$

w = $w_0 + w_1$

w_0 : Assumed imperfection, in mm

$$\frac{a}{250} \geq w_{0x} \leq \frac{b}{250}$$ for longitudinal stiffeners

$$\frac{n \cdot b}{250} \geq w_{0y} \leq \frac{a}{250}$$ for transverse stiffeners

however $w_0 \leq 10mm$

Note: For stiffeners sniped at both ends wo must not be taken less than the distance from the midpoint of plating to the neutral axis of the profile including effective width of plating.

w_1 : Deformation of stiffener due to lateral load p at midpoint of stiffener span, in mm

In case of uniformly distributed load the following values for w_1 may be used:

for longitudinal stiffeners:

$$w_1 = \frac{p \cdot b \cdot a^4}{384 \cdot 10^7 \cdot E \cdot I_x}$$

for transverse stiffeners:

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

c_f : Elastic support provided by the stiffener, , in N/mm^2

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

$$c_{px} = \frac{1}{1 + \frac{0,91 \cdot \left(\frac{12 \cdot 10^4 \cdot I_x}{t^3 \cdot b} - 1 \right)}{c_{xa}}}$$

$$c_{xa} = \left[\frac{a}{2b} + \frac{2b}{a} \right]^2 \quad \text{for} \quad a \geq 2b$$

$$= \left[1 + \left(\frac{a}{2b} \right)^2 \right]^2 \quad \text{for} \quad a \leq 2b$$

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

for transverse. stiffeners

c_S : Factor accounting for the boundary conditions of the transverse stiffener

= 1,0 for simply supported stiffeners

= 2,0 for partially constraint stiffeners

$$c_{py} = \frac{1}{1 + \dfrac{0{,}91 \cdot \left(\dfrac{12 \cdot 10^4 \cdot I_y}{t^3 \cdot a} - 1 \right)}{c_{ya}}}$$

$$c_{ya} = \left[\frac{n \cdot b}{2a} + \frac{2a}{n \cdot b} \right]^2 \quad \text{for} \quad n \cdot b \geq 2a$$

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

W_{st} : Section modulus of stiffener (longitudinal or transverse), in cm^3,including effective width of plating according to [1.2].

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

Note: Longitudinal and transverse stiffeners not subjected to lateral load p have sufficient scantlings if their moments of inertia I_x and I_y are not less than obtained, in cm^4, by the following formulae:

$$I_x = \frac{p_{zx} \cdot a^2}{\pi^2 \cdot 10^4} \left(\frac{w_{0x} \cdot h_w}{\dfrac{R_{eH}}{S} - \sigma_x} + \frac{a^2}{\pi^2 \cdot E} \right)$$

$$I_y = \frac{p_{zy} \cdot (n \cdot b)^2}{\pi^2 \cdot 10^4} \left(\frac{w_{0y} \cdot h_w}{\dfrac{R_{eH}}{S} - \sigma_y} + \frac{(n \cdot b)^2}{\pi^2 \cdot E} \right)$$

2.3 Torsional buckling

2.3.1 Longitudinal stiffeners:

$$\frac{\sigma_x \cdot S}{\kappa_T \cdot R_{eH}} \leq 1{,}0$$

κ_T = 1,0 for $\lambda_T \leq 0{,}2$

$$= \frac{1}{\Phi + \sqrt{\Phi^2 - \lambda_T^2}} \quad \text{for} \quad \lambda_T > 0{,}2$$

$$\Phi = 0{,}5\left(1 + 0{,}21(\lambda_T - 0{,}2) + \lambda_T^2\right)$$

λ_T : Reference degree of slenderness

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

$$\sigma_{KiT} = \frac{E}{I_P}\left(\frac{\pi^2 \cdot I_\omega \cdot 10^2}{a^2}\varepsilon + 0{,}385 \cdot I_T\right) \quad \text{, in N/mm}^2$$

For I_P, I_T, I_ω see Fig 4 and Tab 5.

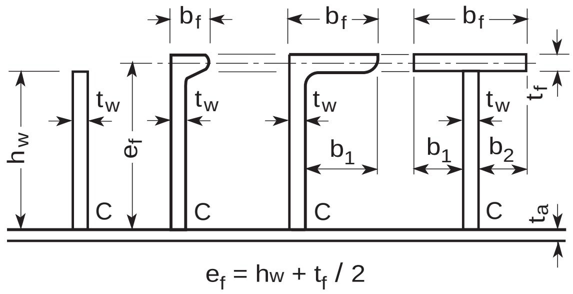


Figure 4:

I_P : Polar moment of inertia of the stiffener, in cm^4, related to the point C

I_T : St. Venant's moment of inertia of the stiffener, in cm^4

I_ω : Sectorial moment of inertia of the stiffener, in cm^6, related to the point C

ε : Degree of fixation

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

h_w : Web height, in mm

t_w : Web thickness, in mm

b_f : Flange breadth, in mm

t_f : Flange thickness, in mm

A_w : Web area $h_w \cdot t_w$

A_f : Flange area $b_f \cdot t_f$

2.3.2 Transverse stiffeners

For transverse stiffeners loaded by compressive stresses and which are not supported by longitudinal stiffeners, proof is to be provided in accordance with [2.3.1] analogously.

Table 5: Moments of inertia

Section	I_P	I_T	I_ω
Flat bar	$\dfrac{h_w^3 \cdot t_w}{3 \cdot 10^4}$	$\dfrac{h_w \cdot t_w^3}{3 \cdot 10^4}\left(1 - 0{,}63\dfrac{t_w}{h_w}\right)$	$\dfrac{h_w^3 \cdot t_w^3}{36 \cdot 10^6}$
Sections with bulb or flange	$\left(\dfrac{A_w \cdot h_w^2}{3} + A_f \cdot e_f^2\right) 10^4$	$\dfrac{h_w \cdot t_w^3}{3 \cdot 10^4}\left(1 - 0{,}63\dfrac{t_w}{h_w}\right)$ + $\dfrac{b_f \cdot t_f^3}{3 \cdot 10^3}\left(1 - 0{,}63\dfrac{t_f}{b_f}\right)$	for bulb and angle sections: $\dfrac{A_f \cdot e_f^2 \cdot b_f^2}{12 \cdot 10^6}\left(\dfrac{A_f + 2.6 A_W}{A_f + A_W}\right)$ for tee-sections: $\dfrac{b_f^3 \cdot t_f \cdot e_f^2}{12 \cdot 10^6}$

3. Effective width of plating under lateral bending

3.1 Frames and stiffeners

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

3.2 Girders

3.2.1

The effective width of plating e_m of frames and girders may be determined according to Tab 6 considering the type of loading.

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

Table 6: Effective Width

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	1,0
e_{m2}/e	0	0,20	0,37	0,52	0,65	0,75	0,84	0,89	0,9

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 × unsupported span in case of constraint of both ends of girder

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

3.2.2

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

3.2.3

The effective width of stiffeners and girders subjected to compressive stresses may be determined according to [1.2] but is in no case to be taken greater than determined by [3.2.1].

4. Transverse vertically corrugated watertight bulkhead in flooding conditions for BC-A and BC-B ships

4.1 General

4.1.1 Shear buckling check of the bulkhead corrugation webs

The shear stress τ, calculated according to Ch 6, Sec 2, [3.2.5], is to comply with the following formula:

$\tau < \tau_C$

where:

τ_C: Critical shear buckling stress to be obtained, in N/mm², from the following formulae:

$$\tau_c = \tau_E \qquad \text{for} \quad \tau_E \leq \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_c = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\tau_E}\right) \qquad \text{for} \quad \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

τ_E: Euler shear buckling stress to be obtained, in N/mm², from the following formula:

$$\tau_E = 0{,}9 k_t E \left(\frac{t_W}{10^3 C}\right)^2$$

k_t: Coefficient, to be taken equal to 6,34

t_W: Net thickness, in mm, of the corrugation webs

C: Width, in m of the corrugation webs (see Ch 3, Sec 6, Fig 26).

Chapter 6 – Hull scantlings

Welcome JBP

Section 4 - PRIMARY SUPPORTING MEMBERS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

I_Y : Net moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to Ch 5, Sec 1, [1.5], on offered gross thickness reduced by $0,5t_C$ for all structural members

I_Z : Net moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to Ch 5, Sec 1, [1.5], on offered gross thickness reduced by $0,5t_C$ for all structural members

N : Z co-ordinate with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4], in m, of the centre of gravity of the hull net transverse section defined in Ch 5, Sec 1, [1.2], considering offered gross thickness reduced by $0,5t_C$ for all structural members

p_S, p_W : Still water and wave pressure, in kN/m^2, in intact conditions, defined in [2.1.2]

σ_X : Normal stress, in N/mm^2, defined in [2.1.3]

s : Spacing, in m, of primary supporting members

ℓ : Span, in m, of primary supporting members, measured between the supporting members, see Ch 3, Sec 6, [4.2]

h_w : Web height, in mm

t_w : Net web thickness, in mm

b_f : Face plate width, in mm

t_f : Net face plate thickness, in mm

b_p : Width, in m, of the plating attached to the member, for the yielding check, defined in Ch 3, Sec 6, [4.3]

w : Net section modulus, in cm^3, of the member, with an attached plating of width b_p, to be calculated as specified in Ch 3, Sec 6, [4.4]

A_{Sh} : Net shear sectional area, in cm^2, of the member, to be calculated as specified in Ch 3, Sec 6, [4.4]

m : Coefficient taken equal to10.

τ_a : Allowable shear stress, in N/mm^2, taken equal to:

$$\tau_a = 0,4\ R_Y$$

k : Material factor, as defined in Ch 1, Sec 4, [2.2.1]

x, y, z : X, Y and Z co-ordinates, in m, of the evaluation point with respect to the reference co-ordinate system defined in Ch 1, Sec 4

1. General

1.1 Application

1.1.1

The requirements of this Section apply for the strength check of primary supporting members, subjected to lateral pressure and hull girder normal stresses for such members contributing to the hull girder longitudinal strength.

The yielding check is also to be carried out for such members subjected to specific loads, such as concentrated loads.

1.2 Primary supporting members for ships less than 150 m in length

1.2.1

For primary supporting members for ships having a length less than 150 m, the strength check of such members is to be carried out according to the provisions specified in [2].

1.2.2

Notwithstanding the above, the s check of such members may be carried out by a direct strength assessment deemed as appropriate by the Society.

1.3 Primary supporting members for ships of 150 m or more in length

1.3.1

For primary supporting members for ships having a length of 150 m or more, the direct strength analysis is to be carried out according to the provisions specified in Chapter 7. In addition, the primary supporting members in of BC-A and BC-B ships are to comply with the requirements in [3].

1.4 Net scantlings

1.4.1

As specified in Ch 3, Sec 2, all scantlings referred to in this Section are net, i.e. they do not include any corrosion addition.

The gross scantlings are obtained as specified in Ch 3, Sec 2, [3].

1.5 Minimum net thicknesses of webs of primary supporting members

1.5.1

The net thickness of the web of primary supporting members, in mm, is to be not less than $0,6\ L^{1/2}$.

2. Scantling of Primary Supporting Members for Ships of less than 150 m in length

2.1 Load model

2.1.1 General

The still water and wave lateral loads induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the primary supporting members under consideration and the type of the compartments adjacent to it.

The wave lateral loads and hull girder loads are to be calculated, for the probability level of 10^{-8}, in the mutually exclusive load cases H1, H2, F1, F2, R1, R2, P1 and P2, as defined in Ch 4, Sec 4.

2.1.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_s) includes:

- the hydrostatic pressure, defined in Ch 4, Sec 5, [1]
- the still water internal pressure, defined in Ch 4, Sec 6 for the various types of cargoes and for ballast.

Wave pressure (p_w) includes for each load case H1, H2, F1, F2, R1, R2, P1 and P2:

- the hydrodynamic pressure, defined in Ch 4, Sec 5, [1]
- the inertial pressure, defined in Ch 4, Sec 6 for the various types of cargoes and for ballast.

2.1.3 Normal stresses

The normal stress to be considered for the strength check of primary supporting members contributing to the hull girder longitudinal strength is the maximum value of σ_X between sagging and hogging conditions, when applicable, obtained , in N/mm², from the following formula:

$$\sigma_X = C_\ell \left[C_{SW} \left| \frac{M_{SW}}{I_Y} \right| (z-N) + C_{WV} \left| \frac{M_{WV}}{I_Y} \right| (z-N) - C_{WH} \left| \frac{M_{WH}}{I_Z} \right| y \right] 10^{-3}$$

where:

C_ℓ : Coefficient defined in Tab 1

M_{SW} : Permissible still water bending moments, in kN.m, in hogging or sagging as the case may be

M_{WV} : Vertical wave bending moment, in kN.m, in hogging or sagging as the case may be, as defined in Ch 4, Sec 3

M_{WH} : Horizontal wave bending moment, in kN.m, as defined in Ch 4, Sec 3

C_{SW} : Combination factor for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and defined in the Tab 2

C_{WV}, C_{WH} : Combination factors defined in Ch 4, Sec 4, [2.4] for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and given in the Tab 2

Table 1: Coefficient C_ℓ

C_ℓ	
Within 0.4L amidships	At ends(x/L = 0 and x/L = 1)
1	0
C_ℓ is to be linearly interpolated between the specified values of x/L.	

Table 2: Combination factors C_{SW}, C_{WV} and C_{WH}

LC	Hogging			Sagging		
	X_{SW}	X_{WV}	X_{WH}	X_{SW}	X_{WV}	X_{WH}
H1	Not Applicable			-1	-1	0
H2	1	1	0	Not Applicable		
F1	Not Applicable			-1	-1	0
F2	1	1	0	Not Applicable		
R1	1	0	$+1.2- T_{LC}/T$	-1	0	$+1.2- T_{LC}/T$
R2	1	0	$-1.2 +T_{LC}/T$	-1	0	$-1.2 +T_{LC}/T$
P1	1	$0.4-T_{LC}/T$	0	-1	$0.4-T_{LC}/T$	0
P2	1	$-0.4 +T_{LC}/T$	0	-1	$-0.4 +T_{LC}/T$	0

2.2 Center Girders and Side Girders

2.2.1 Net web thickness

The thickness of girders in double bottom structure is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$$t_1 = C_1 \frac{pS|x - x_c|}{(d_0 - d_1)\tau_a} \left\{ 1 - 4\left(\frac{y}{B}\right)^2 \right\}$$

Where, $|x - x_c|$ is less than $0.25 l_{DB}$, $|x - x_c|$ is to be taken as $0.25 l_{DB}$

$$t_2 = 1{,}75 \sqrt[3]{\frac{H^2 a^2 \tau_a}{C_1'} t_1}$$

$$t_3 = \frac{C_1'' a}{\sqrt{k}}$$

where,

p : differential pressure given by the following formula in kN/m^2:

$$p = \left| (p_{s,IB} + p_{w,IB}) - (p_{s,BM} + p_{w,BM}) \right|$$

$p_{s,IB}$: cargo or ballast pressure of inner bottom plating in still water, in kN/m^2, as calculated at the center of the double bottom structure under consideration, according to Ch 4, Sec 6

$p_{w,IB}$: cargo or ballast pressure of inner bottom plating due to inertia, in kN/m^2, as calculated at the center of the double bottom structure under consideration, according to Ch 4, Sec 6

$p_{s,BM}$: External sea and ballast pressure of bottom plating in still water, in kN/m^2, as calculated at the center of the double bottom structure under consideration, according to Ch 4, Sec 6

$p_{w,BM}$: External sea and ballast pressure of bottom plating due to inertia, in kN/m^2, as calculated at the center of the double bottom structure under consideration, according to Ch 4, Sec 6

S : Distance between the centers of the two spaces adjacent to the center or side girder under consideration, in m

d_0 : Depth of the center or side girder under consideration, in m

d_1 : Depth of the opening, if any, at the point under consideration, in m

l_{DB} : Length of the double bottom, in m. Where stools are provided at transverse bulkheads, l_{DB} may be taken as the distance between the toes.

x_c : x co-ordinate, in m, of the center of double bottom structure under consideration with respect to the reference co-ordinate system defined in Ch 1, Sec 4

b : Distance between the toes of bilge hoppers at the midship part, in m

C_1 : Coefficient obtained from Tab 3 depending on b/l_{DB}. For intermediate values of b/l_{DB}, C_1 is to be obtained by linear interpolation.

a : Depth of girders at the point under consideration, in m, Where, however, if horizontal stiffeners are fitted on the girder, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or inner bottom plating, or the distance between the horizontal stiffeners under consideration

S_1 : Spacing, in m, of vertical ordinary stiffeners or floors

C_1' : Coefficient obtained from Tab 4 depending on S_1/a. For intermediate values of S_1/a, C_1' is to be determined by linear interpolation.

H : Value obtained from the following formulae :

(a) Where the girder is provided with an unreinforced opening :

$$H = 1 + 0{,}5\frac{\phi}{\alpha}$$

(b) In other cases: $H = 1.0$.

ϕ : Major diameter of the openings, in m

α : The greater of a or S_1, in m.

C_1'' : Coefficient obtained from Tab 5 depending on S_1/a. For intermediate values of S_1/a, is to be obtained by linear interpolation.

Table 3: Coefficient C_1

$\frac{b}{l_{DB}}$	1.0 and Under	1.2	1.4	1.6 and over
C_1	0.88	0.95	0.98	1.00

Table 4: Coefficient C_1'

$\frac{S_1}{a}$	0.3 and Under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_1'	64	38	25	19	15	12	10	9	8	7

Table 5: Coefficient C_1''

$\frac{S_1}{a}$		0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6 and over
C_1''	Centre girder	4.4	5.4	6.3	7.1	7.7	8.2	8.6	8.9	9.3	9.6	9.7
	Side girder	3.6	4.4	5.1	5.8	6.3	6.7	7.0	7.3	7.6	7.9	8.0

2.3 Floors

2.3.1 Net web thickness

The thickness of floors in double bottom structure is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$$t_1 = C_2 \frac{pSb}{(d_0 - d_1)\tau_a}\left(\frac{2|y|}{b'}\right)\left\{1 - 2\left(\frac{x - x_c}{l_{DB}}\right)^2\right\}$$

Where, $|x - x_c|$ is less than $0.25l_{DB}$, $|x - x_c|$ is to be taken as $0.25l_{DB}$, and where $|y|$ is less than $b'/4$, $|y|$ is to be taken as $b'/4$,

$$t_2 = 1{,}75\sqrt[3]{\frac{H^2 a^2 \tau_a}{C_2'} t_1}$$

$$t_3 = \frac{8{,}5S_2}{\sqrt{k}}$$

where :

S : Spacing of solid floors, in m

d_0 : Depth of the solid floor at the point under consideration in m

d_1 : Depth of the opening, if any, at the point under consideration in m

b' : Distance between toes of bilge hoppers at the position of the solid floor under consideration, in m

p , b , x_c , l_{db} : As defined in [2.2.1]

a : Depth of the solid floor at the point under consideration, in m, Where, however, if horizontal stiffeners are fitted on the floor, *a* is the distance from the horizontal stiffener under consideration to the bottom shell plating or the inner bottom plating or the distance between the horizontal stiffeners under consideration

C_2' : Coefficient given in Tab 7 depending on S_1/d_0. For intermediate values of S_1/d_0, C_2' is to be determined by linear interpolation.

H : Value obtained from the following formula:

a) Where openings with reinforcement or no opening are provided on solid floors:

1) Where slots without reinforcement are provided: $H = \sqrt{4{,}0\frac{d_2}{S_1} - 1{,}0}$, without being taken less than 1.0

2) Where slots with reinforcement are provided: $H = 1.0$

b) Where openings without reinforcement are provided on solid floors:

1) Where slots without reinforcement are provided: $H = \left(1 + 0{,}5\dfrac{\phi}{d_0}\right)\sqrt{4{,}0\dfrac{d_2}{S_1} - 1{,}0}$,

without being taken less than $1 + 0{,}5\dfrac{\phi}{d_0}$

2) Where slots with reinforcement are provided: $H = 1 + 0{,}5\dfrac{\phi}{d_0}$

d_2 : Depth of slots without reinforcement provided at the upper and lower parts of solid floors, in m, whichever is greater.

ϕ : Major diameter of the openings, in m.

S_2 : The smaller of S_1 or a, in m

Table 6: Coefficient C_2

$\frac{b}{l_T}$	1.0 and under	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6 and over
C_2	0.43	0.40	0.37	0.34	0.31	0.29	0.26	0.25	0.23

Table 7: Coefficient C_2'

S_1/d_0	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_2'	64	38	25	19	15	12	10	9	8	7

2.4 Stringer of double side structure

2.4.1 Net web thickness

The thickness of stringers in double side structure is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$$t_1 = C_3 \frac{pS|x - x_c|}{(d_0 - d_1)\tau_a}$$

Where $|x - x_c|$ is under $0.25 l_{DS}$, $|x - x_c|$ is to be taken as $0.25 l_{DS}$

$$t_2 = 1{,}75\sqrt[3]{\frac{H^2 a^2 \tau_a}{C_3'} t_1}$$

$$t_3 = \frac{8{,}5 S_2}{\sqrt{k}}$$

Where :

p : differential pressure given by the following formula in kN/m^2:

$$p = \left|(p_{s,SS} + p_{w,SS}) - (p_{s,LB} + p_{w,LB})\right|$$

$p_{s,SS}$: External sea and ballast pressure of side shell plating, in kN/m^2, as measured vertically at the upper end of bilge hopper, longitudinally at the center of l_{ds}, according to Ch 4, Sec 6

$p_{w,SS}$: External sea and ballast pressure of side shell plating at the upper end of bilge hopper, in kN/m^2, according to Ch 4, Sec 6

$p_{s,LB}$: ballast pressure of longitudinal bulkhead in still water, in kN/m^2, as measured vertically at the upper end of bilge hopper, longitudinally at the center of l_{ds}, according to Ch 4, Sec 6

$p_{w,LB}$: ballast pressure of longitudinal bulkhead due to inertia, in kN/m^2 ,as measured vertically at the upper end of bilge hopper, longitudinally at the center of l_{ds}, according to Ch 4, Sec 6

S : Breadth of part supported by stringer, in m

d_0 : Depth of stringers, in m

d_1 : Depth of opening, if any, at the point under consideration, in m.

x_c : x co-ordinate, in m, of the center of double side structure under consideration with respect to the reference co-ordinate system defined in Ch 1, Sec 4

l_{DS} : Length of the double side structure between the transverse bulkheads under consideration, in m

h_{DS} : Height of the double side structure between the upper end of bilge hopper and the lower end of topside tank, in m

C_3 : Coefficient obtained from Tab 8 depending on h_{DS} / l_{DS}. For intermediate values of h_{DS} / l_{DS}, C_3 is to be obtained by linear interpolation.

a : Depth of stringers at the point under consideration, in m, Where horizontal stiffeners are fitted on the stringer, a is the distance from the horizontal stiffener under consideration to the side shell plating or the longitudinal bulkhead of double side structure or the distance between the horizontal stiffeners under consideration

S_1 : Spacing, in m, of transverse ordinary stiffeners or web frames

C_3' : Coefficient obtained from Tab 9 depending on S_1/a. For intermediate values of S_1/a, C_3' is to be obtained by linear interpolation.

H : Value obtained from the following formulae :

(a) Where the stringer is provided with an unreinforced opening : $H = 1 + 0,5\dfrac{\phi}{\alpha}$

(b) In other cases: $H = 1.0$.

ϕ : Major diameter of the openings, in m

α : The greater of a or S_1. in m

S_2 : The smaller of S_1 or a, in m

Table 8: Coefficient C_3

$\frac{h_{DS}}{l_{DS}}$	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_3	0.16	0.23	0.30	0.36	0.41	0.44	0.47	0.50	0.54

Table 9: Coefficient C_3'

$\frac{S_1}{a}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_3'	64	38	25	19	15	12	10	9	8	7

2.5 Transverse web in double side structure

2.5.1 Net web thickness

The thickness of transverse webs in double side structure is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$$t_1 = C_4 \frac{pSh_{DS}}{(d_0 - d_1)\tau_a}\left(1 - 1{,}75\frac{z - z_{BH}}{h_{DS}}\right)$$

where $z - z_{BH}$ is greater than $0.4h_{DS}$, $z - z_{BH}$ is to be taken as $0.4h_{DS}$

$$t_2 = 1{,}75\sqrt[3]{\frac{H^2 a^2 \tau_a}{C_4'} t_1}$$

$$t_3 = \frac{8{,}5S_2}{\sqrt{k}}$$

where :

S : Breadth of part supported by transverses, in m

d_0 : Depth of transverses, in m

d_1 : Depth of opening at the point under consideration, in *m*

C_4 : Coefficient obtained from Tab 10 depending on h_{DS} / l_{DS}. For intermediate values of h_{DS} / l_{DS}, C_4 is to be obtained by linear interpolation.

z_{BH} : z co-ordinates, in m, of the upper end of bilge hopper with respect to the reference co-ordinate system defined in Ch 1, Sec 4.

h_{DS} and l_{DS} : as defined in the requirements of [2.4.1]

a : Depth of transverses at the point under consideration, in *m*. Where vertical stiffeners are fitted on the transverse, distance from the vertical stiffener under consideration to the side shell or the longitudinal bulkhead of double side hull or the distance between the vertical stiffeners under consideration.

S_1 : Spacing, in m, of horizontal ordinary stiffeners or stringers

C_4' : Coefficient obtained from Tab 11 depending on S_1/a. For intermediate values of S_1/a, C_4' is to be obtained by linear interpolation.

H : Value obtained from the following formulae :

(a) Where the transverse is provided with an unreinforced opening : $H = 1 + 0,5\dfrac{\phi}{\alpha}$

(b) In other cases: H = 1.0.

ϕ : Major diameter of the openings, in m

α : The greater of a or S_1. in m

S_2 : The smaller of S_1 or a, in m

Table 10: Coefficient C_4

$\dfrac{h_{DS}}{l_{DS}}$	0.5 and Under	0.6	0.7	0.8	0.9	1.0	11	1.2	1.3 and over
C_4	0.62	0.61	0.59	0.55	0.52	0.49	0.46	0.43	0.41

Table 11: Coefficient C_4'

$\dfrac{S_1}{a}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_4'	64	38	25	19	15	12	10	9	8	7

2.6 Other structures

2.6.1 Load calculation point Horizontal members

For horizontal members, the lateral pressure and hull girder stress, if any, are to be calculated at mid-span of the primary supporting members considered, unless otherwise specified.

For vertical members, the lateral pressure p is to be calculated as the maximum between the values obtained at mid-span and the pressure obtained from the following formula:

- $p = \dfrac{p_U + p_L}{2}$, when the upper end of the vertical member is below the lowest zero pressure level
- $p = \dfrac{\ell_1}{\ell}\dfrac{p_L}{2}$, when the upper end of the vertical member is at or above the lowest zero pressure level (see Fig 1)

where:

ℓ_1 : Distance, in m, between the lower end of vertical member and the lowest zero pressure level

p_U, p_L : Lateral pressures at the upper and lower end of the vertical member span ℓ, respectively

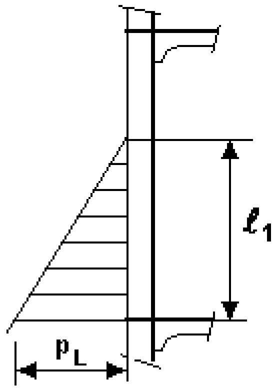


Figure 1: Definition of pressure for vertical members

2.6.2 Boundary conditions

The requirements of this sub-article apply to primary supporting members considered as clamped at both ends. For boundary conditions remarkably deviated from the above, the yielding check is to be considered on a case by case basis.

2.6.3 Net section modulus, net shear sectional area and web thickness under intact conditions

The net section modulus w, in cm^3, the net shear sectional area A_{Sh}, in cm^2, and the net web thickness t_w, in mm, subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \frac{(p_S + p_W) s \ell^2}{m \lambda_S R_Y} 10^3$$

$$A_{sh} = \frac{5(p_S + p_W) s \ell}{\tau_a \sin\phi}$$

$$t_w = 1,75 \cdot \sqrt[3]{\frac{h_w \tau_a}{10 C_5} A_{sh}}$$

where:

λ_S : Coefficient defined in Tab 12.

ϕ : Angle, in deg, between the primary supporting member web and the shell plate, measured at the middle of the member span; the correction is to be applied when ϕ is less than 75 deg.

k : Coefficient defined in Tab 13 according to s_1 and d_0. For intermediate values of s_1/d_0, coefficient k is to be obtained by linear interpolation.

s_1 : Spacing of stiffeners or tripping bracket on web plate, in m

d_0 : Spacing of stiffeners parallel to shell plate on web plate, in m

Table 12: Coefficient λ_S

Primary supporting members	Coefficient λ_S
Longitudinal members contributing to the hull girder longitudinal strength	$\left[1,1\left(1,0-0,85\left\lvert\frac{\sigma_X}{R_Y}\right\rvert\right)\right]$, without being taken greater than [0.8]
Other members	[0.8]

Table 13: Coefficient k

s_1/d_0	0.3 and less	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0 and over
C_5	60.0	40.0	26.8	20.0	16.4	14.4	13.0	12.3	11.1	10.2

3. Additional requirements for primary supporting members of BC-A and BC-B ships

3.1 Evaluation of double bottom capacity and allowable hold loading in flooding conditions

3.1.1 Shear capacity of the double bottom

The shear capacity of the double bottom is to be calculated as the sum of the shear strength at each end of:

- all floors adjacent to both hopper tanks, less one half of the shear strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted (see Fig 2); the floor shear strength is to be calculated according to [3.1.2]
- all double bottom girders adjacent to both stools, or transverse bulkheads if no stool is fitted; the girder shear strength is to be calculated according to [3.1.3].

Where in the end holds, girders or floors run out and are not directly attached to the boundary stool or hopper tank girder, their strength is to be evaluated for the one end only.

The floors and girders to be considered in calculating the shear capacity of the double bottom are those inside the hold boundaries formed by the hopper tanks and stools (or transverse bulkheads if no stool is fitted). The hopper tank side girders and the floors directly below the connection of the stools (or transverse bulkheads if no stool is fitted) to the inner bottom may not be included.

When the geometry and/or the structural arrangement of the double bottom is/are such as to make the above assumptions inadequate, the shear capacity of the double bottom is to be calculated by means of direct calculations to be carried out according to the requirements specified in Ch 7, as far as applicable.

3.1.2 Floor shear strength

The floor shear strength, in kN, is to be obtained from the following formulae:

- in way of the floor panel adjacent to the hopper tank:

$$S_{F1} = A_F \frac{\tau_A}{\eta_1} 10^{-3}$$

- in way of the openings in the outermost bay (i.e. that bay which is closer to the hopper tank):

$$S_{F2} = A_{F,H} \frac{\tau_A}{\eta_2} 10^{-3}$$

where:

A_F : Net sectional area, in mm^2, of the floor panel adjacent to the hopper tank

$A_{F,H}$: Net sectional area, in mm^2, of the floor panels in way of the openings in the outermost bay (i.e. that bay which is closer to the hopper tank)

τ_A : Allowable shear stress, in N/mm^2, equal to the lesser of:

$$\tau_A = 0,645 \frac{R_{eH}^{0,6}}{(s/t_N)^{0,8}} \quad \text{and} \quad \tau_A = \frac{R_{eH}}{\sqrt{3}}$$

t_N : Floor web net thickness, in mm

s : Spacing, in m, of stiffening members of the panel considered

η_1 : Coefficient to be taken equal to 1,1

η_2 : Coefficient generally to be taken equal to 1,2, it may be reduced to 1,1 where appropriate reinforcements are fitted in way of the openings in the outermost bay, to be examined by the Society on a case-by-case basis.

3.1.3 Girder shear strength

The girder shear strength, in kN, is to be obtained from the following formulae:

- in way of the girder panel adjacent to the stool (or transverse bulkhead, if no stool is fitted):

$$S_{g1} = 10^{-3} \cdot A_g \cdot \frac{\tau_a}{\eta_1}$$

- in way of the largest opening in the outermost bay (i.e. that bay which is closer to the stool, or transverse bulk-head, if no stool is fitted):

$$S_{g2} = 10^{-3} \cdot A_{g,h} \cdot \frac{\tau_a}{\eta_2}$$

A_G : Sectional area, in mm^2, of the girder panel adjacent to the stool (or transverse bulkhead, if no stool is fitted)

$A_{G,H}$: Net sectional area, in mm^2, of the girder panel in way of the largest opening in the outermost bay (i.e. that bay which is closer to the stool, or transverse bulkhead, if no stool is fitted)

τ_A : Allowable shear stress, in N/mm^2, defined in [3.1.2], where t_N is the girder web net thickness

η_1 : Coefficient to be taken equal to 1,1

η_2 : Coefficient generally to be taken equal to 1,15, it may be reduced to 1,1 where appropriate reinforcements are fitted in way of the largest opening in the outermost bay, to be examined by the Society on a case-by-case basis.

3.1.4 Allowable hold loading

The allowable hold loading is to be obtained, in t, from the following formula:

$$W = \rho_B V \frac{1}{F}$$

where:

F: Coefficient to be taken equal to:

- F = 1,1 in general
- F = 1,05 for steel mill products

V: Volume, in m^3 , occupied by cargo at a level h_B

h_B: Level of cargo, in m^2, to be obtained from the following formula:

$$h_B = \frac{X}{\rho_B g}$$

X: Pressure, in kN/m , to be obtained from the following formulae:

- for dry bulk cargoes, the lesser of:

$$X = \frac{Z + \rho g(z_F - 0{,}1D_1 - h_F)}{1 + \frac{\rho}{\rho_B}(perm - 1)}$$

$$X = Z + \rho g(z_F - 0{,}1D_1 - h_F perm)$$

- for steel mill products:

$$X = \frac{Z + \rho g(z_F - 0{,}1D_1 - h_F)}{1 - \frac{\rho}{\rho_B}}$$

perm: Permeability of cargo, which need not be taken greater than 0,3

Z: Pressure, in kN/m^2 , to be taken as the lesser of:

$$Z = \frac{C_H}{A_{DB,H}}$$

$$Z = \frac{C_E}{A_{DB,E}}$$

C_H: Shear capacity of the double bottom, in kN, to be calculated according to [3.1.1], considering, for each floor, the lesser of the shear strengths S_{F1} and S_{F2} (see [3.1.2]) and, for each girder, the lesser of the shear strengths S_{G1} and S_{G2} (see [3.1.3])

C_E: Shear capacity of the double bottom, in kN, to be calculated according to [3.1.1], considering, for each floor, the shear strength SF_1 (see [3.1.2]) and, for each girder, the lesser of the shear strengths SG_1 and SG_2 (see [3.1.3])

$$A_{DB,H} = \sum_{i=1}^{n} S_i B_{DB,i}$$

$$A_{DB,E} = \sum_{i=1}^{n} S_i (B_{DB} - s)$$

n: Number of floors between stools (or transverse bulkheads, if no stool is fitted)

S_i: Space of i-th-floor, in m

$B_{DB,i}$: Length, in m, to be taken equal to :

- $B_{DB,i} = B_{DB} - s$ for floors for which $SF_1 < SF_2$ (see [3.1.2])
- $B_{DB,i} = B_{DB,h}$ for floors for which $SF_1 = SF_2$ (see [3.1.2])

B_{DB}: Breadth, in m, of double bottom between the hopper tanks (see Fig 3)

$B_{DB,h}$: Distance, in m, between the two openings considered (see Fig 3)

s: Spacing, in m, of inner bottom longitudinal ordinary stiffeners adjacent to the hopper tanks.

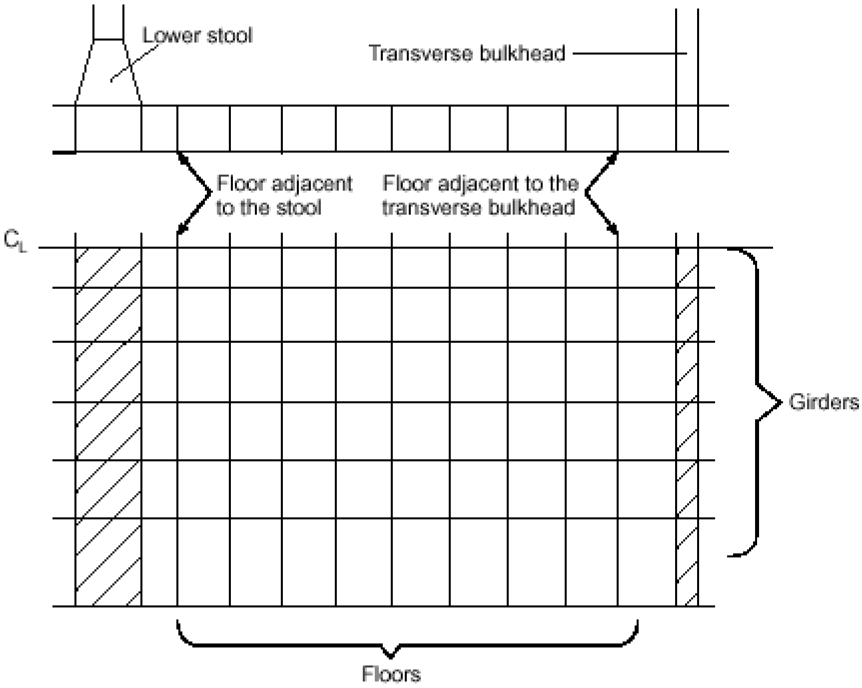


Figure 2 : Double bottom structure

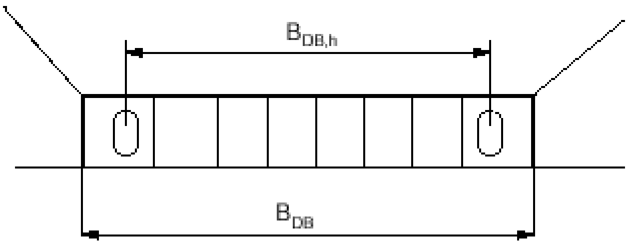


Figure 3 : Dimensions B_{DB} and $B_{DB,h}$

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Section 1 – ANALYSIS PROCEDURE

1. Basic concepts

1.1 General

1.1.1

The direct strength analysis procedure based on a three-dimensional (3D) finite element analysis is applicable to the cargo hold structure of ships as defined in Ch 1 having a length of 150 m or above.

1.1.2

The procedure given in this section focuses on the structural analysis of the midship part of the cargo hold area. Special considerations are to be given to the analysis of the aft and fore parts of the cargo hold area.

1.1.3

A flowchart of the finite element analysis procedure for the direct strength assessment is shown in Fig 1.

1.1.4

A detailed report of the direct strength analysis carried out based on the finite element analysis is to be submitted for approval.

1.1.5

Two alternative methods may be applied in evaluating the finite element stresses:

a) to add the hull girder loads directly to the finite element model (Direct method), or
b) to superimpose the hull girder stresses separately onto the stresses obtained from the structural analysis using the lateral loads (Superimposition method)

1.1.6

In general, the combined effects of bending, shear, axial and torsional forces or moments are to be taken into account in the finite element computation program.

1.2 Net scantling

1.2.1

The direct structural finite element analysis is to be based on the net scantling approach according to Ch 3, Sec 2, [3.2.1]. The element thickness t_{FE} of the finite element model is to be taken as the net thickness given by:

$$t_{FE} = t_{as\text{-}built} - t_{voluntary\ addition} - 0.5\ t_C$$

Where, $t_{as\text{-}built}$ is the as-built thickness,

$t_{voluntary\ addition}$ is the possible extra thickness asked by the ship owner,

and t_C is the corrosion addition obtained from Ch 3, Sec 3, [1].

1.3 Design loads

1.3.1

The direct strength analysis is carried out by applying the design loads given in Ch 4 at a probability level of 10^{-8} considering the loading conditions given in Ch 4, Sec 7 to the 3D finite element model based on the net scantling approach defined in [1.2.1].

1.4 Load combinations

1.4.1

The loading conditions specified in Ch 4, Sec 7, except for ore carriers and OBOs, are to be applied to the 3D finite element model. The loading conditions that are to be applied in the direct strength analysis of ore carriers and OBOs are specially considered at the discretion of the Society.

1.4.2

The load combinations of the loading conditions and the load cases specified in Tab 2 of Ch 4, Sec 7 are to be applied at minimum unless otherwise specified.

Other load combinations may be applied in addition, at the discretion of the Society.

1.5 Hull girder bending moment in still water

1.5.1

The hull girder bending moment specified in Ch 4, Sec 7, [4.2.1] corresponding to each loading condition is to be applied to the 3D finite element model.

1.6 Strength criteria

1.6.1

The net scantlings of the primary structural members are to fulfill the strength criteria given in:

a) Ch 7, Sec 2, [2] for the yielding strength criteria

b) Ch 7, Sec 2, [3] for the buckling and ultimate strength criteria

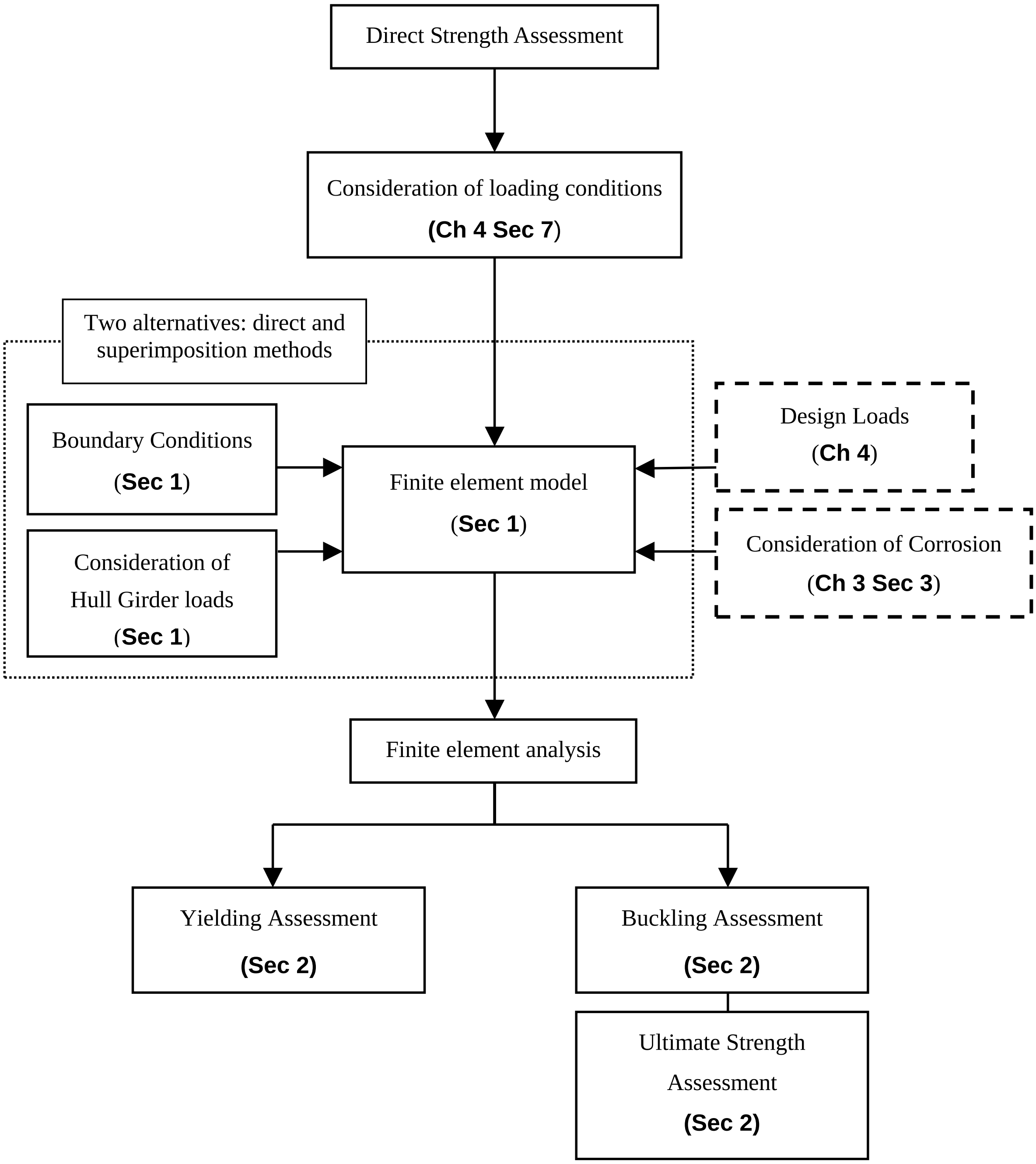


Figure 1: Flowchart of the finite element analysis procedure

2. Finite element model for analysis

2.1 Extent of the finite element model

2.1.1

The following finite element models are to be used according to the applied finite element analysis method, viz. the direct or superimposition method defined in Sec 1, [1.1.5]:

a) three-hold length (1 + 1 + 1) finite element model with three transverse bulkheads for the direct method.

b) two-hold length (1/2 + 1 + 1/2) finite element model with two transverse bulkheads for the direct and superimposition methods.

The finite element model is to be realised by modelling both the starboard and portside sides in order to take into account the unsymmetrical wave-induced loads in the transverse direction.

The details of the extent of the model are referred to in ANNEX.

2.2 Finite element modeling

2.2.1 Element type selection

When selecting an element, attention is to be paid to the stiffness capabilities of the structural member that is to be modeled.

Different types of elements are to be considered for the structural modeling as follows:

1) when modeling the stiffeners, the following element types are to be used:
   - rod element: member with only axial stiffness and a constant cross-sectional area along its length.
   - beam element: member with axial, torsional, bi-directional shear and bending stiffnesses.

2) when modeling the plates, the following element types are to be used:
   - membrane element: member with bi-axial and in-plane stiffnesses.
   - shell element: member with out-of-plane bending stiffness in addition to bi-axial and in-plane stiffnesses.

For membrane and shell elements, only linear quad or triangle elements, as shown in Figure 2, are to be adopted.

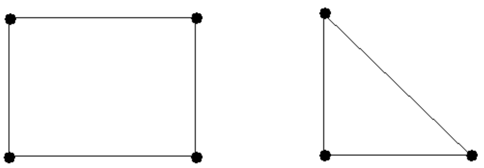


Figure 2: Linear membrane and shell quad and triangle elements

The number of triangle elements is to be minimized as much as possible, especially in the high stressed areas and in the areas subjected to significant stress gradient, such as the areas adjacent to the holes, the brackets, close to the stool connections, etc.

3) when modeling the stiffened plates, two-dimensional (2D) orthotropic elements may also be used. In this case, the 2D orthotropic elements are to take into account the stiffness of the stiffeners belonging to the plate. This is to be performed through suitable membrane and bending stiffness definition of the element.

2.2.2 Membrane/shell element mesh

a) When the model is realised by exclusively using membrane and/or shell elements for the meshing of the plates, as specified in [2.2.1], the mesh size is to be as follows:

- at least one membrane/shell element within one secondary frame spacing; i.e., between two consecutive stiffeners.
- the stiffeners are to be modeled by using rod and/or beam elements.
- where a double hull is fitted, the webs of the primary supporting members are to have at least three elements height-wise.
- where no double hull construction is fitted, the side shell frames and the end brackets are to be modeled by using shell and/or beam elements, with one element on the height of the web of the side shell frames.
- the aspect ratio of the elements is not to exceed 1:4.

b) The refining of the high stressed areas of the model for a second step analysis is left to the Society to decide. In case of refinement, the mesh is to be realised as follows:

- the plates are to be modeled by using shell elements.
- the number of shell elements within one stiffener spacing is not to exceed four.
- the stiffeners are to be modeled by using beam, rod or shell elements.
- where no double hull construction is fitted, the side shell frames and the end brackets are to be modeled by using shell and/or beam elements.
- the aspect ratio is not to exceed 1:3.
- the boundary conditions (nodal displacements, forces, etc.) are to be derived from the results of the analysis of the model meshed according to the criteria of a).

2.2.3 2D orthotropic element mesh

a) When the model is realised by exclusively using orthotropic elements or by using an association of orthotropic and membrane/shell elements for the meshing of the plates, the mesh size is to be as follows:

- for the members such as the double bottom girder or floor, the element height is to be the double bottom height.
- where a stiffener is located at the edge of two orthotropic elements, either it is to be modeled by using beam/rod element, or it is virtually modeled by reporting the stiffness of the stiffener onto the two orthotropic elements.
- where a stiffener is located at the edge of an orthotropic element and a membrane/shell element, it is to be modeled by using beam/rod element.
- where a stiffener is located at the edge of two membrane/shell elements, it is to be modeled by using beam/rod element.
- where a double hull is fitted, the web of the primary supporting members is to be modeled with one element on its height.
- where no double hull construction is fitted, at least one over three frame and its associated end brackets are to be modeled by using shell elements for the webs and shell/beam elements for the flanges.
- the aspect ratio of the elements is not to exceed 1:2.

b) The refining of the high stressed areas of the model for a second step analysis is compulsory and has to fulfill the same meshing criteria of [2.2.2] b).

3. Boundary conditions

3.1 Direct method

3.1.1

A three-hold length finite element model is to be constrained (fixed or spring supported) at one end and left free at the other end, provided that the free end section does not have out-of-plane displacements; i.e., the free end section remains plane after the model deforms. The planarity of the free end section may be released through suitable rigid multi-point constraints applied to the free end section nodes.

A two-hold length finite element model is to be supported (pinned support) at two specified locations along the centerline, provided that:

a) the reaction forces due to the supports are, by any method, counter-reacted, and

b) both end sections remain plane after deformations.

3.2 Superimposition method

3.2.1 Ends of the finite element model

Symmetric boundary condition is applied at the fore and aft end planes in the longitudinal (X) direction; i.e., deformation δ_X, rotations θ_Y and θ_Z are fixed and the other components are free.

3.2.2 Transverse (Y) and vertical (Z) directions

The transverse bulkhead may be simply supported or spring supported in the Y and Z directions.

When it is simply supported, the intersection of the transverse bulkhead and the side shell plate at the upper deck is to be supported in the Z direction (portside & starboard sides), and in the Y direction (starboard side only).

When members near the supported point at the intersection of the transverse bulkhead and the side shell plate at the upper deck are evaluated:

a) the analysis is carried out separately by supporting the model at locations away from the transverse bulkhead, or

b) distributed counter forces along the intersection of the transverse bulkhead and the side shell plate are applied for compensation of the unbalanced forces.

4. Consideration of hull girder loads

4.1 General

4.1.1

In the finite element model, each loading condition specified in Ch 4, Sec 7 is to be associated with its corresponding hull girder loads in still water. The load combination is also to be considered using Load Combination Factors (LCFs) of the wave-induced vertical and horizontal bending moments and of the wave-induced vertical shear forces specified in Ch 4, Sec 4 for each Load Case.

4.2 Direct method

4.2.1

In the case of a three-hold length finite element model, which is constrained at one end section, the equilibrium loads are to be applied at the free end section in order to account for the hull girder loads, as specified in [4.1.1].

In the case of a two-hold length finite element model, the equilibrium loads are to be applied at both ends of the model in order to account for the hull girder loads, as specified in [4.1.1].

4.3 Superimposition method

4.3.1

In the superimposition method, the longitudinal stress term caused by the hull girder loads is estimated separately, and this term is superimposed to correct the stress of the longitudinal strength member obtained from the hold structural analysis.

The corrected longitudinal stress, σ, is given by the following equation:

$$\sigma = \sigma_{FEM} + \sigma_{HG} - \sigma_{Hold}$$

Where,

σ_{FEM}: longitudinal stress obtained from the hold finite element analysis

σ_{HG}: hull girder bending stress obtained from the beam theory applied to the whole ship

σ_{Hold}: longitudinal bending stress obtained from the beam theory applied to the analyzed hold structure

ANNEX: Longitudinal extent of the finite element models

A1. Direct method

A three-hold length finite element model is recommended for the analysis, with the mid-hold as the target of assessment.

The three-hold length finite element model reduces the adverse effects of the boundary conditions to a minimum in the assessed mid-hold. Further extension of the model in the fore and/or aft direction, which may contribute to reduce the adverse effects of the boundary conditions, may be made. However, such extensions are to be limited to one or two primary frame spaces.

As an alternative, a two-hold length finite element model (1/2 + 1 + 1/2) may also be used considering appropriate boundary conditions.

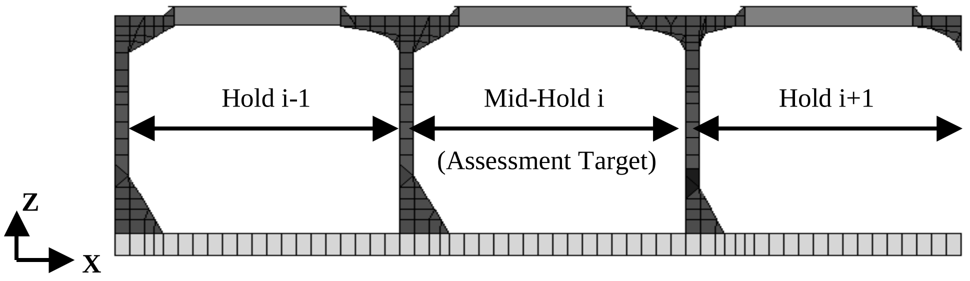
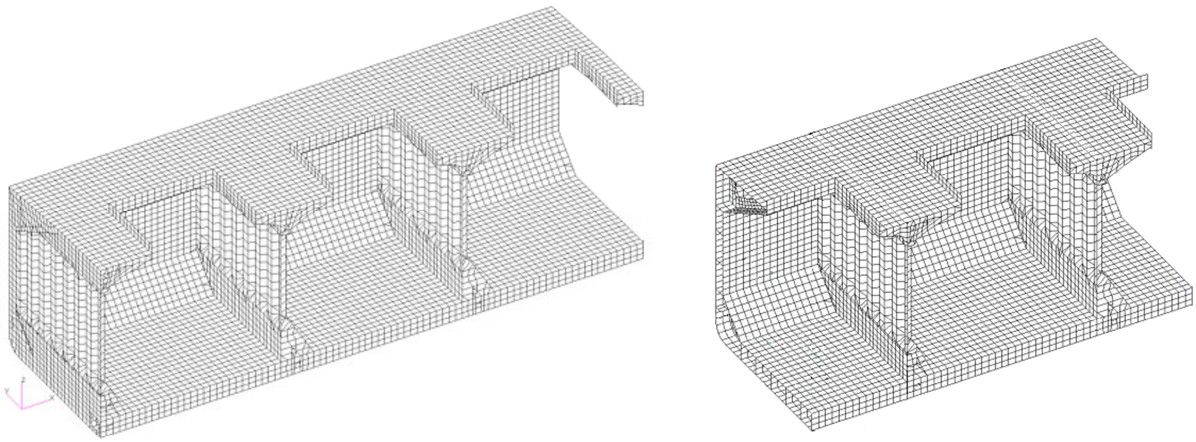


Figure A-1 Longitudinal extent of the finite element model for direct method



(a) Three-hold finite element model

(b) Two-hold finite element model

Figure A-2 Example of finite element models for direct method

A2. Superimposition method

A two-hold length finite element model (1/2 + 1 + 1/2) is to be employed for superimposition method. An example of a two-hold length model is shown in Figure A-3.

The model is to end either at a floor or at the midpoint between two floors. When the model ends at a floor or web frames, the thickness of the end members is to be reduced to half in order to calculate the shear stress correctly.

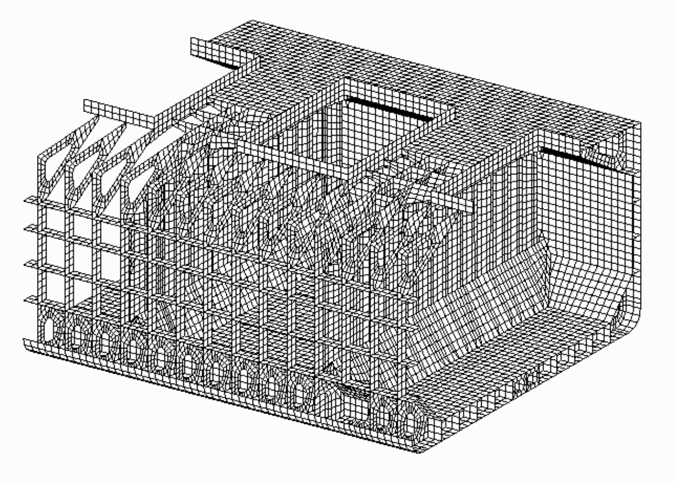


Figure A-3 An example of FE model for superimposition method

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Section 2 – ANALYSIS CRITERIA

1. General

1.1

1.1.1

When the direct method is applied, all primary structural members in the middle hold for the 2-hold (1/2+1+1/2) or 3-hold (1+1+1) FE model, including bulkheads, are subject to strength assessment.

1.1.2

When the stress superimposition method is applied, all primary structural members in the full extent of the 2-hold (1/2+1+1/2) FE model, including bulkheads, are subject to strength assessment in general. However, a limited area of structural members around the locations where the FE model is vertically and horizontally supported is not to be subjected to strength assessment.

1.1.3

While modeling using coarse mesh, finer details such as openings are usually simplified. Attention is to be paid for the simplifications so that the resulting stress truly represents the actual structure behaviour as much as possible.

2. Yielding strength assessment

2.1 Reference stress

2.1.1

Where actual openings are not represented in the FE model for simplification purposes, a method is to be adopted to account for the openings, such as modeling the area with an opening with an equivalent thickness. Otherwise, both the mean shear stress and the element shear stress are to be increased in proportion to the ratio of the modeled web shear area to the net web shear area.

2.1.2

The stresses at the ends of the corrugations of watertight bulkheads are to be obtained by extrapolation of the mean stresses within the adjacent bulkhead plating.

2.1.3

The equivalent stress, σ_{eq}, and axial stress, σ_a, are used as reference stresses for the evaluation of yielding strength. The equivalent stress is used for shell and membrane elements, while the axial stress is used for rod and beam elements.

The equivalent stress is taken as the Von Mises' equivalent stress given by the following formula:

$$\sigma_{eq} = \sqrt{\sigma_1^2 - \sigma_1 \cdot \sigma_2 + \sigma_2^2 + 3\tau_{12}^2}$$

σ_1, σ_2 = in-plane normal stresses in N/mm^2

τ_{12} = shear stress, in N/mm^2, corresponding to σ_1 and σ_2

Where membrane/shell elements are used, the reference stresses are to be evaluated at the centroïd of the element.

[to be completed]

2.2 Maximum permissible stress

2.2.1 Membrane/shell/rod element

The stresses are not to exceed 235/k

[to be completed]

3. Buckling and ultimate strength assessment

3.1 Formulation of buckling and ultimate strength of plate

3.1.1

The buckling and ultimate strength assessment specified in Ch 6, Sec3 is conducted according to Tab 1.

Table 1: Application of the buckling/ultimate strength check for the respective members

Member	Position	Correction factor for boundary, F_1	Load Case in Tables 2 and 3 in Ch 6, Sec3	C_1 of Load Case-2
outer shell plate	bottom and side	1.2	1, 2 and 5	1-F1/α
inner shell plate	Inn. bottom, hopper, Inn. hull, TST slope	1.2	1, 2 and 5	1-F1/α
deck plate	Cross deck	1.1 or 1.2, depending on deck beam	1, 2 and 5	1-F1/α
	Other	checked in longitudinal strength		
bottom girder, horizontally stiffened	non-watertight	1.05	1, 2 and 5/6	1.0
	watertight	1.05	1, 2 and 5/6	1.0
side stringer (non-watertight)	longitudinally stiffened	1.05	1, 2 and 5/6	1.0
	transversally stiffened	1.05	1, 2 and 5/6	1.0
floor		1.05	1, 2 and 5/6	1-F1/α
bilge hopper transverse ring		1.05	1, 2 and 5/6	1-F1/α
side transverse web (See figure)	longitudinal system in DSS	1.05	1, 2 and 5/6	1-F1/α
	transverse system in DSS	1.30	1, 2 and 5/6	1-F1/α
transverse ring in top side tank		1.05	1, 2 and 5/6	1-F1/α
hold bulkhead	stool plate	1.2	1, 2 and 5	1-F1/α
	corrugated plate			

[to be completed]

3.2 Acceptance criteria

3.2.1

The safety factor *S* is to be taken as [1.0].

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Section 1 - GENERAL CONSIDERATION

1. General

1.1 Application

1.1.1

The fatigue strength assessment requirements in this chapter are to be applied to ships of length 150 m and above with respect to 25 years operation life in North Atlantic.

1.1.2

The requirements in Section 2 are to be applied to the fatigue assessment of primary members for which a three dimensional structural analysis is adopted to calculate the stresses.

The requirements in Section 3 are to be applied to the fatigue assessment of longitudinal stiffeners for which an isolated structural model can be adopted.

1.2 Net scantlings

1.2.1

All scantlings referred to in this chapter are net scantlings.

Stresses are to be calculated based on net scantling obtained by subtracting 0.5 t_C (t_C : corrosion addition, in *mm*, defined in Ch3, Sec3 [1.2]) from the offered gross scantling for all structural elements.

1.3 Subject members

1.3.1

Members subjected to fatigue strength assessment are described in Tab 1.

High stress locations are selected from among the locations mentioned in Tab 1.

Table 1 :Members and locations subjected to fatigue strength assessment

Members	Details
Inner bottom plating	Connection with sloping plate of lower stool
	Connection with sloping plate of hopper tank
Inner side plating	Connection with sloping plate of hopper tank
Transverse bulkhead	Connection with sloping plate of lower stool
	Connection with sloping plate of upper stool
Ordinary stiffeners in double side space	Connection of longitudinal stiffeners with web frames and transverse bulkhead
	Connection of transverse stiffeners with stringer or similar
Ordinary stiffeners in double bottom	Connection of longitudinal stiffeners with floors in way of transverse bulkhead

2. Definition

2.1 Hot spot

2.1.1

Hot spot is the location where fatigue crack may initiate.

2.2 Nominal stress

2.2.1

Nominal stress is the stress in a structural component taking into account macro-geometric effects but disregarding the stress concentration due to structural discontinuities and to the presence of welds.

Nominal stresses are to be obtained with the simplified procedure or the coarse mesh FE analysis.

2.3 Hot spot stress

2.3.1

Hot spot stress is defined as the local stress at the hot spot. The hot spot stress takes into account the influence of structural discontinuities due to the geometry of the connection but excludes the effects of welds.

Hot spot stresses are to be obtained in accordance with the application of stress concentration factor to the nominal stress or the fine mesh FE analysis.

2.4 Notch stress

2.4.1

Notch stress is defined as the peak stress at the root of a weld or notch taking into account stress concentrations due to the effects of structural geometry as well as the presence of welds.

Notch stress is to be obtained by multiplying hot spot stress by fatigue notch factor.

3. Loading

3.1 Loading condition

3.1.1

The following loading conditions specified in Tab 2 are to be considered, depending on the ship type.

Table 2 Loading conditions

Type of BC	Full load condition		Ballast condition	
	homogeneous	alternate	normal ballast	heavy ballast
BC-A	✓	✓	✓	✓
BC-B	✓	---	✓	✓
BC-C	✓	---	✓	✓

3.2 Load case

3.2.1 Load cases

For each loading condition, the following load cases defined in Ch4, Sec4 [2] are to be considered:

(a) "H1" and "H2" corresponding to the EDW "H" (Head sea)

(b) "F1" and "F2" corresponding to the EDW "F" (Following sea)

(c) "R1" and "R2" corresponding to the EDW "R" (Beam sea)

(d) "P1" and "P2" corresponding to the EDW "P" (Beam sea)

3.2.2 Predominant load case

From the above mentioned load cases, the load case where the combined stress range becomes the maximum among them is selected as the predominant load case in fatigue assessment for each loading condition.

Section 2 – FATIGUE ASSESSMENT OF PRIMARY MEMBERS

1. General

1.1 Application

1.1.1

A procedure for assessing fatigue strength of primary members is given in this section.

2. Elementary notch stress range

2.1 Notch stress range due to hull girder moments

2.1.1

The hull girder notch stress range, in *N/mm²*, for each load case “H”, “F”, “R” and “P” in each loading condition is to be obtained from the following formula:

$$\Delta\sigma_{GW,i(k)} = K_f K_{gh}\left(C_{WV,i}\Delta\sigma_{WV(k)} + C_{WH,i}\Delta\sigma_{WH(k)}\right)$$

where:

i : Denotes the load case “H”, “F”, “R” and “P”

k : Denotes the loading condition “homogeneous load condition”, “alternate load condition”, “normal ballast condition” and “heavy ballast condition” as defined in Sec 1, Tab 2

K_f : Fatigue notch factor defined in Tab 1

Table 1: Fatigue notch factors

subject	fatigue notch factor
Butt welded joint	1.35
Fillet welded joint	1.42
Non welded part	1.00

K_{gh} : Geometrical stress concentration factor for nominal hull girder stress taken equal to 1.0

$C_{WV,i}$, $C_{WH,i}$: Load combination factor defined in Ch4, Sec4 [2.2]

$\Delta\sigma_{WV(k)}$: Nominal hull girder stress range, in *N/mm²*, induced by vertical wave bending moment

$$\Delta\sigma_{WV(k)} = \frac{\left(M_{WV,H(k)} + M_{WV,S(k)}\right)}{I_Y}\left(z - z_0\right)10^{-3}$$

$M_{WV,H(k)}$, $M_{WV,S(k)}$: Vertical wave bending moments, in *kN-m*, in hogging and sagging defined in Ch4, Sec3 [3.1.1], with f_p=0.5

z_0 : Vertical distance, in *m*, from base line to horizontal neutral

z : Vertical distance, in *m*, from base line to the point considered

$\Delta\sigma_{WH(k)}$: Nominal hull girder stress range, in *N/mm²*, induced by horizontal wave bending moment

$$\Delta\sigma_{WH(k)} = 2\frac{M_{WH(k)}}{I_Z} y 10^{-3}$$

$M_{WH(k)}$: Horizontal wave bending moment, in *kN-m*, defined in Ch4, Sec3, [3.3.1], with f_p=0.5

y : Distance, in *m*, from vertical neutral axis of hull cross section to the point considered

I_Y , I_Z : Net moments of inertia of hull cross-section, in m^4, about transverse and vertical axis respectively, calculated based on offered gross thickness reduced by 0.5 t_C

2.2 Notch stress range due to local loads

2.2.1 Notch stress range

The local notch stress range, in *N/mm²*, for each load case "H", "F", "R" and "P" in each loading condition is to be obtained from the following formula:

$$\Delta\sigma_{LW,i(k)} = K_f \left(\sigma_{HS,i1(k)} - \sigma_{HS,i2(k)}\right)$$

where:

$\sigma_{HS,i1(k)}$, $\sigma_{HS,i2(k)}$:Hot spot stress, in *N/mm²*, in load case "*i1*" and "*i2*" respectively obtained by:

- multiplying nominal stress by geometrical stress concentration factor K_{gl} .For the bilge hopper knuckle, geometrical stress concentration factor specified in [2.2.2] may be used. For other structural members, K_{gl} is to be defined on a case by case basis.
- the direct analysis using fine mesh FE model

2.2.2 Stress concentration factor for bilge hopper knuckle

The geometrical stress concentration factor for the bilge hopper knuckle is given by the following equation:

$$K_{gl} = K_0 K_1 K_2 K_3 K_4$$

where:

K_0 : Stress concentration factor depending on the dimensions of the considered structure, defined in Tab 2

K_1 : Correction coefficient depending on the plate bending process, defined in Tab 3

K_2 : Correction coefficient depending on the thickness increment of the transverse web, defined in Tab 3 or taken equal to 1.0 if there is no thickness increment

K_3 : Correction coefficient depending on the insertion of horizontal gusset or longitudinal rib (Refer to Fig 1), defined in Tab 3 or taken equal to 1.0 if there is no horizontal gusset or longitudinal rib

K_4 : Correction coefficient depending on the insertion of transverse rib, defined in Tab 3. (Refer to Fig 2) or taken equal to 1.0 if there is no transverse rib

Table 2: Stress concentration factor K_0

Plate thickness (*mm*)	**Angle of hopper slope plate to the horizontal (*deg.*)**			
	40	45	50	90

Plate thickness (*mm*)	Angle of hopper slope plate to the horizontal (*deg.*)			
	40	45	50	90
16	3.0	3.2	3.4	4.2
18	2.9	3.1	3.3	4.0
20	2.8	3.0	3.2	3.8
22	2.7	2.9	3.1	3.6
24	2.6	2.8	3.0	3.5
26	2.6	2.7	2.9	3.4
28	2.5	2.7	2.8	3.3
30	2.4	2.6	2.7	3.2
Note: Values for intermediate plate thickness and angle may be interpolated from the values given in the table.				

Table 3: Correction coefficients

Type of knuckle	K_1	K_2	K_3	K_4
Weld Type	1.7	0.9	0.8	0.9
Bend Type	3.1	0.95	0.45	0.8
Note: (1) In using the correction coefficient K_2, the members should be arranged such that the bending deformation of the radius part is effectively suppressed. (2) The increase in web thickness is taken based on the plate thickness of the inner bottom plating				

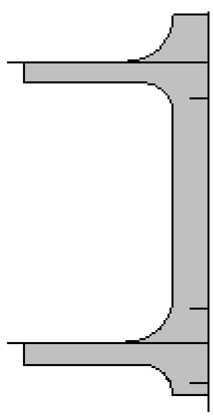


Figure 1: Example of insertion of horizontal stiffener of longitudinal rib

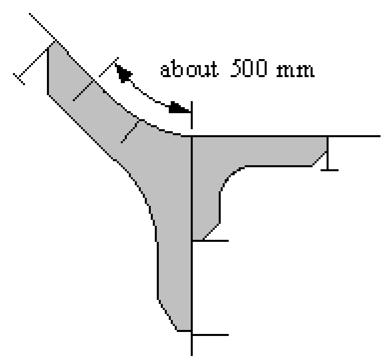


Figure 2: Example of insertion of transverse rib

3. Structural mean stress

3.1 Mean stress due to hull girder moment

3.1.1

The structural mean stress, in N/mm^2, due to still water bending moment in each loading condition is to be obtained from the following formula:

$$\sigma_{GS(k)} = K_f K_{gh} \frac{M_{S(k)}}{I_Y} (z - z_0) 10^{-3}$$

where:

$M_{S(k)}$: Still water vertical bending moment, in *kN.m*, depending on the loading condition, k=1, 2, 3, 4 corresponds to "homogeneous load condition", "alternate load condition", "normal ballast condition" and "heavy ballast condition" respectively

$$M_{S(1)} = -0.5 F_{MS} M_{SW,S}$$

$$M_{S(2)} = F_{MS} M_{SW,H}$$

$$M_{S(3)} = F_{MS} M_{SW,H}$$

$$M_{S(4)} = \begin{cases} 2.66 \dfrac{x}{L} M_{SW,H} & ; \quad 0 < x \le 0.15L \\ 2.66\left(0.3 - \dfrac{x}{L}\right) M_{SW,H} & ; \quad 0.15L < x \le 0.3L \\ -3.5\left(\dfrac{x}{L} - 0.3\right) M_{SW,S} & ; \quad 0.3L < x \le 0.5L \\ -3.5\left(0.7 - \dfrac{x}{L}\right) M_{SW,S} & ; \quad 0.5L < x \le 0.7L \\ 2.66\left(\dfrac{x}{L} - 0.7\right) M_{SW,H} & ; \quad 0.7L < x \le 0.85L \\ 2.66\left(1 - \dfrac{x}{L}\right) M_{SW,H} & ; \quad 0.85L < x \le L \end{cases}$$

$M_{SW,H}$, $M_{SW,H}$: Permissible still water bending moment in hogging and sagging conditions

F_{MS} : Distribution factor according to Ch4, Sec3, Fig 2

3.2 Mean stress due to local loads

3.2.1

The structural mean stress, in *N/mm²*, for each load case "H", "F", "R" and "P" in each loading condition is to be obtained from the following formula:

$$\sigma_{LS,i(k)} = K_f \frac{\left(\sigma_{HS,i1(k)} + \sigma_{HS,i2(k)}\right)}{2}$$

4. Equivalent stress range

4.1 Predominant load case

4.1.1

The predominant load case in fatigue assessment for each loading condition is the load case for which the combined stress range for the considered member is the maximum among the load cases "H", "F", "R" and "P" specified in Sec1, [3.2.1].

$$\Delta\sigma_{W(k)} = \max_i \left\{ \Delta\sigma_{GW,i(k)} + \Delta\sigma_{LW,i(k)} \right\}$$

4.2 Loading 'condition 1'

4.2.1

The 'condition 1' is the condition in which the maximum stress calculated by the equation below for the considered member is the largest on the tension side among the loading conditions "homogeneous load condition", "alternate load condition", "normal ballast condition" and "heavy ballast condition" specified in Sec 1, Tab 2.

$$\sigma_{\max,1} = \max_k \left\{ \sigma_{mean(k)} + \frac{\Delta\sigma_{W(k)}}{2} \right\}$$

where:

$\sigma_{mean(k)}$: Structural mean stress, in *N/mm²*, in loading condition "*k*"

$$\sigma_{mean(k)} = \sigma_{GS(k)} + \sigma_{LS(k)}$$

4.3 Equivalent stress range

4.3.1

The equivalent stress range, in *N/mm²*, is to be calculated for each loading condition with the following formula:

$$\Delta\sigma_{eq,j} = f_{mean,j}\Delta\sigma_{W,j}$$

where:

j : Denotes the loading condition after the determination of 'condition 1'

$f_{mean,j}$: Correction factor for mean stress corresponding to the condition "j"

$$f_{mean,j} = \begin{cases} \left(\dfrac{R_{eH}}{0.5\Delta\sigma_{W,j}} \right)^{0.25} & for \quad R_{eH} \le \sigma_{m,j} + \dfrac{0.5\Delta\sigma_{W,j}}{2} \\ \max\left[0.2, \left(\dfrac{1}{2} + \dfrac{\sigma_{m,j}}{0.5\Delta\sigma_{W,j}} \right)^{0.25} \right] & for \quad R_{eH} > \sigma_{m,j} + \dfrac{0.5\Delta\sigma_{W,j}}{2} \end{cases}$$

$\sigma_{m,j}$: Local mean stress in the condition "j"

$$\sigma_{m,1} = \begin{cases} R_{eH} - 0.6\Delta\sigma_{W,1} & for \quad \sigma_{mean,1} + 0.25R_{eH} + 0.6\Delta\sigma_{W,1} > R_{eH} \\ \sigma_{mean,1} + 0.25R_{eH} & for \quad \sigma_{mean,1} + 0.25R_{eH} + 0.6\Delta\sigma_{W,1} \le R_{eH} \\ 0 & for \quad 0.6\Delta\sigma_{W,i} \ge R_{eH} \end{cases}$$

$$\sigma_{m,j(j\neq 1)} = \begin{cases} \sigma_{m,1} - \left|\sigma_{mean,1} - \sigma_{mean,j}\right| & for \quad \sigma_{m,1} - \left|\sigma_{mean,1} - \sigma_{mean,j}\right| - 0.6\Delta\sigma_{W,j} > -R_{eH} \\ -R_{eH} + 0.6\Delta\sigma_{W,j} & for \quad \sigma_{m,1} - \left|\sigma_{mean,1} - \sigma_{mean,j}\right| - 0.6\Delta\sigma_{W,j} \le -R_{eH} \\ 0 & for \quad 0.6\Delta\sigma_{W,j} \ge R_{eH} \end{cases}$$

$\sigma_{mean,j}$: Structural mean stress corresponding to the condition "j"

5. Calculation of fatigue damage

5.1 Correction of the stress range

5.1.1

The equivalent stress range is to be corrected with the following formula:

$$\Delta\sigma_{E,j} = f_{coat} f_{material} f_{thick} \Delta\sigma_{eq,j}$$

where:

f_{coat} : Correction factor for corrosive environment:

$f_{coat} = 1.2$ for water ballast tanks

$f_{coat} = 1.1$ for dry bulk cargo tanks

$f_{material}$: Correction factor for material

$$f_{material} = \frac{1200}{965 + R_{eH}}$$

f_{thick} : Correction factor for plate thickness

$$f_{thick} = \left(\frac{t}{22}\right)^{0.25} \quad \text{for } t \geq 22mm$$

$$f_{thick} = 1.0 \quad \text{for } t < 22mm$$

t : Net thickness, in *mm*, of the considered member

5.2 Long-term distribution of stresses

5.2.1

The cumulative probability density function of the long term distribution of combined stress ranges is to be taken as a two-parameter Weibull distribution:

$$F(x) = 1 - \exp\left\{-\left(\frac{x}{\Delta\sigma_{W,j}}\right)^{\xi} (\ln N_R)^{1/\xi}\right\}$$

where:

ξ : Weibull shape parameter, ξ may be equal to 1.0

N_R : Number of cycles; 10^4

5.3 Elementary fatigue damage

5.3.1

The elementary fatigue damage for each loading condition is to be calculated with the following formula:

$$D_j = \frac{\alpha_j N_L}{K} \frac{\Delta\sigma_{E-j}{}^4}{(\ln N_R)^{4/\xi}} \left\{ \Gamma\left(\frac{4}{\xi}+1, \nu\right) + \nu^{-3/\xi} \gamma\left(\frac{7}{\xi}+1, \nu\right) \right\}$$

where:

K : S-N curve parameters; $K = 1.014 \cdot 10^{15}$

ν $= \left(\dfrac{100.3}{\Delta\sigma_{E,j}} \right)^{\xi} \ln N_R$

N_R : Number of cycles; 10^4

α_j : Coefficient depending on the loading condition specified in Tab 4.

N_L : Total number of cycles for the design ship's life

ξ : Weibull shape parameter, ξ may be equal to 1.0

Table 4: Coefficient α_j depending on the loading condition

Classification	Loading Conditions	BC-A	BC-B, BC-C
$L < 200\,m$	Homogeneous loading	0.6	0.7
	Alternate loading	0.1	---
	Normal ballast	0.2	0.2
	Heavy ballast	0.1	0.1
$L \geq 200\,m$	Homogeneous loading	0.25	0.5
	Alternate loading	0.25	---
	Normal ballast	0.25	0.25
	Heavy ballast	0.25	0.25

6. Fatigue strength criteria

6.1 Cumulative fatigue damage

6.1.1

The cumulative fatigue damage D calculated for the combined equivalent stress is to comply with the following criteria:

$$D = \sum_j D_j \leq 1.0$$

Section 3 – FATIGUE ASSESSMENT OF STIFFENERS

1. General

1.1 Application

1.1.1

A procedure for assessing fatigue strength of longitudinal stiffener connections is given in this section.

2. Stress evaluation

2.1 Elementary notch stress range

2.1.1 Notch stress range due to hull girder moments

The hull girder notch stress range, in *N/mm²*, for each load case "H", "F", "R" and "P" in each loading condition is to be obtained from the following formula:

$$\Delta\sigma_{GW,i(k)} = K_f K_{gh}\left(C_{WV,i}\Delta\sigma_{WV(k)} + C_{WH,i}\Delta\sigma_{WH(k)}\right)$$

where:

K_{gh} : Geometrical stress concentration factor for nominal hull girder stress depending on the detail of end connection as defined in Tab 1.

$K_f, C_{WV,i}, C_{WH,i}, \Delta\sigma_{WV(k)}, \Delta\sigma_{WH(k)}$ are defined in Sec 2, [2.1]

2.1.2 Notch stress range due to wave pressure

The local notch stress range, in *N/mm²*, due to the wave pressure for each load case "H", "F", "R" and "P" in each loading condition is to be obtained from the following formula:

$$\Delta\sigma_{LW,i(k)} = 2\frac{K_f K_{gl} K_s C_{NE,i(k)} p_{W,i(k)} s\ell^2\left(1-\frac{6x_f}{\ell}+\frac{6x_f{}^2}{\ell^2}\right)}{12w}10^3$$

where:

$p_{W,i(k)}$: Hydrodynamic pressure, in *kN/m²*, specified in Ch4, Sec 5, [1.3], [1.4] and [1.5], with f_p=0.5, in load case "*i*" of loading condition "*k*". When the location of considered member is above the waterline, hydrodynamic pressure is to be taken as the pressure at waterline.

K_{gl} : Geometrical stress concentration factor for stress due to lateral pressure depending on the detail of end connection as defined in Tab 1

K_s =geometrical stress concentration factor due to stiffener geometry

$$K_s = 1+\left[\frac{t_f(a^2-b^2)}{2w_B}\right]\left[1-\frac{b}{b_f}\left(1+\frac{w_B}{w_A}\right)\right]10^{-3}$$

b_f : Flange width, in *mm*

t_f : Flange thickness, in *mm*

a, b : Eccentricity, in *mm*, of the flange as defined in Fig 1

w_A : Section modulus, in cm^3, of the stiffener about z axis with eccentricities a and b as shown in Fig 1, without attached plating

w_B : Section modulus, in cm^3, of the stiffener about z axis assuming $a = b$ without attached plating (i.e. with flange width $2a$ considering an imaginary extension as shown in Fig 1)

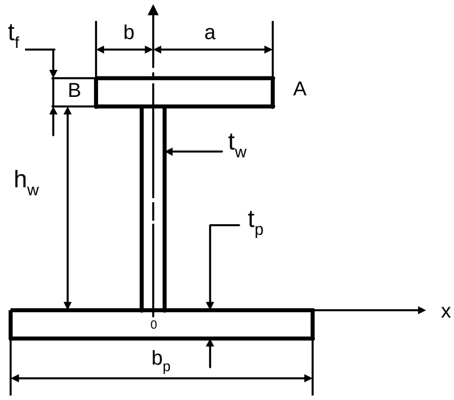


Figure 1: Sectional parameters of a stiffener

$C_{NE,i(k)}$: Correction factor for the non linearity of the wave pressure range in load case "*i*" of loading condition "*k*"

$$C_{NE,i(k)} = \exp\left\{-\left(\frac{z - T_{LC} + \dfrac{p_{W,i\ (k),WL}}{\rho g}}{\dfrac{p_{W,i\ (k),WL}}{\rho g}\left(-\ln 0.5\right)^{-1/2.5}}\right)^{2.5}\right\} \qquad \text{for } z > T_{LC(k)} - \frac{p_{W,i\ (k),WL}}{\rho\, g}$$

$$C_{NE,i(k)} = 1.0 \qquad \text{for } z \le T_{LC(k)} - \frac{p_{W,i\ (k),WL}}{\rho\, g}$$

$T_{LC(k)}$: Draft, in *m*, of the considered loading condition "*k*"

z : Vertical distance, in *m*, from base line to the point considered

s : Stiffener spacing, in *m*

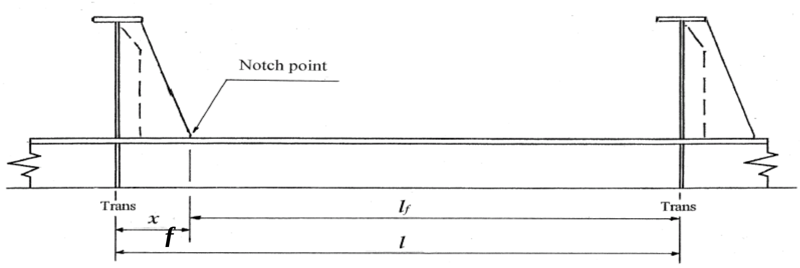
ℓ : Length of span, in *m*, to be measured as shown in Fig 2. The span point is to be taken at the point where the depth of the end bracket, measured from the face of the stiffener is equal to half the depth of the stiffener

x_f : Distance, in *m*, to the hot spot from the closest end of ℓ, (see Fig 2)

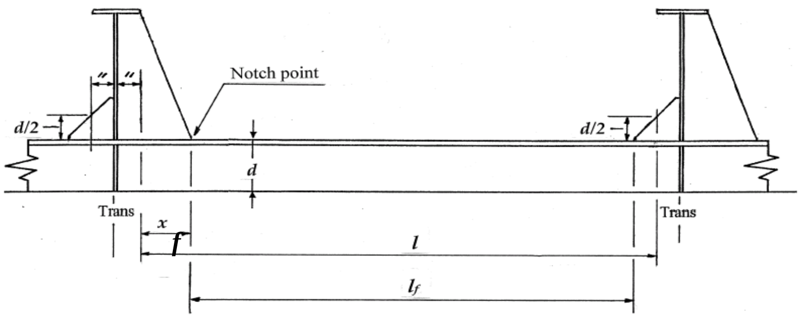
w : Net section modulus, in cm^3, of the considered stiffener, to be calculated based on offered gross thickness reduced by 0.5 t_C.The section modulus w is to be calculated considering an effective breadth s_e, in *m*, of attached plating from the following equation:

$$s_e = 0.67 s \cdot \sin\left[\frac{\pi}{6}\left(\frac{\ell\left(1 - 1/\sqrt{3}\right)}{2s}\right)\right] \qquad \text{for} \qquad \frac{\ell}{s} \le \frac{6}{1 - 1/\sqrt{3}}$$

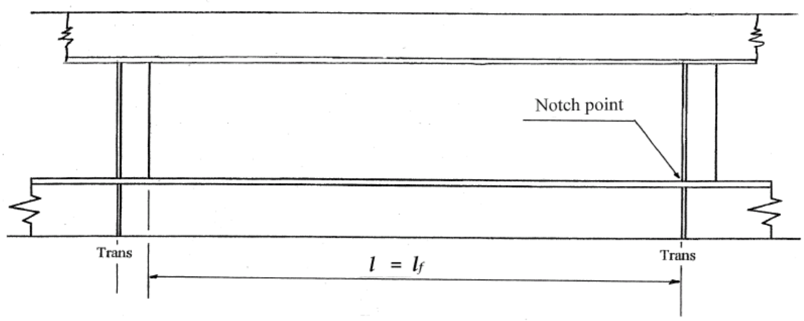
$s_e = 0.67s$ for $\frac{\ell}{s} > \frac{6}{1-1/\sqrt{3}}$



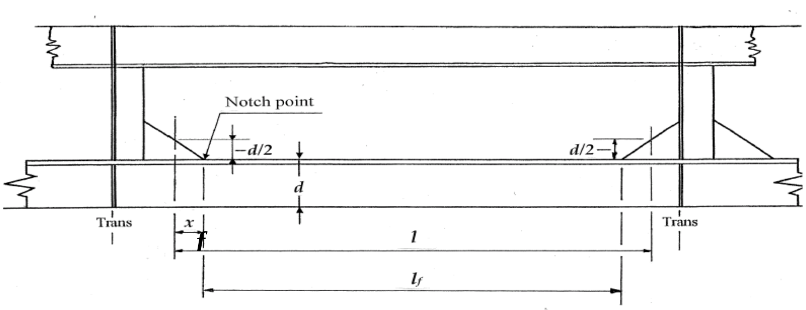
(a) Supported by free flange transverses (1)



(b) Supported by free flange transverses (2)



(c) Supported by double skin / transverse bulkheads (1)



(d) Supported by double skin / transverse bulkheads (2)

Figure 2: Span length and evaluation point of longitudinal stiffeners

Table 1: Stress concentration factors for the stiffener end connection

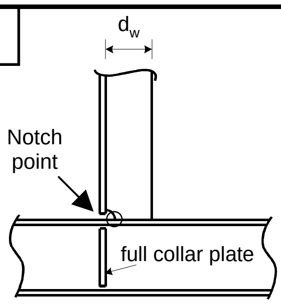
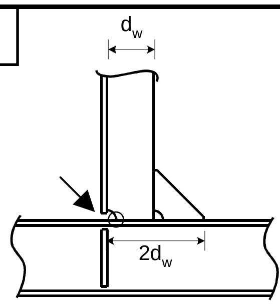
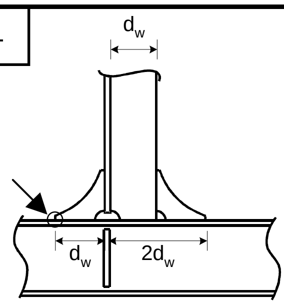
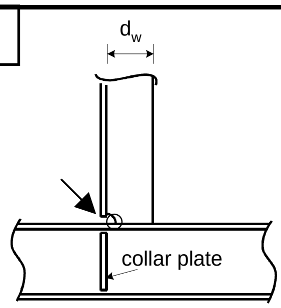
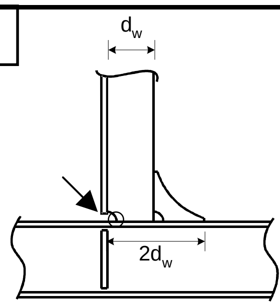
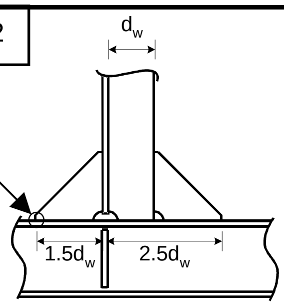
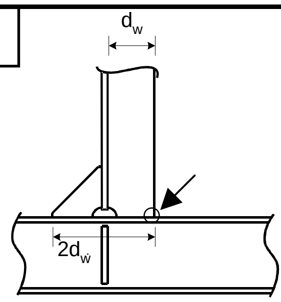
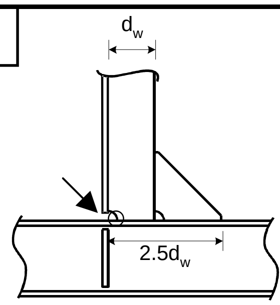
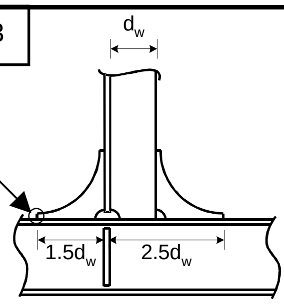
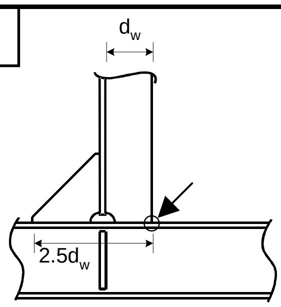
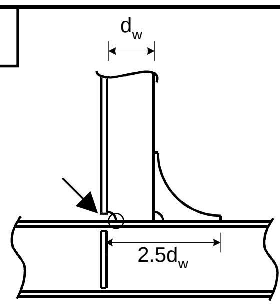
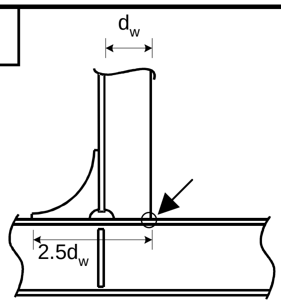
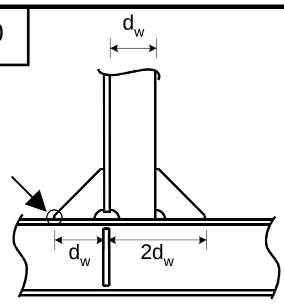
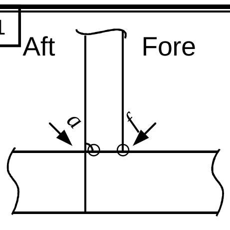
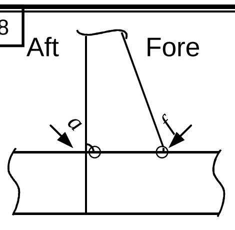
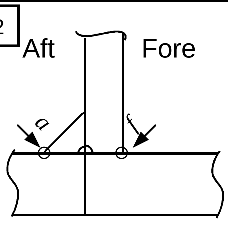
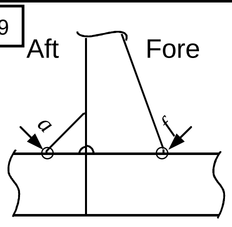
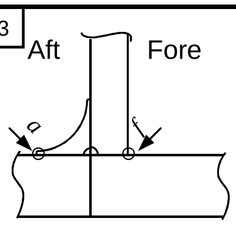
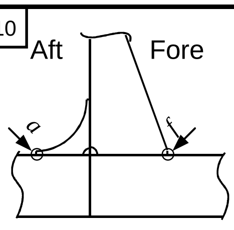
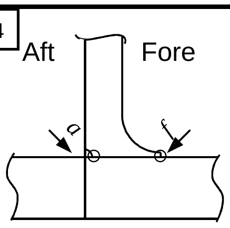
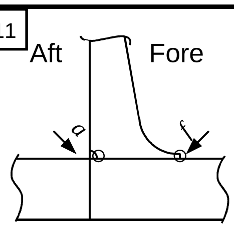
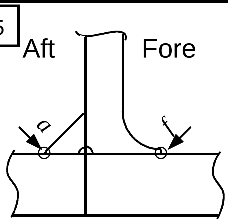
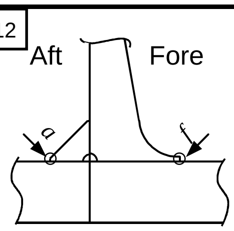
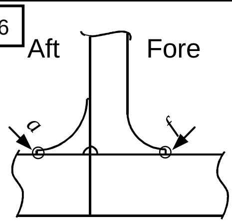
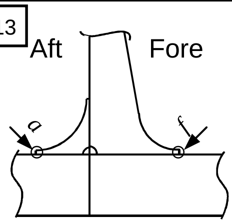
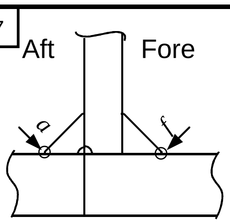
1  $K_{gl} = 1.50, K_{gh} = 1.25$	6  $K_{gl} = 1.55, K_{gh} = 1.30$	11  $K_{gl} = 1.10, K_{gh} = 1.10$
2  $K_{gl} = 1.65, K_{gh} = 1.30$	7  $K_{gl} = 1.50, K_{gh} = 1.25$	12  $K_{gl} = 1.10, K_{gh} = 1.10$
3  $K_{gl} = 1.40, K_{gh} = 1.20$	8  $K_{gl} = 1.50, K_{gh} = 1.25$	13  $K_{gl} = 1.05, K_{gh} = 1.05$
4  $K_{gl} = 1.40, K_{gh} = 1.15$	9  $K_{gl} = 1.45, K_{gh} = 1.20$	
5  $K_{gl} = 1.35, K_{gh} = 1.10$	10  $K_{gl} = 1.15, K_{gh} = 1.15$	

Table 2: Stress concentration factors between stiffener and transverse bulkhead

structural type	SCF	assessed point		structural type	SCF	assessed point	
		a	*f*			*a*	*f*
1 	K_{gl}	1.50	1.10	8 	K_{gl}	1.40	1.70
	K_{dF}	0.95	1.30		K_{dF}	1.00	0.35
	K_{dA}	1.25	0.70		K_{dA}	1.60	0.20
2 	K_{gl}	1.15	1.40	9 	K_{gl}	1.15	1.85
	K_{dF}	0.70	1.25		K_{dF}	0.55	0.55
	K_{dA}	0.90	0.90		K_{dA}	0.75	0.35
3 	K_{gl}	1.10	1.35	10 	K_{gl}	0.90	2.05
	K_{dF}	0.60	1.40		K_{dF}	0.50	0.45
	K_{dA}	0.70	0.95		K_{dA}	0.65	0.30
4 	K_{gl}	1.50	0.85	11 	K_{gl}	1.40	1.65
	K_{dF}	1.00	0.65		K_{dF}	1.00	0.10
	K_{dA}	1.25	0.55		K_{dA}	1.65	0.10
5 	K_{gl}	1.20	1.00	12 	K_{gl}	1.20	1.35
	K_{dF}	0.70	0.60		K_{dF}	0.55	0.20
	K_{dA}	0.90	0.55		K_{dA}	0.75	0.20
6 	K_{gl}	1.10	0.95	13 	K_{gl}	0.95	1.75
	K_{dF}	0.60	0.65		K_{dF}	0.50	0.15
	K_{dA}	0.65	0.60		K_{dA}	0.65	0.15
7 	K_{gl}	1.15	1.00				
	K_{dF}	0.70	0.80				
	K_{dA}	0.85	0.65				

2.1.3 Notch stress range due to liquid pressure

The local notch stress range, in *N/mm²*, due to the liquid inertial pressure for each load case “H”, “F”, “R” and “P” in each loading condition is to be obtained from the following formula:

$$\Delta\sigma_{LBW,i(k)} = 2\frac{K_f K_{gl} K_s C_{NI,i(k)} \left|p_{BW,i(k)}\right| s\ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6{x_f}^2}{\ell^2}\right)}{12w}10^3$$

where:

$p_{BW,i\,(k)}$: Iertial pressure, in *kN/m²*, due to ballast specified in Ch 4, Sec 6, [2.2], with f_p=0.5, in load case “*i*” of loading condition “*k*”

$C_{NI,i(k)}$: Correction factor for the non linearity of the inertial ballast pressure range in load case “*i*” of loading condition “*k*”

$$C_{NI,i(k)} = \exp\left\{-\left(\frac{z - z_{TOP} + \dfrac{p_{BW,i(k)}}{\rho g}}{\dfrac{p_{BW,i(k)}}{\rho g}\left(-\ln 0.5\right)^{-1/2.5}}\right)^{2.5}\right\} \quad \text{for } z > z_{TOP} - \frac{p_{BW,i(k)}}{\rho g}$$

$$C_{NI,i(k)} = 1.0 \quad \text{for } z \le z_{TOP} - \frac{p_{BW,i(k)}}{\rho g}$$

z_{TOP} : Vertical distance, in *m*, from base line to the top of the tank

z : Vvertical distance, in *m*, from base line to the point considered

2.1.4 Notch stress range due to dry bulk cargo pressure

The local notch stress range, in *N/mm²*, due to the dry bulk cargo inertial pressure for each load case “H”, “F”, “R” and “P” in each loading condition is to be obtained from the following formula:

$$\Delta\sigma_{LCW,i(k)} = 2\frac{K_f K_{gl} K_s \left|p_{CW,i(k)}\right| s\ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6{x_f}^2}{\ell^2}\right)}{12w}10^3$$

where:

$p_{CW,i\,(k)}$: Inertial pressure, in *kN/m²*, due to dry bulk cargo specified in Ch 4, Sec 6, [1.3], with f_p=0.5, in load case “*i*” of loading condition “*k*”

2.1.5 Notch stress range due to relative displacement of transverse bulkhead

The additional notch stress range, in *N/mm²*, due to the relative displacement in the transverse direction between the transverse bulkhead and the adjacent transverse web or floor for each load case “H”, “F”, “R” and “P” in each loading condition is to be obtained from the following formula:

$$\Delta\sigma_{d,\,i(k)} = K_{dF,\,a}\Delta\sigma_{dF,\,i(k)} + K_{dA,\,a}\Delta\sigma_{dA,\,i(k)} \quad \text{for point ‘}a\text{’}$$

$$\Delta\sigma_{d,\,i(k)} = K_{dF,\,f}\Delta\sigma_{dF,\,i(k)} + K_{dA,\,f}\Delta\sigma_{dA,\,i(k)} \quad \text{for point ‘}f\text{’}$$

where:

$\Delta\sigma_{dF(or\ A),\,i(k)}$: Additional stress, in *N/mm²*, due to the relative displacement between the forward (or afterward) transverse web or floor and the transverse bulkhead

$$\Delta\sigma_{d\,F(or\ A),\,i(k)} = \frac{1.95\left|\delta_{F(or\ A),\,i1(k)} - \delta_{F(or\ A),\,i2(k)}\right| EI}{w\ell^2\left(1-\dfrac{6x_f}{\ell}+\dfrac{6x_f{}^2}{\ell^2}\right)}10^{-5}$$

$\delta_{F(or\ A),\,i\,j(k)}$: Relative displacement, in *mm*, in the transverse direction between the transverse bulkhead and the forward (or afterward) transverse web or floor

E : Young's modulus, in *N/mm²*, of steel taken as $2.06\cdot10^5$

I : Net moment of inertia of longitudinal, *in* cm⁴, to be calculated based on offered gross thickness reduced by 0.5 t_C

$K_{dF(or\ A)}$: Stress concentration factor for stiffener end connection subject to relative displacement between the forward (or afterward)transverse web and the transverse bulkhead as defined in Tab 2

Suffix "*a*" or "*f*" denotes the location considered indicated in Tab 2

2.2 Structural mean stress

2.2.1 Mean stress due to hull girder moment

The structural mean stress, in *N/mm²*, due to still water bending moment in each loading condition is to be obtained from the following formula:

$$\sigma_{GS(k)} = K_f K_{gh}\frac{M_{S(k)}}{I_Y}\left(z-z_0\right)10^{-3}$$

where $M_{S(k)}$ is defined in Sec 2, [3.1]

2.2.2 Mean stress due to hydrostatic pressure

The structural mean stress, in *N/mm²*, due to hydrostatic pressure in each loading condition is to be obtained from the following formula:

$$\sigma_{LS(k)} = \frac{K_f K_{gl} K_s p_{S(k)} s\ell^2\left(1-\dfrac{6x_f}{\ell}+\dfrac{6x_f{}^2}{\ell^2}\right)}{12w}10^3$$

where:

$p_{S(k)}$: Hydrostatic pressure, in *kN/m²*, specified in Ch 4, Sec 5, [1.2] in loading condition "*k*"

2.2.3 Mean stress due to liquid pressure in still water

The structural mean stress, in *N/mm²*, due to liquid pressure in still water of each loading condition is to be obtained from the following formula:

$$\sigma_{LBS(k)} = \frac{K_f K_{gl} K_s p_{BS(k)} s \ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6{x_f}^2}{\ell^2}\right)}{12w} 10^3$$

where:

$p_{BS(k)}$: Liquid pressure, in *kN/m²*, in still water specified in Ch 4, Sec 6 [2.1] in loading condition "*k*"

2.2.4 Mean stress due to dry bulk cargo pressure in still water

The structural mean stress, in *N/mm²*, due to dry bulk cargo pressure in still water of each loading condition is to be obtained from the following formula:

$$\sigma_{LCS(k)} = \frac{K_f K_{gl} K_s p_{CS(k)} s \ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6{x_f}^2}{\ell^2}\right)}{12w} 10^3$$

where:

$p_{CS(k)}$: Dry bulk cargo pressure, in *kN/m²*, in still water specified in Ch 4, Sec 6, [1.2] in loading condition "*k*"

2.3 Superimposition of stresses

2.3.1 Stress range

The stress range, in *N/mm²*, due to dynamic loads in each loading condition is to be obtained from the following formula:

$$\Delta\sigma_{W,i(k)} = C_{G,i}\Delta\sigma_{GW,i(k)} + C_{W,i}\Delta\sigma_{LW,i(k)} + C_{T,i}\Delta\sigma_{TW,i(k)} + \Delta\sigma_{d,i(k)}$$

where:

$C_{W,i} C_{T,i} C_{G,i}$: Stress combination factors, defined in Tab 3

$\Delta\sigma_{TW,i(k)}$ = $\Delta\sigma_{LBW,i(k)} + \Delta\sigma_{LCW,i(k)}$

Table 3: Stress combination factors

load case	loading condition		$C_{W,i}$	$C_{T,i}$	$C_{G,i}$
H	Full load condition		-0.5	1	1
	Ballast condition		0.8	0.8	1
F	Full load condition		1	---	1
	Ballast condition		1	---	1
R	Full load condition		1	-1	---
	Ballast condition		1	-1	---
P	Full load condition	If $\Delta\sigma_W - 0.7\Delta\sigma_T \geq 0.7\Delta\sigma_W$	1	-1	0.4
		If $\Delta\sigma_W - 0.7\Delta\sigma_T < 0.7\Delta\sigma_W$	0.7	0.0	0.4
	Ballast condition	If $\Delta\sigma_W - 0.7\Delta\sigma_T \geq 0.8\Delta\sigma_W$	1	-1	0.8
		If $\Delta\sigma_W - 0.7\Delta\sigma_T < 0.8\Delta\sigma_W$	0.8	0.0	0.8

2.3.2 Structural mean Stress

The structural mean stress, in *N/mm²*, for each load case "H", "F", "R" and "P" in each loading condition is to be obtained from the following formula:

$$\sigma_{mean(k)} = \sigma_{GS(k)} - \sigma_{LS(k)} + \sigma_{LBS(k)} - \sigma_{LCS(k)}$$

2.4 Equivalent stress range

2.4.1 Predominant load case

The predominant load case in fatigue assessment for each loading condition is the load case for which the combined stress range for the considered member is the maximum among the load cases “H”, “F”, “R” and “P” specified in Sec 1, [3.2].

$$\Delta\sigma_{W(k)} = \max_i \left\{ \Delta\sigma_{W,i(k)} \right\}$$

2.4.2 Loading ‘condition 1’

The‘condition 1’is the condition in which the maximum stress calculated by the equation below for the considered member is the largest on the tension side among the loading conditions “homogeneous load condition”, “alternate load condition”, “normal ballast condition” and “heavy ballast condition” specified in Sec 1, Tab 2.

$$\sigma_{\max,1} = \max_k \left\{ \sigma_{mean(k)} + \frac{\Delta\sigma_{W(k)}}{2} \right\}$$

2.4.3 Equivalent stress range

The equivalent stress range, in N/mm^2, is to be calculated for each loading condition with the following formula:

$$\Delta\sigma_{eq,j} = f_{mean,j}\Delta\sigma_{W,j}$$

where:

j : Denotes the loading condition after the determination of ‘condition 1’

$f_{mean,j}$: Correction factor for mean stress corresponding to the condition “j”

$$f_{mean,j} = \begin{cases} \left(\dfrac{R_{eH}}{0.75\Delta\sigma_{W,j}} \right)^{0.25} & for \quad R_{eH} \le \sigma_{m,j} + \dfrac{0.75\Delta\sigma_{W,j}}{2} \\ \max\left[0.4, \left(\dfrac{1}{2} + \dfrac{\sigma_{m,j}}{0.75\Delta\sigma_{W,j}} \right)^{0.25} \right] & for \quad R_{eH} > \sigma_{m,j} + \dfrac{0.75\Delta\sigma_{W,j}}{2} \end{cases}$$

$\sigma_{m,j}$: Local mean stress in the condition “j”

$$\sigma_{m,1} = \begin{cases} R_{eH} - 0.6\Delta\sigma_{zW,1} & for \quad \sigma_{mean,1} + 0.25R_{eH} + 0.6\Delta\sigma_{zW,1} > R_{eH} \\ \sigma_{mean,1} + 0.25R_{eH} & for \quad \sigma_{mean,1} + 0.25R_{eH} + 0.6\Delta\sigma_{zW,1} \le R_{eH} \\ 0 & for \quad 0.6\Delta\sigma_{zW,1} \ge R_{eH} \end{cases}$$

$$\sigma_{m,j(j\neq1)} = \begin{cases} \sigma_{m,1} - \left|\sigma_{mean,1} - \sigma_{mean,j}\right| & for \quad \sigma_{m,1} - \left|\sigma_{mean,1} - \sigma_{mean,j}\right| - 0.24\Delta\sigma_{W,j} > -R_{eH} \\ -R_{eH} + 0.24\Delta\sigma_{W,j} & for \quad \sigma_{m,1} - \left|\sigma_{mean,1} - \sigma_{mean,j}\right| - 0.24\Delta\sigma_{W,j} \le -R_{eH} \end{cases}$$

$\Delta\sigma_{zW,1}$: Combined stress range considering the long term distribution of non-linear wave pressure. $\Delta\sigma_{zW,1}$ is obtained according to [2.4.1]assuming that the local stress ranges $\Delta\sigma_{LW,i(k)}$ due to wave pressure are evaluated by the pressures as specified below with $C_{NE,i(k)} = 1.0$

$$p_{W,i\,(k)} = 0 \qquad \text{for } T_{LC(k)} + \frac{0.625 \cdot p_{W,i\,(k)}}{\rho g} \le z$$

$$p_{W,i\,(k)} = 0.5 \cdot p_{W,i\,(k)} - \frac{\left(z - T_{LC(k)}\right) \cdot \rho g}{1.25} \qquad \text{for } T_{LC(k)} < z < T_{LC(k)} + \frac{0.625 \cdot p_{W,i\,(k)}}{\rho g}$$

$$p_{W,i\,(k)} = 0.5 \cdot p_{W,i\,(k)} + \frac{\left(T_{LC(k)} - z\right) \cdot \rho g}{1.25} \qquad \text{for } T_{LC(k)} - \frac{0.625 \cdot p_{W,i\,(k)}}{\rho g} < z < T_{LC(k)}$$

$$p_{W,i\,(k)} = p_{W,i\,(k)} \qquad \text{for } z < T_{LC(k)} - \frac{0.625 \cdot p_{W,i\,(k)}}{\rho g}$$

$\sigma_{mean,j}$: Structural mean stress corresponding to the condition "*j*"

3. Fatigue strength assessment

3.1 Calculation of fatigue damage

3.1.1 Correction of the stress range

The equivalent stress range is to be corrected with the following formula:

$$\Delta\sigma_{E,j} = f_{coat} f_{material} f_{thick} \Delta\sigma_{eq,j}$$

where

f_{coat} : Correction factor for corrosive environment defined in Sec 2, [5.1.1]

$f_{material}$: Correction factor for material defined in Sec 2, [5.1.1]

f_{thick} : Correction factor for plate thickness defined in Sec 2, [5.1.1]

3.1.2 Elementary fatigue damage

The elementary fatigue damage for each loading condition is to be calculated with the following formula:

$$D_j = \frac{\alpha_j N_L}{K} \frac{\Delta\sigma_{E,j}^{\ 4}}{(\ln N_R)^{4/\xi}} \left\{ \Gamma\left(\frac{4}{\xi} + 1, \nu\right) + \nu^{-3/\xi} \gamma\left(\frac{7}{\xi} + 1, \nu\right) \right\}$$

where:

$$\nu = \left(\frac{100.3}{\Delta\sigma_{E,j}}\right)^{\xi} \ln N_R$$

N_R : Number of cycles; 10^4

α_j : Coefficient depending on the loading condition specified in Sec 2, Tab 4.

N_L : Total number of cycles for the design ship's life

ξ : Weibull shape parameter, ξ may be equal to 1.0

3.2 Fatigue strength criteria

The cumulative fatigue damage D calculated for the combined equivalent stress is to comply with the following criteria:

$$D = \sum_j D_j \leq 1.0$$

Chapter 9 – Other structures

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Section 1 – FORE PART

Section under development

Symbols

a_B : spacing of fore-hooks [m]

1. Stem

1.1 Bar stem

1.1.1

The cross sectional area of a bar stem below the load waterline is not to be less than:

$$A_b = 1,25\,\mathbf{L} \quad \left[cm^2\right]$$

1.1.2

Starting from the load waterline, the sectional area of the bar stem may be reduced towards the upper end to 0,75 Ab.

1.2 Plate stem and bulbous bows

1.2.1

The thickness, in mm, is not to be less than:

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

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

The plate thickness must not be less than the required thickness according to[2].

The extension l of the stem plate from its trailing edge aftwards must not be smaller than:

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

Dimensioning of the stiffening has to be done according to [ ].

1.2.2

Starting from 600 mm above the load waterline up to T + c0, the thickness may gradually be reduced to 0,8 t.

1.2.3

Plate stems and bulbous bows must be stiffened by fore-hooks and/or cant frames.

2. Strengthening of bottom forward

2.1 Arrangement of floors and girders

2.1.1

For the purpose of arranging floors and girders the following areas are defined:

– forward of $\frac{x}{\mathbf{L}} = 0,7$ for $\mathbf{L} \le 100$ m

– forward of $\frac{x}{\mathbf{L}} = (0,6 + 0,001\,\mathbf{L})$

for $100 < \mathbf{L} \le 150$ m

– forward of $\frac{x}{\mathbf{L}} = 0,75$ for $\mathbf{L} > 150$ m

2.1.2

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.

2.1.3

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.

2.1.4

Distances deviating from those defined in 1.2 and 1.3 may be accepted on the basis of direct calculations.

2.1.5

Within the areas defined in [2.1.1] any scalloping is to be restricted to holes for welding and for limbers.

2.2 Bottom plating forward of x/L = 0.5

2.2.1

The thickness of the bottom plating of the flat part of the ship's bottom up to a height of 0,05 · Tb or 0,3 m above base line, whichever is the smaller value, is not to be less than:

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

Tb = smallest design ballast draft at the forward perpendicular [m]

f_2 = $\sqrt{1,1 - 0,5 \left(\frac{a}{b}\right)^2} \le 1,0$

a = smaller breadth of plate panel

b = larger breadth of plate panel

2.2.2
Above 0,05 Tb or 0,3 m above base line the plate thickness may gradually be tapered to the rule thickness determined according to Ch 6, Sec 1. For ships with a rise of floor the strengthened plating must at least extend to the bilge curvature.

2.3 Stiffeners forward of x/L = 0.5

2.3.1
The section modulus of transverse or longitudinal stiffeners is not to be less than:

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

2.3.2
The shear area of the stiffeners is not to be less than:

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

The area of the welded connection has to be at least twice this value.

3. Framing system in forebody

3.1 General

3.1.1
In the fore body, i.e. from the forward end to 0,15 L behind F.P., 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.

3.2 Tiers of beams

3.2.1
Forward of the collision bulkhead, tiers of beams (beams at every other frame) generally spaced no more than 2,6 m apart, measured vertically, are to be arranged below the lowest deck within the forepeak. Stringer plates are to be fitted on the tiers of beams which are to be connected by continuous welding to the shell plating and by a bracket to each frame. The scantlings of the stringer plates are to be determined from the following formulae:

width: $b = 75\sqrt{\mathbf{L}} \quad [mm]$

thickness: $t = 6{,}0 + \dfrac{\mathbf{L}}{40} \quad [mm]$

3.2.2
The cross sectional area of each beam is to be determined according to Ch 6, Sec 4. for a load

$$P = A \cdot p \quad [kN]$$

A = load area of a beam [m²]

3.2.3

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.

3.2.4

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 3.2.2 are, however, to be complied with.

3.3 Web frames and stringers

3.3.1

Where web frames and supporting stringers are fitted instead of tiers of beams, their scantlings are to be determined as follows:

- Section modulus:

$$W = 0{,}55 \cdot e \cdot \ell^2 \cdot p \cdot n_c \cdot k \quad \left[cm^3\right]$$

- Web shear area at the supports:

$$A_w = 0{,}05 \cdot e \cdot \ell_1 \cdot p \cdot k \qquad \left[cm^2\right]$$

l : unsupported span [m], without consideration of cross ties, if any

l_1 : similar to , however, considering cross ties, if any

n_c : coefficient according to the following Table 1:

Table 1:

Number of cross ties	n_c
0	1,0
1	0,5
3	0,3
≥ 3	0,2

3.3.2

Vertical transverses are to be interconnected by cross ties the cross sectional area of which is to be determined according to3.2.2.

Note: Where a large and long bulbous bow is arranged a dynamic pressure p_{sdyn} is to be applied unilaterally. The unilateral pressure can be calculated approximately as follows :

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

p_o, c_F, z and f according to Chapter 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.

3.4 Web frames and stringers in 'tween decks and superstructure decks

Where the speed of the ship exceeds $v_0 = 1,6 \cdot \sqrt{\mathbf{L}}\,[\text{kn}]$ or in ships with a considerable bow flare respectively, stringers and transverses according to [3.3] are to be fitted within 0,1 L from forward perpendicular in 'tween deck spaces and superstructures.

The spacing of the stringers and transverses must 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.

3.5 Tripping brackets

3.5.1

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. 1 are to be fitted. The thickness of the brackets is to be determined according to [3.2.1]. Where proof of safety against tripping is provided tripping brackets may partly or completely be dispensed with.

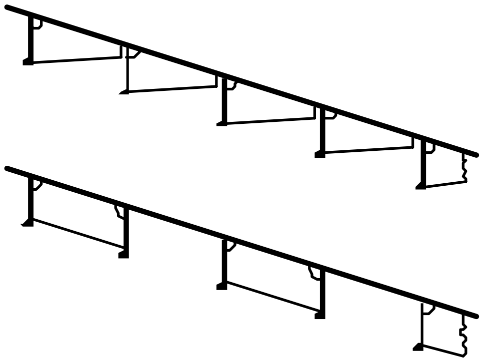


Figure 1: Tripping brackets

3.5.2

In the same range, in 'tween deck spaces and superstructures of 3 m and more in height, tripping brackets according to [3.5.1] are to be fitted.

3.5.3

Where peaks or other spaces forward of the collision bulkhead are intended to be used as tanks, tripping brackets according to [3.5.1] are to be fitted between tiers of beams or stringers.

4. Forecastle

URS28 to be included

Welcome JBP

Section 2 - AFT PART

Symbols

L_1 : Rule length L, but to be taken not greater than 200 m

L_2 : Rule length L, but to be taken not greater than 120 m

k : Material factor, defined in Ch 4, Sec 1, [2.3]

1. General

1.1 Introduction

1.1.1

The requirements of this Section apply for the scantlings of structures located aft of the after peak bulkhead and for the reinforcements of the flat bottom aft area.

1.1.2

Aft peak structures which form the boundary of spaces not intended to carry liquids, and which do not belong to the outer shell, are to be subjected to lateral pressure in flooding conditions. Their scantlings are to be determined according to the relevant criteria in Ch 6.

1.2 Connections of the aft part with structures located fore of the after peak bulkhead

1.2.1 Tapering

Adequate tapering is to be ensured between the scantlings in the aft part and those fore of the after peak bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

1.3 Net scantlings

1.3.1

As specified in Ch 3, Sec 2, all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

Gross scantlings are obtained as specified in Ch 3, Sec 3.

2. Aft peak

2.1 Load point

2.1.1

Unless otherwise specified, lateral pressure is to be calculated at:

- the lower edge of the elementary load panel considered, for plating
- mid-span, for stiffeners.

2.2 Load modal

2.2.1 General

The still water and wave lateral pressures in intact conditions are to be considered. They are to be calculated as specified in [2.3.2] for the elements of the outer shell and in [2.3.3] for the other elements.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Ch 4, Sec 5
- the still water internal pressure due to liquid or ballast, defined in Ch 4, Sec 6
- for decks, the still water internal pressure due to dry uniform weights, defined in Ch 4, Sec 5

Wave pressure (p_W) includes:

- the wave pressure, defined in Ch 4, Sec 5
- the inertial pressure due to liquids or ballast, defined in Ch 4, Sec 6
- for decks, the inertial pressure due to uniform loads, defined in Ch 4, Sec 5.

2.2.2 Lateral pressures for the elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressure, considering the compartment adjacent to the outer shell as being loaded

If the compartment adjacent to the outer shell is not intended to carry liquids, only the external sea pressures are to be considered.

2.2.3 Lateral pressures for elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

3. After peak

3.1 Arrangement

3.1.1 General

The after peak is, in general, to be transversely framed.

3.1.2 Floors

Solid floors are to be fitted at every frame spacing.

The floor height is to be adequate in relation to the shape of the hull. Where a sterntube is fitted, the floor height is to extend at least above the sterntube. Where the hull lines do not allow such extension, plates of suitable height with upper and lower edges stiffened and securely fastened to the frames are to be fitted above the sterntube.

In way of and near the rudder post, propeller post and rudder horn, floors are to be extended up to the peak tank top and are to be increased in thickness; the increase will be considered by the Society on a case by case basis, depending on the arrangement proposed.

Floors are to be fitted with stiffeners having spacing not greater than 800 mm.

3.1.3 Side frames

Side frames are to be extended up to a deck located above the full load waterline.

Side frames are to be supported by one of the following types of structure:

- non-tight platforms, to be fitted with openings having a total area not less than 10% of the area of the platforms
- side girders supported by side primary supporting members connected to deck transverses. side girders supported by side primary supporting members connected to deck transverses.

The distance between the above side frame supports is to be not greater than 2,5 m.

3.1.4 Platforms and side girders

Platforms and side girders within the peak are to be arranged in line with those located in the area immediately forward.

Where this arrangement is not possible due to the shape of the hull and access needs, structural continuity between the peak and the structures of the area immediately forward is to be ensured by adopting wide tapering brackets.

Where the after peak is adjacent to a machinery space whose side is longitudinally framed, the side girders in the after peak are to be fitted with tapering brackets.

3.1.5 Longitudinal bulkheads

A longitudinal non-tight bulkhead is to be fitted on the centreline of the ship, in general in the upper part of the peak, and stiffened at each frame spacing.

Where either the stern overhang is very large or the maximum breadth of the peak is greater than 20 m, additional longitudinal wash bulkheads may be required.

3.2 Scantlings

3.2.1 Plating and ordinary stiffeners (side frames)

The net scantlings of plating and ordinary stiffeners are to be not less than those obtained according to Ch 6, Sec 1 and 2.

3.2.2 Floors

The net thickness of floors is to be not less than that obtained, in mm, from the following formula:

$t = 6{,}5 + 0{,}023\ L_1\ k^{1/2}$

3.2.3 Side transverses

The net section modulus w, in cm^3 , and the net shear sectional area A_{Sh}, in cm^2 , of side transverses are to be not less than the values obtained from the following formulae:

To be completed

3.2.4 Side girders

The net section modulus w, in cm^3 , and the net shear sectional area A_{Sh}, in cm^2 , of side girders are to be not less than the values obtained from the following formulae:

To be completed

3.2.5 Deck primary supporting members

Scantlings of deck primary supporting members are to be in accordance with Ch 6, Sec 4, considering the loads in [2.2].

To be completed

4. Reinforcements of the flat area of the bottom aft

4.1 General

4.1.1

In the flat area of the bottom aft, if any, increased bottom plating thickness as well as additional bottom stiffeners may be considered by the Society on a case by case basis.

5. Connection of hull structures with the rudder horn

5.1 Connection of after peak structures with the rudder horn

5.1.1 General

The requirement of this sub-article apply to the connection between peak structure and rudder horn where the stern-frame is of an open type and is fitted with the rudder horn.

5.1.2 Rudder horn

Horn design is to be such as to enable sufficient access for welding and inspection.

The scantlings of the rudder horn, which are to comply with Ch 10, Sec 1, [9.2], may be gradually tapered inside the hull.

Connections by slot welds are not acceptable.

5.1.3 Hull structures

Between the horn intersection with the shell and the peak tank top, the vertical extension of the hull structures is to be not less than the horn height, defined as the distance from the horn intersection with the shell to the mid-point of the lower horn gudgeon.

The thickness of the structures adjacent to the rudder horn, such as shell plating, floors, platforms and side girders, the centreline bulkhead and any other structures, is to be adequately increased in relation to the horn scantlings.

5.2 Structural arrangement above the after peak

5.2.1 Side transverses

Where a rudder horn is fitted, side transverses, connected to deck beams, are to be arranged between the platform forming the peak tank top and the weather deck.

The side transverse spacing is to be not greater than:

- 2 frame spacings in way of the horn
- 4 frame spacings for and aft of the rudder horn
- 6 frame spacings in the area close to the after peak bulkhead.

The side transverses are to be fitted with end brackets and located within the poop. Where there is no poop, the scantlings of side transverses below the weather deck are to be adequately increased with respect to those obtained from the formulae in [3.2.3].

5.2.2 Side girders

Where the depth from the peak tank top to the weather deck is greater than 2,6 m and the side is transversely framed, one or more side girders are to be fitted, preferably in line with similar structures existing forward.

6. Sternframes

6.1 General

6.1.1

Sternframes may be made of cast or forged steel, with a hollow section, or fabricated from plate.

6.1.2

Cast steel and fabricated sternframes are to be strengthened by adequately spaced horizontal plates.

Abrupt changes of section are to be avoided in castings; all sections are to have adequate tapering radius.

6.2 Connections

6.2.1 Connection with hull structure

Sternframes are to be effectively attached to the aft structure and the lower part of the sternframe is to be extended forward of the propeller post to a length not less than 1500 + 6L mm, in order to provide an effective connection with the keel. However, the sternframe need not extend beyond the after peak bulkhead.

The net thickness of shell plating connected with the stern-frame is to be not less than that obtained, in mm, from the following formula:

$t = 0{,}045\ L\ k^{1/2} + 8{,}5.$

6.2.2 Connection with the keel

The thickness of the lower part of the sternframes is to be gradually tapered to that of the solid bar keel or keel plate.

Where a keel plate is fitted, the lower part of the sternframe is to be so designed as to ensure an effective connection with the keel.

6.2.3 Connection with transom floors

Rudder posts and, in the case of ships greater than 90 m in length, propeller posts are to be connected with transom floors having height not less than that of the double bottom and net thickness not less than that obtained, in mm, from the following formula:

$t = 9 + 0{,}023\ L_1\ k^{1/2}$

6.2.4 Connection with centre keelson

Where the sternframe is made of cast steel, the lower part of the sternframe is to be fitted, as far as practicable, with a longitudinal web for connection with the centre keelson.

6.3 Propeller posts

6.3.1 Gross scantlings

With reference to Ch 3, Sec 2, all scantlings and dimensions referred to in [6.3.2] to [6.3.4] are gross, i.e. they include the margins for corrosion.

6.3.2 Gross scantlings of propeller posts

The gross scantlings of propeller posts are to be not less than those obtained from the formulae in Tab 1 for single screw ships and Tab 2 for twin screw ships.

Scantlings and proportions of the propeller post which differ from those above may be considered acceptable provided that the section modulus of the propeller post section about its longitudinal axis is not less than that calculated with the propeller post scantlings in Tab 1 or Tab 2, as applicable.

6.3.3 Section modulus below the propeller shaft bossing

In the case of a propeller post without a sole piece, the section modulus of the propeller post may be gradually reduced below the propeller shaft bossing down to 85% of the value calculated with the scantlings in Tab 1 or Tab 2, as applicable.

In any case, the thicknesses of the propeller posts are to be not less than those obtained from the formulae in the tables.

6.3.4 Welding of fabricated propeller post with the propeller shaft bossing

Welding of a fabricated propeller post with the propeller shaft bossing is to be in accordance with Ch 11, Sec 1.

6.4 Integral rudder posts

6.4.1 Net section modulus of integral rudder post

The net section modulus around the horizontal axis X (see Fig 1) of an integral rudder post is to be not less than that obtained, in cm^3 , from the following formula:

$w_{RP} = 14{,}4\ C_R\ L_D\ 10^{-6}$

where:

C_R: Rudder force, in N, acting on the rudder blade, defined in Ch 10, Sec 1, [2.1.2] and Ch 10, Sec 1, [2.2.2], as the case may be

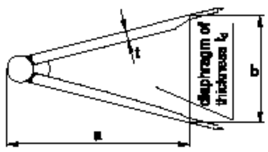
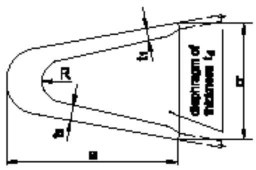
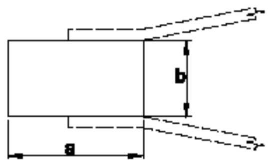
L_D: Length of rudder post, in m.

6.5 Propeller shaft bossing

6.5.1

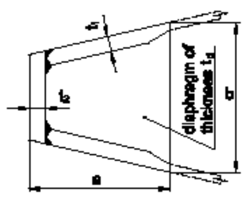
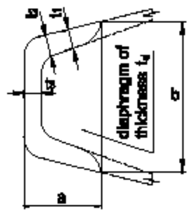
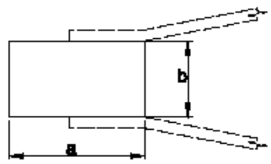
In single screw ships, the thickness of the propeller shaft bossing, included in the propeller post, is to be not less than 60% of the dimension "b" required in [6.3.2] for bar propeller posts with a rectangular section.

Table 1: Single screw ships - Gross scantlings of propeller posts

Gross scantlings of propeller posts, in mm	**Fabricated propeller post** 	**Cast propeller post** 	**Bar propeller post, cast or forged, having rectangular section** 
a	$50\ L^{1/2}$	$33\ L^{1/2}$	$10 \cdot \sqrt{2{,}5(L+10)}$ for $L \le 60$ $10 \cdot \sqrt{7{,}2L - 256}$ for $L > 60$
b	$35\ L^{1/2}$	$23\ L^{1/2}$	$10 \cdot \sqrt{1{,}6(L+10)}$ for $L \le 60$ $10 \cdot \sqrt{4{,}6L - 164}$ for $L > 60$
t_1 **(1)**	$2{,}5\ L^{1/2}$	$3{,}2\ L^{1/2}$ to be taken not less than 19 mm	ϕ
t_2 **(1)**	ϕ	$4{,}4\ L^{1/2}$ to be taken not less than 19 mm	ϕ
t_D	$1{,}3\ L^{1/2}$	$2{,}0\ L^{1/2}$	ϕ
R	ϕ	$50\ L^{1/2}$	ϕ

(1) Propeller post thicknesses t_1 and t_2 are, in any case, to be not less than (0,05 L + 9,5) mm.
Note 1: ϕ = not applicable.

Table 2: Twin screw ships - Gross scantlings of propeller posts

Gross scantlings of propellerposts, in mm	Fabricated propeller post 	Cast propeller post 	Bar propeller post, cast or forged, having rectangular section 
a	$25\ L^{1/2}$	$12{,}5\ L^{1/2}$	$0{,}72\ L + 90$ for $L \le 50$ $2{,}40\ L + 6$ for $L > 50$
b	$25\ L^{1/2}$	$25\ L^{1/2}$	$0{,}24\ L + 30$ for $L \le 50$ $0{,}80\ L + 2$ for $L > 50$
t_1 **(1)**	$2{,}5\ L^{1/2}$	$2{,}5\ L^{1/2}$	ϕ
t_2 **(1)**	$3{,}2\ L^{1/2}$	$3{,}2\ L^{1/2}$	ϕ
t_3 **(1)**	ϕ	$4{,}4\ L^{1/2}$	ϕ
t_D	$1{,}3\ L^{1/2}$	$2\ L^{1/2}$	ϕ

(1) Propeller post thicknesses t_1, t_2 and t_3 are, in any case, to be not less than $(0{,}05\ L + 9{,}5)$ mm.
Note 1: ϕ = not applicable.

6.6 Rudder gudgeon

6.6.1 Rudder gudgeons

In general, gudgeons are to be solidly forged or cast with the sternframe.

The height of the gudgeon is to be not greater than 1,2 times the pintle diameter. In any case, the height and diameter of the gudgeons are to be suitable to house the rudder pintle.

The thickness of the metal around the finished bore of the gudgeons is to be not less than half the diameter of the pintle.

6.6.2 Sterntubes

The sterntube thickness is considered by the Society on a case by case basis. In no case, however, may it be less than the thickness of the side plating adjacent to the stern-frame.

Where the materials adopted for the sterntube and the plating adjacent to the sternframe are different, the sterntube thickness is to be at least equivalent to that of the plating.

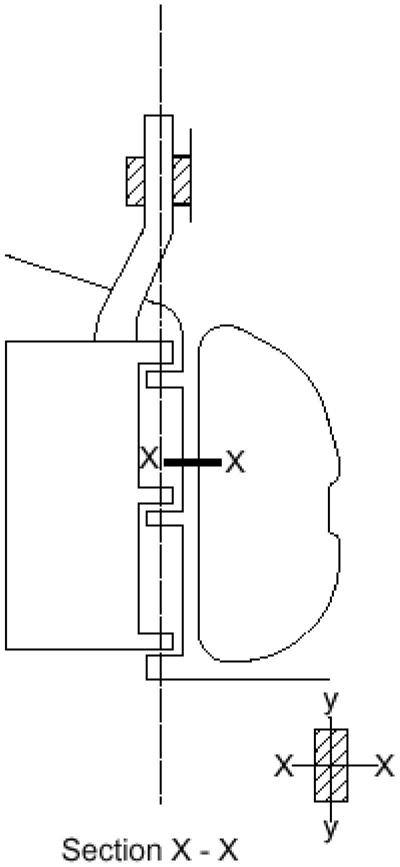


Figure 1: Integral rudder post

Chapter 9 – Other structures

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Section 3 - MACHINERY SPACE

Symbols

L_2 : Rule length L, but to be taken not greater than 120 m

k : Material factor, defined in Ch 4, Sec 1, [2.3]

P : Maximum power, in kW, of the engine

n_r : Number of revolutions per minute of the engine shaft at power equal to P

L_E : Effective length, in m, of the engine foundation plate required for bolting the engine to the seating, as specified by the engine manufacturer.

1. General

1.1 Application

1.1.1

The requirements of this Section apply for the arrangement and scantling of machinery space structures as regards general strength. It is no substitute to machinery manufacturer's requirements which have to

1.2 Scantlings

1.2.1 Net scantlings

As specified in Ch 3, Sec 2 all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 3, Sec 3.

1.2.2 General

Unless otherwise specified in this Section, the scantlings of plating, ordinary stiffeners and primary supporting members in the machinery space are to be determined according to the relevant criteria in Ch 6.

In addition, the minimum thickness requirements specified in this Section apply.

1.2.3 Primary supporting members

The Designer may propose arrangements and scantlings alternative to the requirements of this Section, on the basis of direct calculations which are to be submitted to the Society for examination on a case by case basis.

The Society may also require such direct calculations to be carried out whenever deemed necessary.

1.3 Connections of the machinery space with structures located aft and forward

1.3.1 Tapering

Adequate tapering is to be ensured between the scantlings in the machinery space and those aft and forward. The. tapering is to be such that the scantling requirements for all areas are fulfilled.

1.3.2 Deck discontinuities

Decks which are interrupted in the machinery space are to be tapered on the side by means of horizontal brackets.

2. Double bottom

2.1 Arrangement

2.1.1 General

Where the machinery space is immediately forward of the after peak, the double bottom is to be transversely framed. In all other cases it may be transversely or longitudinally framed.

2.1.2 Double bottom height

The double bottom height at the centreline, irrespective of the location of the machinery space, is to be not less than the value defined in Ch 3, Sec 6, [4.2.1]. This depth may need to be considerably increased in relation to the type and depth of main machinery seatings.

The above height is to be increased by the Shipyard where the machinery space is very large and where there is a considerable variation in draught between light ballast and full load conditions.

Where the double bottom height in the machinery space differs from that in adjacent spaces, structural continuity of longitudinal members is to be ensured by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the sloped inner bottom are to be located in way of floors.

2.1.3 Centre bottom girder

In general, the centre bottom girder may not be provided with holes. In any case, in way of any openings for manholes on the centre girder, permitted only where absolutely necessary for double bottom access and maintenance, local strengthening is to be arranged.

2.1.4 Side bottom girders

In the machinery space the number of side bottom girders is to be adequately increased, with respect to the adjacent areas, to ensure adequate rigidity of the structure. The side bottom girders are to be a continuation of any bottom longitudinals in the areas adjacent to the machinery space and are generally to have a spacing not greater than 3 times that of longitudinals and in no case greater than 3 m..

2.1.5 Side bottom girders in way of machinery seatings

Additional side bottom girders are to be fitted in way of machinery seatings.

Side bottom girders arranged in way of main machinery seatings are to extend for the full length of the machinery space.

Where the machinery space is situated amidships, the bottom girders are to extend aft of the after bulkhead of such space for at least three frame spaces, and beyond to be connected to the hull structure by tapering.

Where the machinery space is situated aft, the bottom girders are to extend as far aft as practicable in relation to the shape of the bottom and to be supported by floors and side primary supporting members at the ends.

Forward of the machinery space forward bulkhead, the bottom girders are to be tapered for at least three frame spaces and are to be effectively connected to the hull structure.

2.1.6 Floors in longitudinally framed double bottom

Where the double bottom is longitudinally framed, the floor spacing is to be not greater than:

- 1 frame spacing in way of the main engine and thrust bearing
- 2 frame spacings in other areas of the machinery space.

Additional floors are to be fitted in way of other important machinery.

2.1.7 Floors in transversely framed double bottom

Where the double bottom in the machinery space is transversely framed, floors are to be arranged at every frame. Furthermore, additional floors are to be fitted in way of boiler foundations or other important machinery.

2.1.8 Floors stiffeners

In addition to the requirements in Ch 3, Sec 6, floors are to have web stiffeners sniped at the ends and spaced not more than approximately 1 m apart.

The section modulus of web stiffeners is to be not less than 1,2 times that required in Ch 3, Sec 6.

2.1.9 Manholes and wells

The number and size of manholes in floors located in way of seatings and adjacent areas are to be kept to the minimum necessary for double bottom access and maintenance.

The depth of manholes is generally to be not greater than 40% of the floor local depth, and in no case greater than 750 mm, and their width is to be equal to approximately 400 mm.

In general, manhole edges are to be stiffened with flanges; failing this, the floor plate is to be adequately stiffened with flat bars at manhole sides.

Manholes with perforated portable plates are to be fitted in the inner bottom in the vicinity of wells arranged close to the aft bulkhead of the engine room.

Drainage of the tunnel is to be arranged through a well located at the aft end of the tunnel.

2.2 Minimum thicknesses

2.2.1

The net thicknesses of inner bottom, floor and girder webs are to be not less than the values given in Tab 1.

Table 1: Double bottom - Minimum net thicknesses of inner bottom, floor and girder webs

Element	Minimum net thickness, in mm	
	Machinery space within 0,4L amidships	Machinery space outside 0,4L amidships
Inner bottom	$[0,75L^{1/2} + 1,35 + 4,5(s - 0,23L^{1/4})]k^{1/2}$ The Society may require the thickness of the inner bottom in way of the main machinery seatings and on the main thrust blocks to be increased, on a case by case basis.	
Margin plate	$L^{1/2} k^{1/4} + 1$	$0,9\ L^{1/2} k^{1/4} + 1$
Centre girder	$1,8\ L^{1/3} k^{1/6} + 4$	$1,55\ L^{1/3} k^{1/6} + 3,5$
Floors and side girders	$1,7\ L^{1/3} k^{1/6} + 1$	
Girder bounding a duct keel	$0,8\ L^{1/2} k^{1/4} + 2,5$ to be taken not less than that required for the centre girder	

3. Single bottom

3.1 Arrangement

3.1.1 Bottom girder

For single bottom girder arrangement, the requirements of Ch 3, Sec 6 and Ch 3, Sec 6 for double bottom apply.

3.1.2 Floors in longitudinally framed single bottom

Where the single bottom is longitudinally framed, the floor spacing is to be not greater than:

- 1 frame spacing in way of the main engine and thrust bearing
- 2 frame spacings in other areas of the machinery spaces.

Additional floors are to be fitted in way of other important machinery.

3.1.3 Floors in transversely framed single bottom

Where the single bottom is transversely framed, the floors are to be arranged at every frame.

Furthermore, additional floors are to be fitted in way of boiler foundations or other important machinery.

3.1.4 Floor height

The height of floors in way of machinery spaces located amidships is to be not less than B/14,5. Where the top of the floors is recessed in way of main machinery, the height of the floors in way of this recess is generally to be not less than B/16. Lower values will be considered by the Society on a case by case basis.

Where the machinery space is situated aft or where there is considerable rise of floor, the depth of the floors will be considered by the Society on a case by case basis.

3.1.5 Floor flanging

Floors are to be fitted with welded face plates in way of:

- engine bed plates
- thrust blocks
- auxiliary seatings.

3.2 Minimum thicknesses

3.2.1 Floors in longitudinally framed single bottom

The net thicknesses of inner bottom, floor and girder webs are to be not less than the values given in Tab 2.

Table 2: Single bottom - Minimum net thicknesses of inner bottom, floor and girder webs

Element	Minimum net thickness, in mm	
	Machinery space within 0,4L amidships	Machinery space outside 0,4L amidships
Centre girder	$7 + 0,05\ L_2\ k^{1/2}$	$6 + 0,05\ L_2\ k^{1/2}$
Floors and side girder	$6,5 + 0,05\ L_2\ k^{1/2}$	$5 + 0,05\ L_2\ k^{1/2}$

4. Side

4.1 Arrangement

4.1.1 General

The type of side framing in machinery spaces is generally to be the same as that adopted in the adjacent areas.

4.1.2 Extension of the hull longitudinal structure within the machinery space

In ships where the machinery space is located aft and where the side is longitudinally framed, the longitudinal structure is preferably to extend for the full length of the machinery space.

In any event, the longitudinal structure is to be maintained for at least 0,3 times the length of the machinery space, calculated from the forward bulkhead of the latter, and abrupt structural discontinuities between longitudinally and transversely framed structures are to be avoided..

4.1.3 Side transverses

Side transverses are to be aligned with floors. One is preferably to be located in way of the forward end and another in way of the after end of the machinery casing.

For a longitudinally framed side, the side transverse spacing is to be not greater than 4 frame spacings.

For a transversely framed side, the side transverse spacing is to be not greater than 5 frame spaces. The web height is to be not less than twice that of adjacent frames and the section modulus is to be not less than four times that of adjacent frames.

Side transverse spacing greater than that above may be accepted provided that the scantlings of ordinary frames are increased, according to the Society's requirements to be defined on a case by case basis.

5. Platforms

5.1 Arrangement

5.1.1 General

The location and extension of platforms in machinery spaces are to be arranged so as to be a continuation of the structure of side longitudinals, as well as of platforms and side girders located in the adjacent hull areas.

5.1.2 Platform transverses

In general, platform transverses are to be arranged in way of side or longitudinal bulkhead transverses.

For longitudinally framed platforms, the spacing of platform transverses is to be not greater than 4 frame spacings.

5.2 Minimum thicknesses

5.2.1

The net thickness of platforms is to be not less than that obtained, in mm, from the following formula:

$t = 0,018\, L_2\, k^{1/2} + 4,5$

6. Pillaring

6.1 Arrangement

6.1.1 General

The pillaring arrangement in machinery spaces is to account both for the concentrated loads transmitted by machinery and superstructures and for the position of main machinery and auxiliary engines..

6.1.2 Pillars

Pillars are generally to be arranged in the following positions:

- in way of machinery casing corners and corners of large openings on platforms; alternatively, two pillars may be fitted on the centreline (one at each end of the opening)
- in way of the intersection of platform transverses and girders
- in way of transverse and longitudinal bulkheads of the superstructure.

In general, pillars are to be fitted with brackets at their ends.

6.1.3 Pillar bulkheads

In general, pillar bulkheads, fitted 'tweendecks below the upper deck, are to be located in way of load-bearing bulkheads in the superstructures.

Longitudinal pillar bulkheads are to be a continuation of main longitudinal hull structures in the adjacent spaces forward and aft of the machinery space.

Pillar bulkhead scantlings are to be not less than those required in [7.3] for machinery casing bulkheads.

7. Machinery casing

7.1 Arrangement

7.1.1 Ordinary stiffener spacing

Ordinary stiffeners are to be located:

- at each frame, in longitudinal bulkheads
- at a distance of about 750 mm, in transverse bulkheads.

The ordinary stiffener spacing in portions of casings which are particularly exposed to wave action is considered by the Society on a case by case basis.

7.2 Openings

7.2.1 General

All machinery space openings, which are to comply with the requirements in Sec 9, [5], are to be enclosed in a steel casing leading to the highest open deck. Casings are to be reinforced at the ends by deck beams and girders associated to pillars.

In the case of large openings, the arrangement of cross-ties as a continuation of deck beams may be required.

Skylights, where fitted with openings for light and air, are to have coamings of a height not less than:

- 900 mm, if in position 1
- 760 mm, if in position 2.

7.2.2 Access doors

Access doors to casings are to comply with Ch 9, Sec 6, [6.2].

7.3 Scantlings

7.3.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than those obtained according to the applicable requirements in Ch 9, Sec 4.

7.3.2 Minimum thicknesses

The net thickness of bulkheads is to be not less than:

- 5,5 mm for bulkheads in way of cargo holds
- 4 mm for bulkheads in way of accommodation spaces.

8. Main machinery seating

8.1 Arrangement

8.1.1 General

The scantlings of main machinery seatings and thrust bearings are to be adequate in relation to the weight and power of engines and the static and dynamic forces transmitted by the propulsive installation.

8.1.2 Seating supporting structure

Transverse and longitudinal members supporting the seatings are to be located in line with floors and double or single bottom girders, respectively.

They are to be so arranged as to avoid discontinuity and ensure sufficient accessibility for welding of joints and for surveys and maintenance.

8.1.3 Seatings included in the double bottom structure

Where high-power internal combustion engines or turbines are fitted, seatings are to be integral with the double bottom structure. Girders supporting the bedplates in way of seatings are to be aligned with double bottom girders and are to be extended aft in order to form girders for thrust blocks.

The girders in way of seatings are to be continuous from the bedplates to the bottom shell.

8.1.4 Seatings above the double bottom plating

Where the seatings are situated above the double bottom plating, the girders in way of seatings are to be fitted with flanged brackets, generally located at each frame and extending towards both the centre of the ship and the sides.

The extension of the seatings above the double bottom plating is to be limited as far as practicable while ensuring adequate spaces for the fitting of bedplate bolts. Bolt holes are to be located such that they do not interfere with seating structures.

8.1.5 Seatings in a single bottom structure

For ships having a single bottom structure within the machinery space, seatings are to be located above the floors and to be adequately connected to the latter and to the girders located below.

8.1.6 Number of girders in way of machinery seatings

In general, at least two girders are to be fitted in way of main machinery seatings.

One girder may be fitted only where the following three formulae are complied with:

$L < 150$ m

$P < 7100$ kW

$P < 2,3\, n_R\, L_E$

8.2 Minimum scantlings

8.2.1

As a guidance, the net scantlings of the structural elements in way of the internal combustion engine seatings may be obtained from the formulae in Tab 3.

Table 3: Minimum scantlings of the structural elements in way of machinery seatings

Scantling	Minimum value
Net cross-sectional area, in cm², of each bedplate of the seatings	$40 + 70\dfrac{P}{n_r L_E}$
Bedplate net thickness, in mm	• Bedplates supported by two or more girders: $\sqrt{240 + 175\dfrac{P}{n_r L_E}}$ • Bedplates supported by one girder: $5 + \sqrt{240 + 175\dfrac{P}{n_r L_E}}$
Total web net thickness, in mm, of girders fitted in way of machinery seatings	• Bedplates supported by two or more girders: $\sqrt{320 + 215\dfrac{P}{n_r L_E}}$ • Bedplates supported by one girder: $\sqrt{95 + 65\dfrac{P}{n_r L_E}}$
Web net thickness, in mm, of floors fitted in way of machinery seatings	$\sqrt{55 + 40\dfrac{P}{n_r L_E}}$

Chapter 9 – Other structures

Welcome JBP

Section 4 – SUPERSTRUCTURES AND DECKHOUSES

Symbols

ℓ = unsupported span, in m, according to Ch. 3 Sec. 6.

e = width of deck supported, in m

p = deck load p_D, p_{DA} or p_L, inkN/m², as used in [3.1] and [3.3]

c = 0,55

= 0,75 for beams, girders and transverses which are simply supported on one or both ends

1. General

1.1 Definitions

1.1.1

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.

1.1.2

A deckhouse is a decked structure above the strength deck the side plating being inboard of the shell plating more than 0,04 B.

1.1.3

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.

1.1.4

A short deckhouse is a deckhouse not covered by the definition given in 1.3.

1.1.5

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).

1.1.6

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.

1.1.7

Scantlings of insulated funnels are to be determined as for deckhouses.

1.2 Load centre

1.2.1 For plates:

- Vertical stiffening system:

0,5 times the 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

1.2.2 For stiffeners and girders:

centre of span ℓ

1.3 Loads

1.3.1 Basic external dynamic load

p_0 : basic external dynamic load

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

f : probability factor

= 1,0 for plate panels of the outer hull (shell plating, weather decks)

= 0,75 for secondary stiffening members and of the outer hull (frames, deck beams)

= 0,60 for girders and girder systems of the outer hull (web frames, stringers, grillage systems)

c_0 : wave coefficient, as defined in Ch 1, Sec 4, [2.3.1]

c_L : length coefficient

$$= \sqrt{\frac{L}{90}} \qquad for\ L \prec 90m$$

$$= 1{,}0 \qquad for\ L \geq 90m$$

1.3.2 Loads on weather decks

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

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

c_D : distribution factors according to Table 1

1.3.3 Load on decks of superstructures and deckhouses

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:

$$p_{DA} = p_D \cdot n \quad \left[kN/m^2\right]$$

p_D = load according to [1.3.2]

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

= 1,0 for the forecastle deck

n_{min} = 0,5

For deckhouses the value so determined may be multiplied by the factor

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

b' = breadth of deckhouse

B' = largest breadth of ship at the position considered

Except for the forecastle deck the minimum load is:

$$p_{DA\,min} = 4 \quad \left[kN/m^2\right]$$

1.3.4 Load on exposed wheel house top

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

$$p = 2{,}5 \quad \left[kN/m^2\right]$$

1.3.5 Load on sides of superstructures

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

c_F : distribution factors according to Tab 1

1.3.6 Load on bow structures

The design load for bow structures from forward to 0,1 L behind the forward perpendicular. and above the ballast waterline in accordance with the draft T_b in 4 is to be determined according to the following formula:

$$p_e = c\left(0{,}20 \cdot v_0 + 0{,}6\sqrt{L}\right)^2 \ \left[kN/m^2\right]$$
$$with\ L_{max} = 300m$$

c : 0,8 in general

: $\dfrac{0{,}4}{\left(1{,}2 - 1{,}09 \cdot \sin\alpha\right)}$

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 must not be smaller than p_s according to [1.3.5] respectively.

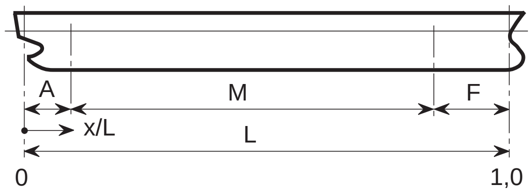
Aft of 0,1 L from F.P. up to 0,15 L from F.P. the pressure between p_e and p_s is to be graded steadily.

Table 1: Distribution factors for Loads

Range		Factor c_D	Factor c_F[1]
A	$0 \leq \frac{x}{\mathbf{L}} < 0{,}2$	$1{,}2 - \frac{x}{\mathbf{L}}$	$1{,}0 + \frac{5}{C_B}\left(0{,}2 - \frac{x}{\mathbf{L}}\right)$
M	$0{,}2 \leq \frac{x}{\mathbf{L}} < 0{,}7$	1,0	1,0

Range		Factor c_D	Factor c_F[1]
F	$0,7 \le \frac{x}{\mathbf{L}} \le 1,0$	$1,0 + \frac{c}{3}\left(\frac{x}{\mathbf{L}} - 0,7\right)$ $c = 0,15\,\mathbf{L} - 10$ where: $\mathbf{L}_{min} = 100$ m $\mathbf{L}_{max} = 250$ m	$1,0 + \frac{20}{C_B}\left(\frac{x}{\mathbf{L}} - 0,7\right)^2$

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.



1.4 Arrangement of superstructures

1.4.1

According to ILLC 66, Regulation 39, a minimum bow height is required at the forward perpendicular, which may be obtained by sheer extending for at least 0,15 L_c, measured from the forward perpendicular, or by fitting a forecastle extending from the stem to a point at least 0,07 L_c abaft the forward perpendicular.

1.4.2

Ships carrying timber deck cargo and which are to be assigned the respective permissible freeboard, are to have a forecastle of the Rule height and a length of at least 0,07 L_c. Furthermore, ships the length of which is less than 100 m, are to have a poop of Rule height or a raised quarter deck with a deckhouse.

1.5 Strengthening at the ends of superstructures

1.5.1

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 Tab 2. The strengthenings shall extend over a region from 4 frame spacings abaft the end bulkhead to 4 frame spacings forward of the end bulkhead.

Table 2: Strengthening [%]

Type of superstructure	strength deck and sheer strake	side plating of superstructure
Effective according 1.5	30	20
non-effective according 1.6	20	10

1.5.2

Under strength decks in way of 0,6 L amidships, girders are to be fitted in alignment with longitudinal walls, which are to extend at least over three frame spacings beyond the end points of the longitudinal walls. The girders are to overlap with the longitudinal walls by at least two frame spacings.

1.6 Transverse structure of superstructures and deckhouses

1.6.1

The transverse structure of superstructures and deckhouses is to be sufficiently dimensioned by a suitable arrangement of end bulkheads, webframes, steel walls of cabins and casings, or by other measures.

1.7 Openings in closed superstructures

1.7.1

All access openings in end bulkheads of closed superstructures shall be fitted with weather tight doors permanently attached to the bulkhead, having the same strength as the bulkhead. The doors shall 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 ILLC 66.

1.7.2

Any opening in a superstructure deck or in a deckhouse deck directly above the freeboard deck (deckhouse surrounding companionways), is to be protected by efficient weather tight closures.

2. Plating of Non-Effective Superstructures

2.1 Side plating

The thickness of the side plating above the strength deck is not to be less than the greater of the following values:

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

or

$$t = 0{,}8 \cdot t_{min} \quad [\mathrm{mm}]$$

p = p_s or p_e

$$t_{\min} = \sqrt{L \cdot k}$$

2.2 Deck plating

2.2.1

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

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

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

$p = p_{DA}$

$C = 1{,}21$, if $p = p_{DA}$

L need not be taken greater than 200 m.

2.2.2

Where additional superstructures are arranged on non-effective superstructures located on the strength deck, the thickness required by 2.2.1 may be reduced by 10 per cent.

2.2.3

Where plated decks are protected by sheathing, the thickness of the deck plating according to [2.2.1] and [2.2.2] may be reduced by t_K, however, it is not to be less than 5 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

3.1 Transverse deck beams and deck longitudinals

3.1.1

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 are to be determined by the following formula:

$$W_d = c \cdot \mathbf{a} \cdot p \cdot \ell^2 \cdot k \qquad \left[cm^3\right]$$

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

3.2 Attachment of deck beams

3.2.1

Transverse deck beams are to be connected to the frames by brackets according to Ch. 3 Sec. 6.

3.2.2

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 Girders and transverses

3.3.1

Section modulus W and shear area A_w are not to be less than:

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

$$A_w = 0{,}05 \cdot p \cdot e \cdot \ell \cdot k \qquad \left[cm^2\right]$$

3.3.2

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.

3.3.3

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.

3.4 Attachment of girders and transverses

3.4.1

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.

3.4.2

Face plates are to be stiffened by tripping brackets according to Ch. 3 Sec. 6. At girders of symmetrical section, they are to be arranged alternately on both sides of the web.

4. Superstructure Frames

4.1 General

4.1.1

In ships having a speed exceeding $v_0 = 1{,}6 \cdot \sqrt{L}\ [kn]$ the forecastle frames forward of 0,1 L from F.P. are to have at least the same scantlings as the frames located between the first and the second deck.

4.1.2

Where further superstructures, or big deckhouses are arranged on the superstructures strengthening of the frames of the space below may be required.

4.2 Scantlings

4.2.1

The section modulus W_t and shear area A_t of the superstructure frames are not to be less than:

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

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

b = unsupported span of the deck beam below the respective deck frame [m]

4.3 End attachment

4.3.1

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. 1.

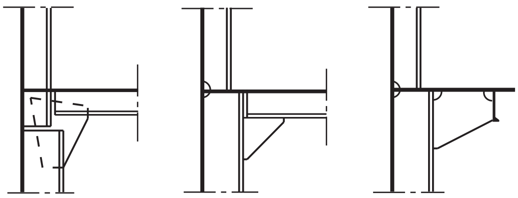


Figure 1: End Attachment

4.3.2

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 Ch. 3 Sec. 6 on the basis of the section modulus of the frames.

5. Superstructure End Bulkheads and Deckhouse Walls

5.1 General

The following requirements apply to superstructure end bulkheads and deckhouse walls forming the only protection for openings as per Regulation 18 of ILLC 66 and for accommodations.

5.2 Definitions

The design load for determining the scantlings is:

$$p_A = n \cdot c \left(b \cdot c_L \cdot c_o - z\right) \quad \left[kN/m^2\right]$$

c_L and c_o : see 1.3.1

h_N = standard superstructure height

= $1{,}05 + 0{,}01\,L$ $[m]$, $1{,}8 \le h_N \le 2{,}3$

$$n = 20 + \frac{L}{12}$$

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 exceeds the minimum non-corrected tabular freeboard according to ILLC by at least one standard superstructure height h_N, this tier may be defined as the 2nd tier and the tier above as the 3rd tier.

$n = 10 + \dfrac{L}{12}$ for 2nd tier unprotected fronts

$n = 5 + \dfrac{L}{15}$ for 3rd tier and tiers above of unprotected fronts, for sides and protected fronts

$n = 7 + \dfrac{L}{100} - 8\dfrac{x}{L}$ for aft ends abaft amidships

$n = 5 + \dfrac{L}{100} - 4\dfrac{x}{L}$ for aft ends forward of amidships

L need not be taken greater than 300 m.

$$b = 1{,}0 + \left(\frac{\frac{x}{L} - 0{,}45}{C_B + 0{,}2} \right)^2 \qquad for \quad \frac{x}{L} < 0{,}45$$

$$b = 1{,}0 + 1{,}5 \left(\frac{\frac{x}{L} - 0{,}45}{C_B + 0{,}2} \right)^2 \qquad for \quad \frac{x}{L} \geq 0{,}45$$

$0{,}60 \leq C_B \leq 0{,}80$; when determining scantlings of aft ends forward of amidships, C_B need not be taken less than 0,8.

x : distance [m] between the bulkhead considered and 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

$$c = 0{,}3 + 0{,}7 \frac{b'}{B'}$$

For exposed parts of machinery casings, 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]; ℓ is to be taken as the superstructure height or deckhouse height respectively, however, not less than 2,0 m.

The design load p_A up to the third tier inclusive is not to be taken less than the minimum values given in Tab 3.

Table 3:

L	**p_{Amin} [kN/m²] for**	
	lowest tier of unprotected fronts	**elsewhere**
$L \leq 50$	30	15
$50 < L \leq 250$	$25 + \frac{L}{10}$	$12{,}5 + \frac{L}{20}$
$250 < L$	50	25

For the 4th tier and all following ones $p_{A\,min}$ is to be taken as 12,5 kN/m^2 .

5.3 Scantlings

5.3.1 Stiffeners

The section modulus of the stiffeners is to be determined according to the following formula:

$$W = 0{,}35 \cdot \mathbf{a} \cdot \ell^2 \cdot p_A \cdot k \quad [cm^3]$$

These requirements assume the webs of lowest 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 to be greater than that of side frames on the deck situated directly below; taking account of spacing a and unsupported span ℓ.

5.3.2 Plate thickness

The thickness of the plating is to be determined according to the following formula:

$$t = 0{,}9 \cdot a \sqrt{p_A \cdot k} + t_k \; [mm]$$

$$t_{min} = \left(5{,}0 + \frac{L}{100}\right)\sqrt{k} \quad [mm]$$ for the lowest tier

$$t_{min} = \left(4{,}0 + \frac{L}{100}\right)\sqrt{k} \quad [mm]$$ for the upper tiers, however, not less than 5,0 mm.

L need not be taken greater than 300 m.

6. Decks of Short Deckhouses

6.1 Plating

6.1.1

The thickness of deck plating exposed to weather but not protected by sheathing is not to be less than:

$$t = 8 \cdot \mathbf{a} \sqrt{k} + t_K \quad [mm]$$

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.

6.2 Deck beams

The deck beams and the supporting deck structure are to be determined according to [3].

Chapter 9 – Other structures

Welcome JBP

Section 5 - HATCH COVERS

Symbols

p_s : Still water pressure, in kN/m², defined in [4.1]

p_w : Wave pressure, in kN/m², defined in [4.1]

p_C : Pressure acting on the hatch coaming, in kN/m², defined in [6.2]

s : Length, in m, of the shorter side of the elementary plate panel

: Length, in m, of the longer side of the elementary plate panel

b_P : Effective width, in m, of the plating attached to the ordinary stiffener or primary supporting member, defined in [3]

w : Net section modulus, in cm³, of the ordinary stiffener or primary supporting member, with an attached plating of width b_p

A_{Sh} : Net shear sectional area, in cm², of the ordinary stiffener or primary supporting member, to be calculated as specified in Ch 3, Sec 2

m : Boundary coefficient for ordinary stiffeners and primary supporting members, taken equal to:

- m = 8 in the case of ordinary stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other end
- m = 12 in the case of ordinary stiffeners and primary supporting members clamped at both ends

t_C : Corrosion additions, in mm, defined in [1.4]

σ_a , τ_a : Allowable stresses, in N/mm², defined in [1.5]

R_m : Minimum ultimate tensile strength, in N/mm², of the material

1. General

1.1 Application

1.1.1

The requirements in [1] to [8] apply to steel hatch covers in positions 1 and 2 on weather decks, defined in Ch 1, Sec 4, [3.16].

The requirements in [9] apply to steel hatch covers of small hatches fitted on the exposed fore deck over the forward 0,25 L.

1.2 Materials

1.2.1 Steel

The formulae for scantlings given in [5] are applicable to steel hatch covers.

Materials used for the construction of steel hatch covers are to comply with the applicable requirements of the Society.

1.2.2 Other materials

The use of materials other than steel is considered by the Society on a case by case basis, by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

1.3 Net scantlings

1.3.1

All scantlings referred to in this Section, except otherwise specified, are net, i.e. they do not include any margin for corrosion.

When calculating the stresses σ and τ in [5.3] and [5.4], the net scantlings are to be used.

The gross scantlings are obtained as specified in Ch 3, Sec 2.

1.4 Corrosion additions

1.4.1 Corrosion additions for steel other than stainless steel

The corrosion addition for both sides to be considered for the plating and internal members of hatch covers, hatch coamings and coaming stays is equal to the value specified in Tab 1.

Table 1: Corrosion additions t_c for steel hatch covers and hatch coamings

Corrosion addition t_c, in mm, for both sides	
Plating and stiffeners of single skin hatch cover	2,0
Top and bottom plating of pontoon hatch cover	2,0
Internal structures of pontoon hatch cover	1,5
Hatch coamings structures and coaming stays	1,5

1.4.2 Corrosion additions for stainless steel

For structural members made of stainless steel, the corrosion addition t_c is to be taken equal to 0.

1.4.3 Corrosion additions for aluminium alloys

For structural members made of aluminium alloys, the corrosion addition t_c is to be taken equal to 0.

1.5 Allowable stresses

1.5.1

The allowable stresses σ_a and τ_a, in N/mm^2, are to be obtained from Tab 2.

Table 2: Allowable stresses, in N/mm^2

Members of:	σ_a, in N/mm^2	τ_a, in N/mm^2
Weathertight hatch cover	0.80 R_{eH}	0.46 R_{eH}
Pontoon hatch cover	0.68 R_{eH}	0.39 R_{eH}
Hatch coaming	0.95 R_{eH}	0.50 R_{eH}

2. Arrangements

2.1 Height of hatch coamings

2.1.1

The height above the deck of hatch coamings closed by portable covers is to be not less than:

- 600 mm in position 1
- 450 mm in position 2.

2.1.2

The height of hatch coamings in positions 1 and 2 closed by steel covers provided with gaskets and securing devices may be reduced with respect to the above values or the coamings may be omitted entirely.

In such cases the scantlings of the covers, their gasketing, their securing arrangements and the drainage of recesses in the deck are considered by the Society on a case by case basis.

2.1.3

Regardless of the type of closing arrangement adopted, the coamings may have reduced height or be omitted in way of openings in closed superstructures or decks below the freeboard deck.

2.2 Hatch covers

2.2.1

Hatch covers on exposed decks are to be weathertight.

Hatch covers in closed superstructures need not be weathertight.

However, hatch covers fitted in way of ballast tanks, fuel oil tanks or other tanks are to be watertight.

2.2.2

The ordinary stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

2.2.3

The spacing of primary supporting members parallel to the direction of ordinary stiffeners is to be not greater than 1/3 of the span of primary supporting members.

2.2.4

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 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

The flange outstand is not to exceed 15 times the gross flange thickness.

2.2.5

The ends of hatch covers are normally to be protected by efficiently secured galvanised steel strips.

2.2.6
Efficient retaining arrangements are to be provided to prevent translation of the hatch cover under the action of the longitudinal and transverse forces exerted by cargoes and stacks of containers on the cover. These retaining arrangements are to be located in way of the hatch coaming side brackets.

- Solid fittings are to be welded on the hatch cover where the corners of the containers are resting. These parts are intended to transmit the loads of the container stacks onto the hatch cover on which they are resting and also to prevent horizontal translation of the stacks by means of special intermediate parts arranged between the supports of the corners and the container corners.
- Longitudinal stiffeners are to stiffen the hatch cover plate in way of these supports and connect at least the nearest three transverse stiffeners.

2.2.7
The width of each bearing surface for hatch covers is to be at least 65 mm.

2.3 Hatch coamings

2.3.1
Coamings, stiffeners and brackets are to be capable of withstanding the local forces in way of the clamping devices and handling facilities necessary for securing and moving the hatch covers as well as those due to cargo stowed on the latter.

2.3.2
Special attention is to be paid to the strength of the fore transverse coaming of the forward hatch and to the scantlings of the closing devices of the hatch cover on this coaming.

2.3.3
Longitudinal coamings are to be extended at least to the lower edge of deck beams.

- Where they are not part of continuous deck girders, longitudinal coamings are to extend for at least two frame spaces beyond the end of the openings.
- Where longitudinal coamings are part of deck girders, their scantlings are to be as required in Ch 6.

2.3.4
A web frame or a similar structure is to be provided below the deck in line with the transverse coaming. Transverse coamings are to extend below the deck and to be connected with the web frames.

2.4 Small hatchways

2.4.1
The height of small hatchway coamings is to be not less than 600 mm if located in position 1, and 450 mm if located in position 2.

Where the closing appliances are in the form of hinged steel covers secured weathertight by gaskets and swing bolts, the height of the coamings may be reduced or the coamings may be omitted altogether.

2.4.2

Small hatch covers are to have strength equivalent to that required for main hatchways and are to be of steel, weathertight and generally hinged.

Securing arrangements and stiffening of hatch cover edges are to be such that weathertightness can be maintained in any sea condition.

At least one securing device is to be fitted at each side. Circular hole hinges are considered equivalent to securing devices.

2.4.3

Hold accesses located on the weather deck are to be provided with watertight metallic hatch covers, unless they are protected by a closed superstructure. The same applies to accesses located on the forecastle deck and leading directly to a dry cargo hold through a trunk.

2.4.4

Accesses to cofferdams and ballast tanks are to be manholes fitted with watertight covers fixed with bolts which are sufficiently closely spaced.

2.4.5

Hatchways of special design are considered by the Society on a case by case basis.

3. Width of attached plating

3.1 Ordinary stiffeners

3.1.1

The width of the attached plating to be considered for the check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where the attached plating extends on both sides of the stiffener:

  $b_P = s$

- where the attached plating extends on one side of the stiffener:

  $b_P = 0,5\ s$

3.2 Primary supporting members

3.2.1

The effective width of the attached plating to be considered for the yielding and buckling checks of primary supporting members analysed through isolated beam or grillage model is to be obtained, in m, from the following formulae:

- Where the plating extends on both sides of the primary supporting member:

  $b_p = b_{p,1} + b_{p,2}$

- Where the plating extends on one side of the primary supporting member:

  $b_p = b_{p,1}$

where:

$b_{p,1}$ = min (0,165 $_{p}$, $S_{p,1}$)

$b_{p,2}$ = min (0,165 $_{p}$, $S_{p,2}$)

$_{p}$: Span, in m, of the considered primary supporting member

$S_{p,1}$, $S_{p,2}$: Half distance, in m, between the considered primary supporting member and the adjacent ones, $S_{p,1}$ for one side, $S_{p,2}$ for the other side.

When a isolated beam or a grillage analysis is used, the ordinary stiffeners are not to be included in the attached flange area of the primary members.

4. Load model

4.1 Lateral pressures and concentrated loads

4.1.1 General

The lateral pressures and concentrated loads to be considered as acting on hatch covers are indicated in [4.1.2] to [4.1.6]. When two or more panels are connected by hinges, each individual panel is to be considered separately.

In any case, the sea pressures defined in [4.1.2] are to be considered for hatch covers located on exposed decks.

Additionally, when the hatch cover is intended to carry uniform cargoes, special cargoes or containers, the pressures and forces defined in [4.1.3] to [4.1.6] are to be considered independently from the sea pressures.

4.1.2 Sea pressures

The still water and wave lateral pressures are to be considered and are to be taken equal to:

- still water pressure: $p_S = 0$
- wave pressure p_W, as defined in Ch 4, Sec 5 [3.2].

4.1.3 Internal pressures due to liquid cargo or ballast tanks

If applicable, the still water and wave lateral pressures are to be considered and are defined in Ch 4, Sec 6.

4.1.4 Pressures due to uniform cargoes

If applicable, the still water and wave lateral pressures are to be considered and are defined in Ch 4, Sec 5

4.1.5 Pressures due to special cargoes

In the case of carriage on the hatch covers of special cargoes (e.g. pipes, etc.) which may temporarily retain water during navigation, the lateral pressure to be applied is considered by the Society on a case by case basis.

4.1.6 Forces due to containers

In the case of carriage of containers on the hatch covers, the concentrated forces under the containers corners are to be determined in accordance with the applicable requirements of the Society.

4.2 Load point

4.2.1 Wave lateral pressure for hatch covers on exposed decks

The wave lateral pressure to be considered as acting on each hatch cover is to be calculated at a point located:

- longitudinally, at the hatch cover mid-length
- transversely, on the longitudinal plane of symmetry of the ship

- vertically, at the top of the hatch coaming.

4.2.2 Lateral pressures other than the wave pressure

The lateral pressure is to be calculated:

- in way of the geometrical centre of gravity of the plate panel, for plating
- at mid-span, for ordinary stiffeners and primary supporting members.

5. Strength check

5.1 General

5.1.1 Application

The strength check is applicable to rectangular hatch covers subjected to a uniform pressure, designed with primary supporting members arranged in one direction or as a grillage of longitudinal and transverse primary supporting members.

In the latter case, the stresses in the primary supporting members are to be determined by a grillage or a finite element analysis.

It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in [5.4.4].

5.1.2 Hatch covers supporting containers

The scantlings of hatch covers supporting container stacks are to comply with the applicable provisions of the Society.

5.1.3 Hatch covers subjected to concentrated loads

For hatch covers supporting concentrated loads, ordinary stiffeners and primary supporting members are generally to be checked by direct calculations, taking into account the stiffener arrangements and their relative inertia. It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in [5.3.5].

5.1.4 Covers of small hatchways

The gross thickness of covers is to be not less than 8 mm. This thickness is to be increased or an efficient stiffening fitted to the Society's satisfaction where the greatest horizontal dimension of the cover exceeds 0,60 m.

5.2 Plating

5.2.1 Net thickness

The net thickness of steel hatch cover top plating, in mm, is to be not less than the value obtained from the following formula:

$$t = 15,8 F_p s \sqrt{\frac{p_s + p_W}{0,95 R_{eH}}}$$

where: .

F_p : Factor for combined membrane and bending response, equal to:

- $F_p = 1,50$ in general, for $\sigma < 0,8\,\sigma_a$, for the attached plating of primary supporting members
- $F_p = 1,90\,\sigma / \sigma_a$ for $\sigma \geq 0,8\,\sigma_a$, for the attached plating of primary supporting members

σ : Normal stress, in N/mm², in the attached plating of primary supporting members, calculated according to [5.4.3] or determined through a grillage analysis or a finite element analysis, as the case may be

5.2.2 Minimum net thickness

In addition to [5.2.1], the net thickness, in mm, of hatch cover plating is to be not less than the greater of the following values :

$t = 0.01\ s$

$t = 6$

5.2.3 Critical buckling stress check

The compressive stress σ in the hatch cover plating, induced by the bending of primary supporting members, either parallel or perpendicular to the direction of ordinary stiffeners, calculated according to [5.4.3] or determined through a grillage analysis or a finite element analysis, as the case may be, is to comply with the following formula:

$\sigma \leq 0.8\ \sigma_{CP}$

where σ_{CP} is the critical buckling stress defined in Ch 6, Sec 3.

In addition, the bi-axial compression stress in the hatch cover plating, when calculated by means of finite element analysis, is to comply with the requirements in Ch 6, Sec 3.

5.3 Ordinary stiffeners

5.3.1

For flat bar ordinary stiffeners, the ratio h_w / t_w is to comply with the following formula:

$$\frac{h_w}{t_w} \leq 15\sqrt{\frac{235}{R_{eH}}}$$

where:

h_w : Web height, in mm, of the ordinary stiffener

t_w : Net thickness, in mm, of the ordinary stiffener.

5.3.2 Minimum net thickness of web

The web net thickness of the ordinary stiffener, in mm, is to be not less than the minimum values given in [5.2.2].

5.3.3 Net section modulus and net shear sectional area

The net section modulus w, in cm³, and the net shear sectional area A_{sh}, in cm², of an ordinary stiffener subject to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \frac{(p_S + p_W) s l_s{}^2 10^3}{12\sigma_a}$$

$$A_{sh} = \frac{5(p_S + p_W) s l_s}{\tau_a}$$

where:

$_s$: Ordinary stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all ordinary stiffener spans, the ordinary stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the gross span, for each bracket.

5.3.4 Critical buckling stress check

The compressive stress σ in the top flange of ordinary stiffeners, induced by the bending of primary supporting members, parallel to the direction of ordinary stiffeners, calculated according to [5.4.3] or determined through a grillage analysis or a finite element analysis, as the case may be, is to comply with the following formula:

$$\sigma \le 0.8\,\sigma_{CS}$$

where σ_{CS} is the critical buckling stress defined in Ch 6, Sec 3.

5.4 Primary supporting members

5.4.1 Application

The requirements in [5.4.3] to [5.4.5] apply to primary supporting members which may be analysed through isolated beam models.

Primary supporting members whose arrangement is of a grillage type and which cannot be analysed through isolated beam models are to be checked by direct calculations, using the checking criteria in [5.4.4].

5.4.2 Minimum net thickness of web

The web net thickness of primary supporting members, in mm, is to be not less than the minimum values given in [5.2.2].

5.4.3 Normal and shear stress for isolated beam

In case that grillage analysis or finite element analysis are not carried out, according to the requirements in [5.1.1], the maximum normal stress σ and shear stress τ in the primary supporting members are to be obtained, in N/mm², from the following formulae:

$$\sigma = \frac{s(p_s + p_w) l_m^2 10^3}{mW}$$

$$\tau = \frac{5 s(p_s + p_w) l_m}{A_{sh}}$$

where:

$_m$: Span of the primary supporting member.

5.4.4 Checking criteria

The normal stress σ and the shear stress τ, calculated according to [5.4.3] or determined through a grillage analysis or finite element analysis, as the case may be, are to comply with the following formulae:

$$\sigma \le \sigma_a$$

$$\tau \le \tau_a$$

5.4.5 Deflection limit

The net moment of inertia of a primary supporting member is to be such that the deflection does not exceed μ_{max}, where:

μ : Coefficient taken equal to:

- 0,0056 for weathertight hatch covers
- 0,0044 for pontoon hatch covers

$_{max}$: Greatest span, in m, of primary supporting members.

5.4.6 Critical buckling stress check of the web panels of the primary supporting members.

The shear stress τ in the web panels of the primary supporting members, calculated according to [5.4.3] or determined through a grillage analysis or a finite element analysis, as the case may be, is to comply with the following formula:

$\tau \le 0.80\ \tau_c$

where:

τ_c : Critical shear buckling stress, defined in Ch 6, Sec 3.

For primary supporting members parallel to the direction of ordinary stiffeners, τ_c is to be calculated by considering the actual dimensions of the panels.

For primary supporting members perpendicular to the direction of ordinary stiffeners or for hatch covers built without ordinary stiffeners, a presumed square panel of dimension d is to be taken for the determination of the stress τ_c, where d is the smaller dimension, in m, of web panel of the primary supporting member. the In such a case, the average shear stress τ between the values calculated at the ends of this panel is to be considered.

5.4.7 Primary supporting members of variable cross-section

The net section modulus of primary supporting members with a variable cross-section is to be not less than the greater of the value obtained, in cm^3, from the following formulae:

$$w = w_{CS}$$

$$w = \left(1 + \frac{3{,}2\alpha - \psi - 0{,}8}{7\psi + 0{,}4}\right) w_{CS}$$

where:

w_{CS} : Net section modulus, in cm^3, for a constant cross-section, complying with the checking criteria in[5.4.4]

α : Coefficient taken equal to:

$$\alpha = \frac{_1}{_0}$$

ψ : Coefficient taken equal to:

$$\psi = \frac{w_1}{w_0}$$

$_1$: Length of the variable section part, in m (see Fig 1)

$_0$: Span measured, in m, between end supports (see Fig 1)

w_1 : Net section modulus at end, in cm^3 (see Fig 1)

w_0 : Net section modulus at mid-span, in cm^3 (see Fig 1).

Moreover, the net moment of inertia of primary supporting members with a variable cross-section is to be not less than the greater of the values obtained, in cm^4, from the following formulae:

$I = I_{CS}$

$$I = \left[1 + 8\alpha^3\left(\frac{1-\varphi}{0,2 + 3\sqrt{\varphi}}\right)\right]I_{CS}$$

where:

I_{CS} : Net moment of inertia with a constant cross-section, in cm^4, complying with [5.4.5]

φ : Coefficient taken equal to:

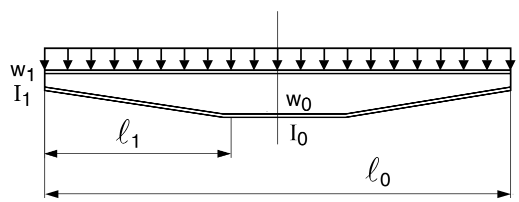
$$\varphi = \frac{I_1}{I_0}$$

I_1 : Net moment of inertia at end, in cm^4 (see Fig 1)

I_0 : Net moment of inertia at mid-span, in cm^4 (see Fig 1).

The use of these formulae is limited to the determination of the strength of primary supporting members in which abrupt changes in the cross-section do not occur along their length.

Figure 1: Variable cross-section stiffener



5.4.8

For buckling stiffeners on webs of primary supporting members, the ratio h_w / t_w is to comply with the following formula:

$$\frac{h_w}{t_w} \le 15\sqrt{\frac{235}{R_{eH}}}$$

where:

h_w : Web height, in mm, of the stiffener

t_w : Net thickness, in mm, of the stiffener.

6. Hatch coamings

6.1 Stiffening

6.1.1

The ordinary stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

6.1.2

Coamings are to be stiffened on their upper edges with a stiffener suitably shaped to fit the hatch cover closing appliances.

Moreover, when covers are fitted with tarpaulins, an angle or a bulb section is to be fitted all around coamings of more than 3 m in length or 600 mm in height; this stiffener is to be fitted at approximately 250 mm below the upper edge. The width of the horizontal flange of the angle is not to be less than 180 mm.

6.1.3

Where hatch covers are fitted with tarpaulins, coamings are to be strengthened by brackets or stays with a spacing not greater than 3 m.

Where the height of the coaming exceeds 900 mm, additional strengthening may be required.

However, reductions may be granted for transverse coamings in protected areas.

6.1.4

When two hatches are close to each other, underdeck stiffeners are to be fitted to connect the longitudinal coamings with a view to maintaining the continuity of their strength.

Similar stiffening is to be provided over 2 frame spacings at ends of hatches exceeding 9 frame spacings in length.

In some cases, the Society may require the continuity of coamings to be maintained above the deck.

6.1.5

Where watertight metallic hatch covers are fitted, other arrangements of equivalent strength may be adopted.

6.2 Load model

6.2.1

The lateral pressure p_c to be considered as acting on the hatch coamings are those specified in [6.2.2] and [6.2.3].

6.2.2

The wave lateral pressure p_{wc}, in kN/m^2, on the hatch coaming is to be taken equal to:

- $p_{wc} = 220$

6.2.3

For cargo holds intended for the carriage of liquid cargoes, the liquid internal pressures applied on hatch coaming is also to be determined according to Ch 4, Sec6.

6.3 Scantlings

6.3.1 Plating

The net thickness of the hatch coaming plate is to be not less than the greater value obtained, in mm, from the following formulae:

$$t = 15.98 s \sqrt{\frac{p_c}{0.95 R_{eH}}}$$

t = 9.5

6.3.2 Ordinary stiffeners

The net section modulus of the longitudinal or transverse ordinary stiffeners of hatch coamings is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 1.21 \frac{p_c s l^2 10^3}{m c_p R_{eH}}$$

where:

m : m = 16 in general

m = 12 for the end span of stiffeners sniped at the coaming corners

c_p : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with an attached plate breadth, in mm, equal to 40 t, where t is the plate net thickness.

c_p = 1,16 in the absence of more precise evaluation.

6.3.3 Coaming stays

The net section modulus w, in cm^3, and the net thickness t_w, in mm, of the coaming stays designed as beams with flange connected to the deck or sniped and fitted with a bracket (examples shown in Fig 2 and Fig 3) are to be not less than the values obtained from the following formulae:

$$w = \frac{s_c p_c H_c^2 10^3}{2\sigma_a}$$

$$t_w = \frac{s_c p_c H_c 10^3}{h\, \tau_a}$$

where:

H_c : Stay height, in m

s_c : Stay spacing, in m

h : Stay depth, in mm, at the connection with deck.

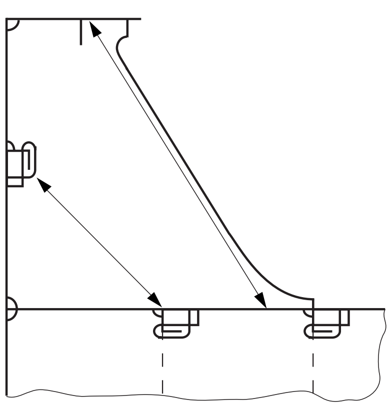


Figure 2: Coaming stay: example1

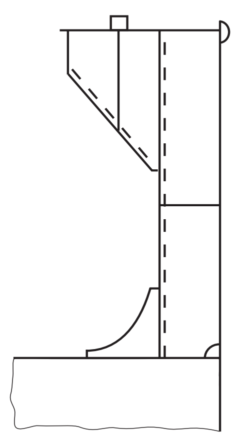


Figure 3: Coaming stay: example 2

For calculating the section modulus of coaming stays, their face plate area is to be taken into account only when it is welded with full penetration welds to the deck plating and adequate underdeck structure is fitted to support the stresses transmitted by it.

For other designs of coaming stays, such as, for example, those shown in Fig 4 and Fig 5, the stress levels determined through a grillage analysis or finite element analysis, as the case may be, apply and are to be checked at the highest stressed locations. The stress levels are to comply with the following formulae:

$\sigma \leq \sigma_a$

$\tau \leq \tau_a$

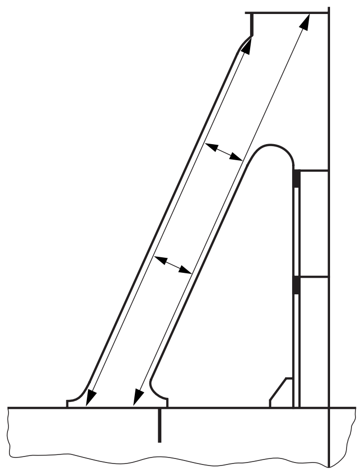


Figure 4: Coaming stay: example 3

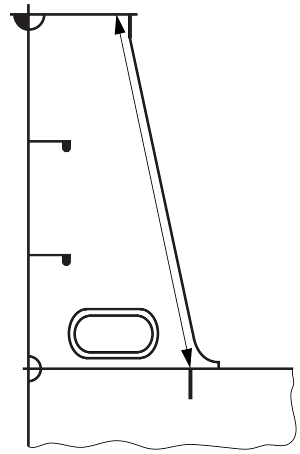


Figure 5: Coaming stay: example 4

6.3.4 Local details

The design of local details is to comply with the requirements in this section for the purpose of transferring the pressures on the hatch covers to the hatch coamings and, through them, to the deck structures below.

Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

The normal stress σ and the shear stress τ, in N/mm^2, induced in the underdeck structures by the loads transmitted by stays are to comply with the following formulae:

$\sigma \leq \sigma_a$

$\tau \leq \tau_a$

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the Society's requirements.

Double continuous fillet welding is to be adopted for the connections of stay webs with deck plating and the weld throat thickness is to be not less than 0,44 t_w, where t_w is the gross thickness of the stay web.

Toes of stay webs are to be connected to the deck plating with full penetration double bevel welds extending over a distance not less than 15% of the stay width.

6.3.5 Coamings of small hatchways

The coaming plate thickness is to be not less than the lesser of the following values:

- the thickness for the deck inside line of openings calculated for that position, assuming as spacing of stiffeners the lesser of the values of the height of the coaming and the distance between its stiffeners, if any, or
- 10 mm.

Coamings are to be suitably strengthened where their height exceeds 0,80 m or their greatest horizontal dimension exceeds 1,20 m, unless their shape ensures an adequate rigidity.

7. Weathertightness, closing arrangement, securing devices and stoppers

7.1 Weathertightness

7.1.1

Where the hatchway is exposed and closed with a single panel, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality.

Weathertightness may also be ensured means of tarpaulins.

7.1.2

The mean spacing of swing bolts or equivalent devices is, in general, to be not greater than:

- 2,0 m for dry cargo holds
- 1,5 m for ballast compartments
- 1,0 m for liquid cargo holds.

7.2 Gaskets

7.2.1

The weight of hatch covers and any cargo stowed thereon, together with inertia forces generated by ship motions, are to be transmitted to the ship's structure through steel to steel contact.

This may be achieved by continuous steel to steel contact of the hatch cover skirt plate with the ship's structure or by means of defined bearing pads.

7.2.2

The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements.

Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and to be made of a corrosion-resistant material.

7.2.3

The gasket and the securing arrangements are to maintain their efficiency when subjected to large relative movements between the hatch cover and the ship's structure or between hatch cover elements.

If necessary, suitable devices are to be fitted to limit such movements.

7.2.4

The gasket material is to be of a quality suitable for all environmental conditions likely to be encountered by the ship, and is to be compatible with the cargoes transported.

The material and form of gasket selected are to be considered in conjunction with the type of hatch cover, the securing arrangement and the expected relative movement between the hatch cover and the ship's structure.

The gasket is to be effectively secured to the hatch cover.

7.2.5

Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

7.2.6

Metallic contact is required for an earthing connection between the hatch cover and the hull structures. If necessary, this is to be achieved by means of a special connection for the purpose.

7.3 Closing arrangement, securing devices and stoppers

7.3.1 General

Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements.

The securing and stop arrangements are to be fitted using appropriate means which cannot be easily removed.

In addition to the requirements above, all hatch covers, and in particular those carrying deck cargo, are to be effectively secured against horizontal shifting due to the horizontal forces resulting from ship motions.

Towards the ends of the ship, vertical acceleration forces may exceed the gravity force. The resulting lifting forces are to be considered when dimensioning the securing devices according to [7.3.5] to [7.3.7]. Lifting forces from cargo secured on the hatch cover during rolling are also to be taken into account.

Hatch coamings and supporting structure are to be adequately stiffened to accommodate the loading from hatch covers.

Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height (see [2.1]) are considered by the Society on a case by case basis.

In the case of hatch covers carrying containers, the scantlings of the closing devices are to take into account the possible upward vertical forces transmitted by the containers.

7.3.2 Arrangements

The securing and stopping devices are to be arranged so as to ensure sufficient compression on gaskets between hatch covers and coamings and between adjacent hatch covers.

Arrangement and spacing are to be determined with due attention to the effectiveness for weathertightness, depending on the type and the size of the hatch cover, as well as on the stiffness of the hatch cover edges between the securing devices.

At cross-joints of multipanel covers, (male/female) vertical guides are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.

The location of stoppers is to be compatible with the relative movements between hatch covers and the ship's structure in order to prevent damage to them. The number of stoppers is to be as small as possible.

7.3.3 Spacing

The spacing of the securing arrangements is to be generally not greater than 6 m.

7.3.4 Construction

Securing arrangements with reduced scantlings may be accepted provided it can be demonstrated that the possibility of water reaching the deck is negligible.

Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or hatch covers.

Individual securing devices on each hatch cover are to have approximately the same stiffness characteristics.

7.3.5 Area of securing devices

The net cross area of each securing device is to be not less than the value obtained, in cm^2, from the following formula:

$$A = 1{,}4 S_S \left(\frac{235}{R_{eH}} \right)^{\alpha}$$

where:

S_S : Spacing, in m, of securing devices

α : Coefficient taken equal to:

- 0,75 for $R_{eH} > 235$ N/mm^2
- 1,00 for $R_{eH} \le 235$ N/mm^2.

In the above calculations, R_{eH} may not be taken greater than 0,7 R_m.

Between hatch cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by securing devices. For packing line pressures exceeding 5 N/mm, the net cross area A is to be increased in direct proportion. The packing line pressure is to be specified.

In the case of securing arrangements which are particularly stressed due to the unusual width of the hatchway, the net cross area A of the above securing arrangements is to be determined through direct calculations.

7.3.6 Inertia of edges elements

The hatch cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices.

The moment of inertia of edge elements is to be not less than the value obtained, in cm^4, from the following formula:

$$I = 6\, p_L\, S_S^4$$

where:

p_L : Packing line pressure, in N/mm, to be taken not less than 5 N/mm

S_S : Spacing, in m, of securing devices.

7.3.7 Diameter of rods or bolts

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

7.3.8 Stoppers

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.

Hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

The equivalent stress in stoppers, their supporting structures and calculated in the throat of the stopper welds is to be equal to or less than the allowable value, equal to 0,8 R_{eH}.

7.4 Tarpaulins

7.4.1

Where weathertightness of hatch covers is ensured by means of tarpaulins, at least two layers of tarpaulins are to be fitted.

Tarpaulins are to be free from jute and waterproof and are to have adequate characteristics of strength and resistance to atmospheric agents and high and low temperatures.

The mass per unit surface of tarpaulins made of vegetable fibres, before the waterproofing treatment, is to be not less than:

- 0,65 kg/m^2 for waterproofing by tarring
- 0,60 kg/m^2 for waterproofing by chemical dressing
- 0,55 kg/m^2 for waterproofing by dressing with black oil.

In addition to tarpaulins made of vegetable fibres, those of synthetic fabrics or plastic laminates may be accepted by the Society provided their qualities, as regards strength, waterproofing and resistance to high and low temperatures, are equivalent to those of tarpaulins made of vegetable fibres.

7.5 Cleats

7.5.1

The arrangements for securing the tarpaulins to hatch coamings are to incorporate cleats of a suitable pattern giving support to battens and wedges and with edges rounded so as to minimise damage to the wedges.

7.5.2

Cleats are to be spaced not more than 600 mm from centre to centre and are to be not more than 150 mm from the hatch corners.

7.5.3

The thickness of cleats is to be not less than 9,5 mm for angle cleats and 11 mm for forged cleats.

7.5.4

Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

7.5.5

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.

7.6 Wedges, battens and locking bars

7.6.1 Wedges

Wedges are to be of tough wood, generally not more than 200 mm in length and 50 mm in width.

They are generally to be tapered not more than 1 in 6 and their thickness is to be not less than 13 mm.

7.6.2 Battens and locking bars

For all hatchways in exposed positions, battens or transverse bars in steel or other equivalent means are to be provided in order to efficiently secure the portable covers after the tarpaulins are battened down.

Portable covers of more than 1,5 m in length are to be secured by at least two such securing appliances.

8. Drainage

8.1 Arrangement

8.1.1

Drainage is to be arranged inside the line of gaskets by means of a gutter bar or vertical extension of the hatch side and end coaming.

8.1.2

Drain openings are to be arranged at the ends of drain channels and are to be provided with efficient means for preventing ingress of water from outside, such as non-return valves or equivalent.

8.1.3

Cross-joints of multi-panel hatch covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

8.1.4

If a continuous outer steel contact is arranged between the cover and the ship’s structure, drainage from the space between the steel contact and the gasket is also to be provided.

9. Small hatches fitted on the exposed fore deck

9.1 Application

9.1.1

The requirements in [9] apply to steel covers of small hatches fitted on the exposed fore deck over the forward 0,25 L, 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.

Small hatches are hatches designed for access to spaces below the deck and are capable to be closed weather-tight or watertight, as applicable. Their opening is generally equal to or less than 2,5 m^2.

9.1.2

Small hatches designed for use of emergency escape are to comply with the requirements in [9] with exception of the requirements in [9.4.1] a) and b), [9.4.3] and [9.5.1].

9.2 Strength

9.2.1

For small rectangular steel hatch covers, the gross plate thickness, stiffener arrangement and scantlings are to be not less than those obtained, in mm, from Tab 3 and Fig 6.

Ordinary stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in [9.3.1] (see also Fig 6).

Primary stiffeners are to be continuous.

All stiffeners are to be welded to the inner edge stiffener (see Fig 7).

9.2.2

The upper edge of the hatchway coamings is to be suitably reinforced by a horizontal section, generally not more than 170 to 190 mm from the upper edge of the coamings.

9.2.3

For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement are to comply with [5.1].

9.2.4

For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

9.3 Weathertightness

9.3.1

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 6 and a sufficient capacity to withstand the bearing force.

Table 3: Gross scantlings for small steel hatch covers on the fore deck

Nominal size (mm x mm)	Cover plate thickness (mm)	Primary stiffeners	Secondary stiffeners
		Flat bar (mm x mm); number	
630 x 630	8	–	–
630 x 830	8	100 x 8 ; 1	–
830 x 630	8	100 x 8 ; 1	–
830 x 830	8	100 x 10 ; 1	–
1030 x 1030	8	120 x 12 ; 1	80 x 8 ; 2
1330 x 1330	8	150 x 12 ; 2	100 x 10 ; 2

9.4 Primary securing devices

9.4.1

Small hatches located on exposed fore deck are to be fitted with primary securing devices such their hatch covers can be secured in place and weather-tight by means of a mechanism employing any one of the following methods:

a) Butterfly nuts tightening onto forks (clamps)

b) Quick acting cleats

c) Central locking device

Dogs (twist tightening handles) with wedges are not acceptable.

9.4.2

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.

9.4.3

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 to be not less than 16 mm. An example arrangement is shown in Fig 7.

9.4.4

For small hatch covers located on the exposed deck forward of the fore-most cargo hatch, the hinges are to be fitted such that the predominant direction of green seas will cause the cover to close, which means that the hinges are normally to be located on the fore edge.

9.4.5

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.

9.5 Secondary securing devices

9.5.1

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.

Figure 6: Arrangement of stiffeners

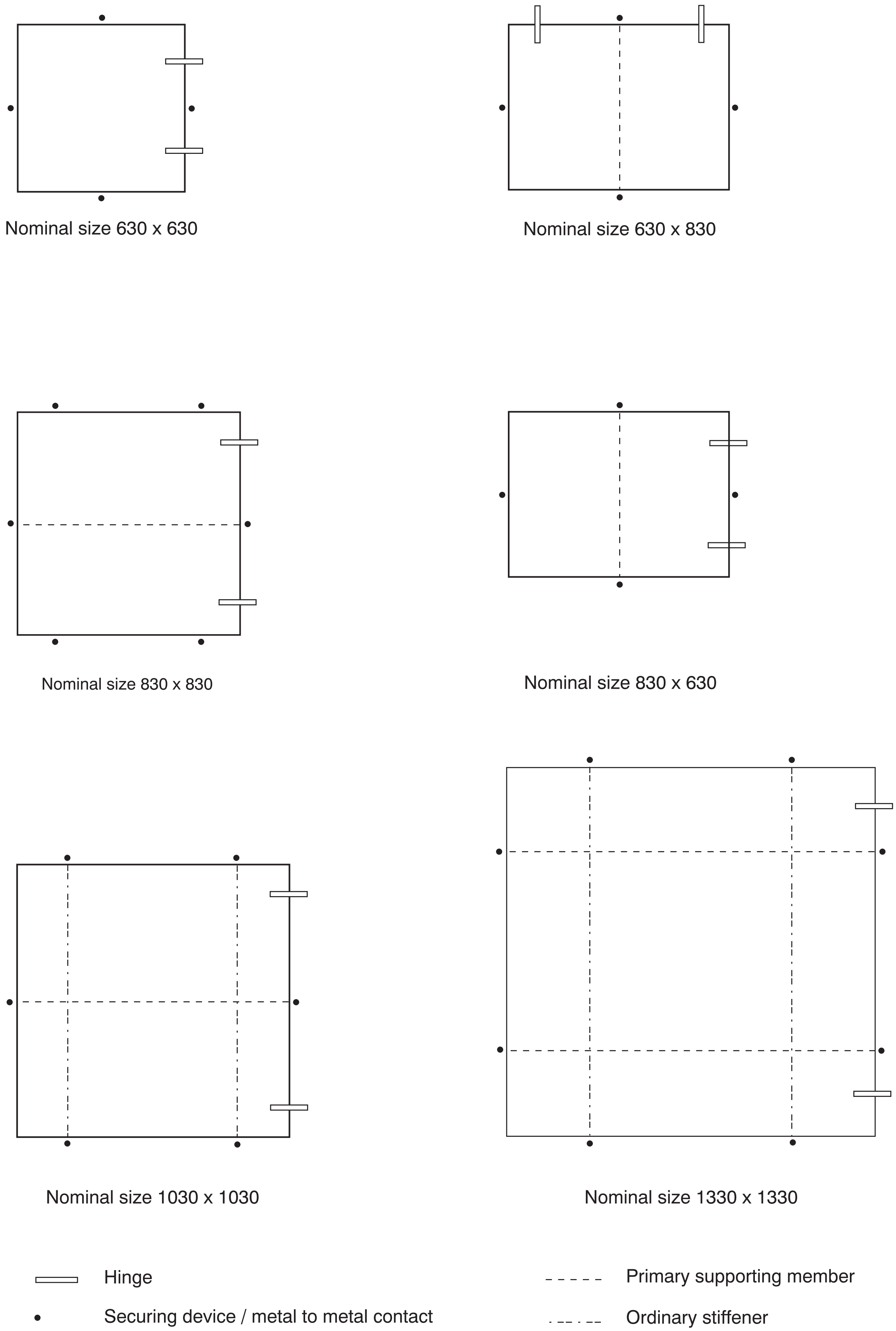
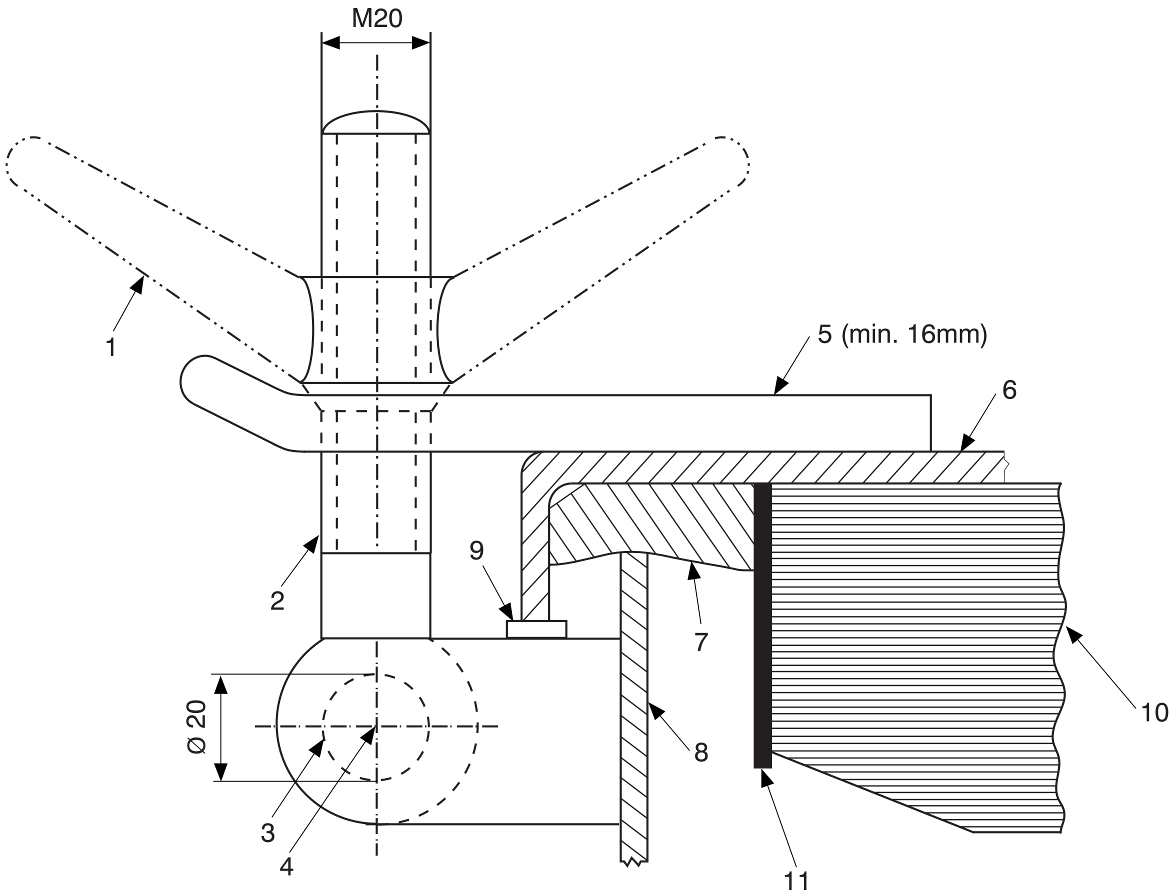


Figure 7: Example of a primary securing method



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.

Section 6 - Arrangement of Hull and Superstructure Openings

1. General

1.1 Application

1.1.1

The requirements of this Section apply to the arrangement of hull and superstructure openings excluding hatchways, for which the requirements in Ch 9, Sec 5 apply.

1.2 Definitions

1.2.1 Standard height of superstructure

The standard height of superstructure is that defined in Ch 1, Sec 4.

1.2.2 Standard sheer

The standard sheer is that defined according to regulation 38 of the International Load Line Convention 1966, as amended.

1.2.3 Exposed zones

Exposed zones are the boundaries of superstructures or deckhouses set in from the ship's side at a distance equal to or less than 0,04 B.

1.2.4 Unexposed zones

Unexposed zones are the boundaries of deckhouses set in from the ship's side at a distance greater than 0,04 B.

2. External openings

2.1 General

2.1.1

All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, are required to be watertight.

2.1.2

External openings required to be watertight in accordance with [2.1.1] are to be of sufficient strength and, except for cargo hatch covers, are to be fitted with indicators on the bridge.

2.1.3

No openings, be they permanent openings or temporary openings such as shell doors, windows or ports, are allowed on the side shell between the embarkation station of the marine evacuation system and the waterline in the lightest seagoing condition. Windows and side scuttles of the non-opening type are allowed if the Society's applicable criteria for fire integrity are complied with.

2.1.4
Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of internal openings are to be provided with a notice affixed to each appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

3. Side scuttles, windows and skylights

3.1 General

3.1.1 Application
The requirements in [3.1] to [3.4] apply to side scuttles and rectangular windows providing light and air, located in positions which are exposed to the action of sea and/or bad weather.

3.1.2 Side scuttle definition
Side scuttles are round or oval openings with an area not exceeding 0,16 m^2. Round or oval openings having areas exceeding 0,16 m^2 are to be treated as windows.

3.1.3 Window definition
Windows are rectangular openings generally, having a radius at each corner relative to the window size in accordance with recognised national or international standards, and round or oval openings with an area exceeding 0,16 m^2.

3.1.4 Number of openings in the shell plating
The number of openings in the shell plating are to be reduced to the minimum compatible with the design and proper working of the ship.

3.1.5 Material and scantlings
Side scuttles and windows together with their glasses, deadlights and storm covers, if fitted, are to be of approved design and substantial construction in accordance with, or equivalent to, recognised national or international standards.

Non-metallic frames are not acceptable. The use of ordinary cast iron is prohibited for side scuttles below the freeboard deck.

3.1.6 Means of closing and opening
The arrangement and efficiency of the means for closing any opening in the shell plating are to be consistent with its intended purpose and the position in which it is fitted is to be generally to the satisfaction of the Society.

3.1.7 Opening of side scuttles
All side scuttles, the sills of which are below the freeboard deck, are to be of such construction as to prevent effectively any person opening them without the consent of the Master of the ship.

3.2 Opening arrangement

3.2.1 General

Side scuttles are not be 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 0,025B or 0,5 m, whichever is the greater distance, above the summer load waterline (or timber summer load waterline if assigned).

3.2.2 Side scuttles below (1,4 + 0,025 B) m above the water

Where in ‘tweendecks the sills of any of the side scuttles are below a line drawn parallel to the freeboard deck at side and having its lowest point 1,4+0,025B m above the water when the ship departs from any port, all the sidescuttles in that ‘tweendecks are to be closed watertight and locked before the ship leaves port, and they may not be opened before the ship arrives at the next port. In the application of this requirement, the appropriate allowance for fresh water may be made when applicable.

For any ship that has one or more side scuttles so placed that the above requirements apply when it is floating at its deepest subdivision load line, the Society may indicate the limiting mean draught at which these side scuttles are to have their sills above the line drawn parallel to the freeboard deck at side, and having its lowest point 1,4+0,025B above the waterline corresponding to the limiting mean draught, and at which it is therefore permissible to depart from port without previously closing and locking them and to open them at sea under the responsibility of the Master during the voyage to the next port. In tropical zones as defined in the International Convention on Load Lines in force, this limiting draught may be increased by 0,3 m.

3.2.3 Cargo spaces

No side scuttles may be fitted in any spaces which are appropriated exclusively for the carriage of cargo or coal.

Side scuttles may, however, be fitted in spaces appropriated alternatively for the carriage of cargo or passengers, but they are to be of such construction as to prevent effectively any person opening them or their deadlights without the consent of the Master.

If cargo is carried in such spaces, the side scuttles and their deadlights are to be closed watertight and locked before the cargo is shipped. The Society, at its discretion, may prescribe that the time of closing and locking is to be recorded in a log book.

3.2.4 Non-opening type side scuttles

Side scuttles are to be of the non-opening type in the following cases:

- where they become immersed by any intermediate stage of flooding or the final equilibrium waterline in any required damage case for ships subject to damage stability regulations
- where they are fitted outside the space considered flooded and are below the final waterline for those ships where the freeboard is reduced on account of subdivision characteristics.

3.2.5 Manholes and flush scuttles

Manholes and flush scuttles in positions 1 or 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

3.2.6 Automatic ventilating scuttles

Automatic ventilating side scuttles, fitted in the shell plating below the freeboard deck, are considered by the Society on a case by case basis.

3.2.7 Window arrangement

Windows are not to be fitted below the freeboard deck, in first tier end bulkheads or sides of enclosed superstructures and in first tier deckhouses considered buoyant in the stability calculations or protecting openings leading below.

In the front bulkhead of a superstructure situated on the upper deck, in the case of substantially increased freeboard, rectangular windows with permanently fitted storm covers are acceptable.

3.2.8 Skylights

Fixed or opening skylights are to have glass thickness appropriate to their size and position as required for side scuttles and windows. Skylight glasses in any position are to be protected from mechanical damage and, where fitted in positions 1 or 2, to be provided with permanently attached robust deadlights or storm covers.

3.2.9 Gangway, cargo and coaling ports

Gangway, cargo and coaling ports fitted below the freeboard deck are to be of sufficient strength. They are to be effectively closed and secured watertight before the ship leaves port, and to be kept closed during navigation

Such ports are in no case to be so fitted as to have their lowest point below the deepest subdivision load line.

3.3 Glasses

3.3.1 General

In general, toughened glasses with frames of special type are to be used in compliance with, or equivalent to, recognised national or international standards. The use of clear plate glasses is considered by the Society on a case by case basis.

3.3.2 Design loads

The design load is to be determined in accordance with the applicable requirements of Ch 9, Sec 4.

3.3.3 Materials

Toughened glasses are to be in accordance with ISO 1095 for side scuttles and ISO 3254 for windows.

3.3.4 Thickness of toughened glasses in side scuttles

The thickness of toughened glasses in side scuttles is to be not less than that obtained, in mm, from the following formula:

$$t = \frac{d}{358}\sqrt{p}$$

where:

d : Side scuttle diameter, in mm

p : Lateral pressure, in kN/m^2, defined in [3.3.2].

3.3.5 Thickness of toughened glasses in rectangular windows

The thickness of toughened glasses in rectangular windows is to be not less than that obtained, in mm, from the following formula:

$$t = \frac{b}{200}\sqrt{\beta p}$$

where:

p : Lateral pressure, in kN/m², defined in [3.3.2].

β : Coefficient defined in Tab 1. β may be obtained by linear interpolation for intermediate values of a/b

a : Length, in mm, of the longer side of the window

b : Length, in mm, of the shorter side of the window.

Table 1: Coefficient β

a/b	β
1,0	0,284
1,5	0,475
2,0	0,608
2,5	0,684
3,0	0,716
3,5	0,734
≥ 4,0	0,750

The Society may require both limitations on the size of rectangular windows and the use of glasses of increased thickness in way of front bulkheads which are particularly exposed to heavy sea.

3.4 Deadlight arrangement

3.4.1 General

Side scuttles to the following spaces are to be fitted with hinged inside deadlights:

- spaces below freeboard deck
- spaces within the first tier of enclosed superstructures
- first tier deckhouses on the freeboard deck protecting openings leading below or considered buoyant in stability calculations.

3.4.2 Watertight deadlights

Efficient, hinged inside deadlights so arranged that they can be easily and effectively closed and secured watertight, are to be fitted to all side scuttles except that abaft one eighth of the ship's length from the forward perpendicular and above a line drawn parallel to the freeboard deck at side and having its lowest point at a height of (3,7+0,025B) m above the deepest subdivision load line. The deadlights may be portable in passenger accommodation other than that for steerage passengers, unless the deadlights are required by the International Convention on Load Lines in force to be permanently attached in their proper positions. Such portable deadlights are to be stowed adjacent to the side scuttles they serve.

3.4.3 Openings at the side shell in the second tier

Side scuttles and windows at the side shell in the second tier are to be provided with efficient, 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,.

3.4.4 Openings set inboard in the second tier

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 [3.4.2], are to be provided with either hinged inside deadlights or, where they are accessible, permanently attached external storm covers of approved design and substantial construction capable of being closed and secured weathertight.

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.

Note 1: Deadlights in accordance with recognised standards are fitted to the inside of windows and side scuttles, while storm covers of comparable specifications to deadlights are fitted to the outside of windows, where accessible, and may be hinged or portable.

3.4.5 Deckhouses on superstructures of less than standard height

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 the height of the raised quarterdeck or superstructure is equal to or greater than the standard quarter deck height.

3.4.6 Openings protected by a deckhouse

Where an opening in a superstructure deck or in the top of a deckhouse on the freeboard deck which gives access to a space below the freeboard deck or to a space within an enclosed superstructure is protected by a deckhouse, then it is considered that only those side scuttles fitted in spaces which give direct access to an open stairway need to be fitted with deadlights.

4. Discharges

4.1 Arrangement of discharges

4.1.1 Inlets and discharges

All inlets and discharges in the shell plating are to be fitted with efficient and accessible arrangements for preventing the accidental admission of water into the ship.

4.1.2 Inboard opening of ash-shoot, rubbish-shoot, etc.

The inboard opening of each ash-shoot, rubbish-shoot, etc. is to be fitted with an efficient cover.

If the inboard opening is situated below the freeboard deck, the cover is to be watertight, and in addition an automatic non-return valve is to be fitted in the shoot in an easily accessible position above the deepest subdivision load line. When the shoot is not in use, both the cover and the valve are to be kept closed and secured.

4.2 Arrangement of garbage chutes

4.2.1 Inboard end above the waterline

The inboard end is to be located above the waterline formed by an 8,5° heel, to port or starboard, at a draft corresponding to the assigned summer freeboard, but not less than 1000 mm above the summer load waterline.

Where the inboard end of the garbage chute exceeds 0,01L above the summer load waterline, valve control from the freeboard deck is not required, provided the inboard gate valve is always accessible under service conditions.

4.2.2 Inboard end below the waterline

Where the inboard end of a garbage chute is below the waterline corresponding to the deepest draught after damage in a ship of more than 100 m in length, then:

- the inboard end hinged cover/valve is to be watertight
- the valve is to be a screw-down non-return valve fitted in an easily accessible position above the deepest subdivision load line
- the screw-down non-return valve is to be controlled from a position above the freeboard deck and provided with open/shut indicators. The valve control is to be clearly marked: «Keep closed when not in use».

4.2.3 Gate valves

For garbage chutes, two gate valves controlled from the working deck of the chute may be accepted instead of a non-return valve with a positive means of closing it from a position above the freeboard deck. In addition, the lower gate valve is to be controlled from a position above the freeboard deck. An interlock system between the two valves is to be arranged.

The distance between the two gate valves is to be adequate to allow the smooth operation of the interlock system.

4.2.4 Hinged cover and discharge flap

The upper and lower gate valves, as required in [4.2.3], may be replaced by a hinged weathertight cover at the inboard end of the chute together with a discharge flap.

The cover and discharge flap are to be arranged with an interlock so that the flap cannot be operated until the hopper cover is closed.

4.2.5 Marking of valve and hinged cover

The controls for the gate valves and/or hinged covers are to be clearly marked: «Keep closed when not in use».

4.3 Scantlings of garbage chutes

4.3.1 Material

The chute is to be constructed of steel. Other equivalent materials are considered by the Society on a case by case basis.

4.3.2 Wall thickness

The wall thickness of the chute up to and including the cover is to be not less than that obtained, in mm, from Tab 2.

Table 2: Wall thickness of garbage chutes

External diameter d, in mm	Thickness, in mm
$d \le 80$	7,0
$80 < d < 180$	7,0 + 0,03 (d – 80)
$180 \le d \le 220$	10,0 + 0,063 (d – 180)

5. Freeing ports

5.1 General provisions

5.1.1 General

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.

A well is any area on the deck exposed to the weather, where water may be entrapped. Wells are considered to be deck areas bounded on four sides by deck structures; however, depending on their configuration, deck areas bounded on three or even two sides by deck structures may be deemed wells.

5.1.2 Freeing port areas

The minimum required freeing port areas in bulwarks on the freeboard deck are specified in Tab 3.

Table 3: Freeing port area in bulwark located on freeboard deck

Ship types or ship particulars	Area A of freeing ports, in m^2	Applicable requirement
Type B-100	0,33 $_B$ h_B	[5.5.2]
Type B-60	0,25 $_B$ h_B	[5.5.1]
Ships fitted with a trunk included in freeboard calculation and/ or breadth ≥ 0,6B	0,33 $_B$ h_B	[5.3.1]
Ships fitted with a trunk not included in freeboard calculation and/or continuous or substantially continuous hatch coamings	A_2	[5.3.1]
Ships fitted with non-continuous trunk and/ or hatch coamings	A_3	[5.3.2]
Ships fitted with open superstructure	A_S for superstructures A_W for wells	[5.4.2] [5.4.3]
Other ships	A_1	[5.2.1]

Note 1:

$_B$: Length, in m, of bulwark in a well at one side of the ship

h_B : Mean height, in m, of bulwark in a well of length $_B$.

5.1.3 Freeing port arrangement

Where a sheer is provided, two thirds of the freeing port area required is to be provided in the half of the well nearer the lowest point of the sheer curve.

Where the exposed freeboard deck or an exposed superstructure deck has little or no sheer, the freeing port area is to be spread along the length of the well.

However, bulwarks may not have substantial openings or accesses near the breaks of superstructures, unless they are effectively detached from the superstructure sides.

5.1.4 Freeing port positioning

The lower edge of freeing ports is to be as near the deck as practicable, at not more than 100 mm above the deck. All the openings in the bulwark are to be protected by rails or bars spaced approximately 230 mm apart.

5.1.5 Freeing port closures

If shutters or closures are fitted to freeing ports, ample clearance is to be provided to prevent jamming. Hinges are to have pins or bearings of non-corrodible material. If shutters are fitted with securing appliances, these appliances are to be of approved construction.

5.1.6 Gutter bars

Gutter bars greater than 300 mm in height fitted around the weather decks of tankers, in way of cargo manifolds and cargo piping, are to be treated as bulwarks. The freeing port area is to be calculated in accordance with the applicable requirements of this Section.

5.2 Freeing port area in a well not adjacent to a trunk or hatchways

5.2.1 Freeing port area

Where the sheer in way of the well is standard or greater than the standard, the freeing port area on each side of the ship for each well is to be not less than that obtained, in m^2, in Tab 4.

Table 4: Freeing port area in a well not adjacent to a trunk or hatchways

Location	Area A_1 of freeing ports, in m^2	
	$_B \le 20$	$_B > 20$
Freeboard deck and raised quarterdecks	$0{,}7 + 0{,}035\ _B + A_C$	$0{,}07\ _B + A_C$
Superstructure decks	$0{,}35 + 0{,}0175\ _B + 0{,}5\ A_C$	$0{,}035\ _B + 0{,}5\ A_C$

Note 1:

$_B$: Length, in m, of bulwark in the well, to be taken not greater than 0,7 L_{LL}

A_C : Area, in m^2, to be taken, with its sign, equal to:

$$A_C = \frac{l_B}{25}(h_B - 1{,}2) \quad \text{for } h_B > 1{,}2$$
$$A_C = 0 \quad \text{for } 0{,}9 \le h_B \le 1{,}2$$
$$A_C = \frac{l_B}{25}(h_B - 0{,}9) \quad \text{for } h_B < 0{,}9$$

h_B : Mean height, in m, of the bulwark in a well of length $_B$.

In ships with no sheer, the above area is to be increased by 50%. Where the sheer is less than the standard, the percentage of increase is to be obtained by linear interpolation.

5.2.2 Minimum freeing port area for a deckhouse having breadth not less than 0,8 B

Where a flush deck ship is fitted amidships with a deckhouse having breadth not less than 0,8 B and the width of the passageways along the side of the ship less than 1,5 m, the freeing port area is to be calculated for two separate wells, before and abaft the deckhouse. For each of these wells, the freeing port area is to be obtained from Tab 4, where $_{B}$ is to be taken equal to the actual length of the well considered (in this case the limitation $_{B} \leq 0,7\ L_{LL}$ may not be applied).

5.2.3 Minimum freeing port area for screen bulkhead

Where a screen bulkhead is fitted across the full breadth of the ship at the fore end of a midship deckhouse, the weather deck is to be considered as divided into two wells, irrespective of the width of the deckhouse, and the freeing port area is to be obtained in accordance with [5.1.2].

5.3 Freeing port area in a well contiguous to a trunk or hatchways

5.3.1 Freeing area for continuous trunk or continuous hatchway coaming

Where the ship is fitted with a continuous trunk not included in the calculation of freeboard or where continuous or substantially continuous hatchway side coamings are fitted between detached superstructures, the freeing port area is to be not less than that obtained, in m², from Tab 5.

Table 5: Freeing port area in a well contiguous to a continuous trunk or hatchway

Breadth B_H, in m, of hatchway or trunk	Area A_2 of freeing ports, in m²
$B_H \leq 0,4\ B$	$0,2\ _{B}\ h_B$
$0,4\ B < B_H < 0,75\ B$	$\left[0,2 - 0,286\left(\frac{B_H}{B} - 0,4\right)\right] l_B h_B$
$B_H \geq 0,75\ B$	$0,1\ _{B}\ h_B$
Note 1:	
$_{B}$: Length, in m, of bulwark in a well at one side of the ship	
h_B : Mean height, in m, of bulwark in a well of length $_{B}$.	

Where the ship is fitted with a continuous trunk having breadth not less than 0,6 B, included in the calculation of freeboard, and where open rails on the weather parts of the freeboard deck in way of the trunk for at least half the length of these exposed parts are not fitted, the freeing port area in the well contiguous to the trunk is to be not less than 33% of the total area of the bulwarks.

5.3.2 Freeing area for non-continuous trunk or hatchway coaming

Where the free flow of water across the deck of the ship is impeded due to the presence of a non-continuous trunk, hatchway coaming or deckhouse in the whole length of the well considered, the freeing port area in the bulwark of this well is to be not less than that obtained, in m², from Tab 6.

Table 6: Freeing port area in a well contiguous to a non-continuous trunk or hatchway

Free flow area f_P, in m²	Freeing port area A_3, in m²
$f_P \leq A_1$	A_2
$A_1 < f_P < A_2$	$A_1 + A_2 - f_P$
$f_P \geq A_2$	A_1

Note 1:

f_P : Free flow area on deck, equal to the net area of gaps between hatchways, and between hatchways and superstructures and deckhouses up to the actual height of the bulwark

A_1 : Area of freeing ports, in m², to be obtained from Tab 4

A_2 : Area of freeing ports, in m², to be obtained from Tab 5.

5.4 Freeing port area in an open space within superstructures

5.4.1 General

In ships having superstructures on the freeboard 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.

5.4.2 Freeing port area for open superstructures

The freeing port area on each side of the ship for the open superstructure is to be not less than that obtained, in m², from the following formula:

$$A_S = A_1 c_{SH}\left[1-\left(\frac{l_W}{l_T}\right)^2\right]\left(\frac{b_0 h_S}{2 l_T h_W}\right)$$

where:

l_T : Total well length, in m, to be taken equal to:

$$l_T = l_W + l_S$$

l_W : Length, in m, of the open deck enclosed by bulwarks

l_S : Length, in m, of the common space within the open superstructures

A_1 : Freeing port area, in m², required for an open well of length l_T, in accordance with Tab 4, where A_C is to be taken equal to zero

c_{SH} : Coefficient which accounts for the absence of sheer, if applicable, to be taken equal to:

- c_{SH} = 1,0 in the case of standard sheer or sheer greater than standard sheer
- c_{SH} = 1,5 in the case of no sheer

b_0 : Breadth, in m, of the openings in the end bulkhead of enclosed superstructures

h_S : Standard superstructure height, in m, defined in [1.2.1]

h_W : Distance, in m, of the well deck above the freeboard deck.

5.4.3 Freeing port area for open well

The freeing port area on each side of the ship for the open well is to be not less than that obtained, in m², from the following formula:

$$A_W = A_1 c_{SH}\left(\frac{h_S}{2 h_W}\right)$$

A_1 : Freeing port area, in m², required for an open well of length l_W, in accordance with Tab 4

c_{SH}, h_S, h_W, l_W: Defined in [5.4.2].

The resulting freeing port areas for the open superstructure A_S and for the open well A_W are to be provided along each side of the open space covered by the open superstructure and each side of the open well, respectively.

5.5 Freeing port area in bulwarks of the freeboard deck for ships of types A, B-100 and B-60

5.5.1 Freeing arrangement for type B-60

For type B-60 ships, the freeing port area in the lower part of the bulwarks of the freeboard deck is to be not less than 25% of the total area of the bulwarks in the well considered.

The upper edge of the sheer strake is to be kept as low as possible.

5.5.2 Freeing arrangement for type A and type B-100 ships with trunks

For type A and type B-100 ships, open rails are to be fitted on the weather parts of the freeboard deck in way of the trunk for at least half the length of these exposed parts.

Alternatively, if a continuous bulwark is fitted, the freeing port area in the lower part of the bulwarks of the freeboard deck is to be not less than 33% of the total area of the bulwarks in the well considered.

6. Machinery space openings

6.1 Engine room skylights

6.1.1

Engine room skylights in positions 1 or 2 are to be properly framed, securely attached to the deck and efficiently enclosed by steel casings of suitable strength. Where the casings are not protected by other structures, their strength will be considered by the Society on a case by case basis.

6.2 Closing devices

6.2.1 Machinery casings

Openings in machinery space casings in positions 1 or 2 are to be fitted with doors of steel or other equivalent materials, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and weathertight when closed. The doors are to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

Other openings in such casings are to be fitted with equivalent covers, permanently attached in their proper position.

6.2.2 Height of the sill of the door

The height of the sill of the door is to be not less than:

- 600 mm above the deck if in position 1
- 380 mm above the deck if in position 2
- 230 mm in all other cases.

6.2.3 Double doors

Where casings are not protected by other structures, double doors (i.e. inner and outer doors) are required for ships assigned freeboard less than that based on Table B of regulation 28 of the International Load Line

Convention 1966, as amended. An inner sill of 230 mm in conjunction with the outer sill of 600 mm is to be provided.

6.2.4 Fiddly openings

Fiddly openings are to be fitted with strong covers of steel or other equivalent material permanently attached in their proper positions and capable of being secured weathertight.

6.3 Coamings

6.3.1

Coamings of any fiddly, 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 and, on demand, the emergency generator room are to have coamings whose height is in compliance with [8.1.3], but need not be fitted with weathertight closing appliances.

Where, due to the ship's size and arrangement, this is not practicable, lesser heights for machinery space and emergency generator room ventilator coamings, fitted with weathertight closing appliances in accordance with [8.1.2], may be permitted by the Society in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

7. Companionway

7.1 General

7.1.1 Openings in freeboard deck

Openings in freeboard deck other than hatchways, machinery space openings, manholes and flush scuttles are to be protected by an enclosed superstructure or by a deckhouse or companionway of equivalent strength and weathertightness.

7.1.2 Openings in superstructures

Openings in an exposed superstructure deck or in the top of a deckhouse on the freeboard deck which give 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.

7.1.3 Openings in superstructures having height less than standard height

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 provided the height of the deckhouse is at least the height of the superstructure.

7.2 Scantlings

7.2.1
Companionways on exposed decks protecting openings leading into enclosed spaces are to be of steel and strongly attached to the deck and are to have adequate scantlings.

7.3 Closing devices

7.3.1 Doors
Doorways in deckhouses or companionways leading to or giving access to spaces below the freeboard deck or to enclosed superstructures are to be fitted with weathertight doors. The doors are to be made of steel, to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

Alternatively, if stairways within a deckhouse are enclosed within properly constructed companionways fitted with weathertight doors, the external door need not be weathertight.

Where the closing appliances of access openings in superstructures and deckhouses are not weathertight, interior deck openings are to be considered exposed, i.e. situated in the open deck.

7.3.2 Height of sills
The height above the deck of sills to the doorways in companionways is to be not less than:

- 600 mm in position 1
- 380 mm in position 2.

Where access is provided from the deck above as an alternative to access from the freeboard deck, the height of the sills into the bridge or poop is to be 380 mm. This also applies to deckhouses on the freeboard deck.

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.

8. Ventilators

8.1 Closing appliances

8.1.1 General
Ventilator openings are to be provided with efficient weathertight closing appliances of steel or other equivalent material.

8.1.2 Closing appliance exemption
Ventilators need not be fitted with closing appliances, unless specifically required by the Society, if the coamings extend for more than:

- 4,5 m above the deck in position 1
- 2,3 m above the deck in position 2.

8.1.3 Closing appliances for ships of not more than 100 m in length
In ships of not more than 100 m in length, the closing appliances are to be permanently attached to the ventilator coamings.

8.1.4 Closing appliances for ships of more than 100 m in length

Where, in ships of more than 100 m in length, the closing appliances are not permanently attached, they are to be conveniently stowed near the ventilators to which they are to be fitted.

8.1.5 Ventilation of machinery spaces and emergency generator room

In order to satisfactorily ensure, in all weather conditions:

- the continuous ventilation of machinery spaces,
- and, when necessary, the immediate ventilation of the emergency generator room,

the ventilators serving such spaces are to comply with [8.1.2], i.e. their openings are to be so located that they do not require closing appliances.

8.1.6 Reduced height of ventilator coamings for machinery spaces and emergency generator room

Where, due to the ship's size and arrangement, the requirements in [8.1.5] are not practicable, lesser heights may be accepted for machinery space and emergency generator room ventilator coamings fitted with weathertight closing appliances in accordance with [8.1.1], [8.1.3] and [8.1.4] in combination with other suitable arrangements, such as separators fitted with drains, to ensure an uninterrupted, adequate supply of ventilation to these spaces.

8.1.7 Closing arrangements of ventilators led overboard or through enclosed superstructures

Closing arrangements of ventilators led overboard to the ship side or through enclosed superstructures are considered by the Society on a case by case basis. If such ventilators are led overboard more than 4,5 m above the freeboard deck, closing appliances may be omitted provided that satisfactory baffles and drainage arrangements are fitted.

8.2 Coamings

8.2.1 General

Ventilators in positions 1 or 2 to spaces below freeboard decks or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck.

Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the freeboard deck.

8.2.2 Scantlings

The scantlings of ventilator coamings exposed to the weather are to be not less than those obtained from Tab 7.

In exposed locations or for the purpose of compliance with buoyancy calculations, the height of coamings may be required to be increased to the satisfaction of the Society.

9. Tank cleaning openings

9.1 General

9.1.1

Ullage plugs, sighting ports and tank cleaning openings may not be arranged in enclosed spaces.

Table 7: Scantlings of ventilator coamings

Feature	Scantlings
Height of the coaming, in mm, above the deck	h = 900 in position 1 h = 760 in position 2
Thickness of the coaming, in mm **(1)**	$t = 5,5 + 0,01\ d_V$ with $7,5 \le t \le 10,0$
Support	If h > 900 mm, the coaming is to be suitably stiffened or supported by stays.

(1) Where the height of the ventilator exceeds the height h, the thickness of the coaming may be gradually reduced, above that height, to a minimum of 6,5 mm.

Note 1:

d_V : Internal diameter of the ventilator, in mm.

Chapter 10 – Hull outfitting

Welcome JBP

Section 1 – RUDDER AND MANOEUVRING ARRANGEMENT

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

C_R : rudder force, in N

Q_R : rudder torque, in N.m

A : total movable area of the rudder, in m², measured at the mid-plane of the rudder

For nozzle rudders, A is not to be taken less than 1,35 times the projected area of the nozzle.

A_t : A + area of a rudder horn, if any, in m²

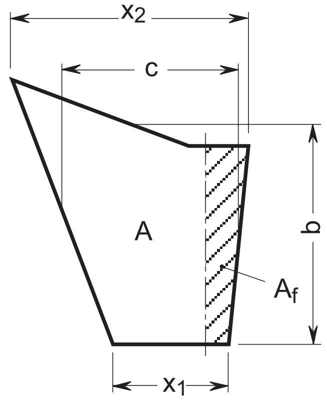
A_f : portion of rudder area located ahead of the rudder stock axis, in m²

b : mean height of rudder area, in m

c : mean breadth of rudder area, in m, see Fig 1

Λ : aspect ratio of rudder area At

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



$$c = \frac{x_1 + x_2}{2} \qquad b = \frac{A}{c}$$

Figure 1:

v_0 : maximum ahead speed of ship, in knots as defined in Ch.1, Sec 4

if this speed is less than 10 knots, v_0 is to be taken as

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

v_a : maximum astern speed of ship, in knots, to be taken not less than $0,5 \cdot v_0$. For greater astern speeds special evaluation of rudder force and torque as a function of the rudder angle may be required. If no limitations for the rudder angle at astern condition is stipulated, the factor κ_2 is not to be taken less than given in Tab 1 for astern condition.

1. General

1.1 Manoeuvring arrangement

1.1.1

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

The manoeuvring arrangement includes all parts from the rudder and steering gear to the steering position necessary for steering the ship.

1.1.2

Rudder stock, rudder coupling, rudder bearings and the rudder body are dealt with in this Section. The steering gear is to comply with the appropriate rules of the Society.

1.1.3

The steering gear compartment shall be readily accessible and, as far as practicable, separated from the machinery space.

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.

1.2 Structural details

1.2.1

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

1.2.2

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

1.2.3

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.

1.2.4

The rudder stock is to be carried through the hull either enclosed in a watertight trunk, or glands are to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.

1.3 Size of rudder area

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

$$A = c_1 \cdot c_2 \cdot c_3 \cdot c_4 \frac{1,75 \cdot \mathbf{L} \cdot \mathbf{T}}{100} \quad \left[m^2\right]$$

c_1 : factor taken equal to 0.9

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 rudders 50 % of the projected area of the rudder horn may be included into the rudder area A.

Where more than one rudder is arranged the area of each rudder can be reduced by 20 %.

In estimating the rudder area A, [2.1] is to be observed.

1.4 Materials

1.4.1

For materials for rudder stock, pintles, coupling bolts etc. refer to the Society's Rules for Materials.

1.4.2

In general materials having a minimum nominal upper yield point R_{eH} of less than 200 N/mm² and a minimum tensile strength of less than 400 N/mm² or more than 900 N/mm² 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/mm². If material is used having a R_{eH} differing from 235 N/mm², the material factor k_r is to be determined as follows:

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

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

R_{eH} : minimum nominal upper yield point of material used, in N/mm². R_{eH} is not to be taken greater than $0,7 \cdot R_m$ or 450 N/mm², whichever is less. R_m = tensile strength of the material used.

1.4.3

Before significant reductions in rudder stock diameter due to the application of steels with R_{eH} exceeding 235 N/mm² are accepted, the Society 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.

1.4.4

The permissible stresses given in [5.1] are applicable for normal strength hull structural steel. When higher tensile steels are used, higher values may be used which will be fixed in each individual case.

2. Rudder Force and Torque

2.1 Rudder force and torque for normal rudders

2.1.1

The rudder force is to be determined according to the following formula:

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

v : v_0 for ahead condition

: v_a for astern condition

κ_1 : coefficient, depending on the aspect ratio λ

= (λ + 2)/3, where λ need not be taken greater than 2

κ_2 : coefficient, depending on the type of the rudder and the rudder profile according to Tab 1

Table 1:

Profile / type of rudder	κ_2 ahead	κ_2 astern
NACA-00 series Göttingen profiles	1.1	0.8
flat side profiles	1.1	0.9
mixed profiles (e. g. HSVA)	1.21	0.9
hollow profiles	1.35	0.9
high lift rudders	1.7	to be specially considered; if not known: 1.3
Fish tail	1.4	0.80
Single plate	1.00	1.00

κ_3 : coefficient, depending on the location of the rudder

= 0.8 for rudders outside the propeller jet

= 1.0 elsewhere, including also rudders within the propeller jet

= 1.15 for rudders aft of the propeller nozzle

κ_t : coefficient depending on the thrust coefficient C_{Th}

= 1.0 normally

In special cases for thrust coefficients C_{Th} > 1,0 determination of k_t according to the following formula may be required:

$$\kappa_t = \frac{C_R(C_{Th})}{C_R(C_{Th} = 1,0)}$$

2.1.2

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

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

$$r = c\,(\alpha - k_b) \quad [m]$$

α = 0,33 for ahead condition

= 0,66 for astern condition (general)

= 0,75 for astern condition (hollow profiles)

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

For high lift rudders α is to be specially considered. If not known, α= 0,40 may be used for the ahead condition

k_b : balance factor as follows:

: $\dfrac{A_f}{A}$

: 0.08 for unbalanced rudders

r_{min} = $0.1 \cdot c$, in m, for ahead condition

2.1.3

Effects of the provided type of rudder/profile on choice and operation of the steering gear are to be observed.

2.2 Rudder force and torque for rudder blades with cut-outs (semi-spade rudders)

2.2.1

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

The rudder area may be divided into two rectangular or trapezoidal parts with areas A_1 and A_2, see Fig 2.

The resulting force of each part may be taken as:

$$C_{R1} = C_R \frac{A_1}{A} \quad [N]$$

$$C_{R2} = C_R \frac{A_2}{A} \quad [N]$$

2.2.2

The resulting torque of each part may be taken as:

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

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

$$r_1 = c_1 \,(\alpha - k_{b1}) \quad [m]$$

$$r_2 = c_2 \,(\alpha - k_{b2}) \quad [m]$$

$$k_{b1} = \frac{A_{1f}}{A_1}$$

$$k_{b2} = \frac{A_{2f}}{A_2}$$

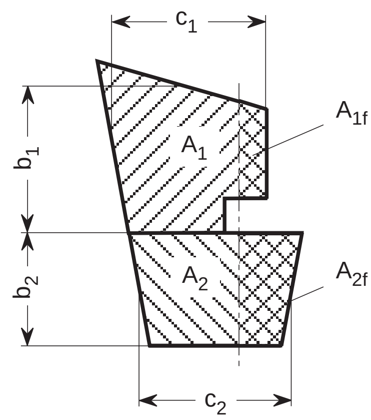
A_{1f} , A_{2f} see Fig 2

$$c_1 = \frac{A_1}{b_1}$$

$$c_2 = \frac{A_2}{b_2}$$

b_1, b_2 : mean heights of the partial rudder areas A_1 and A_2 , see Fig 2

Figure 2:



2.2.3

The total rudder torque is to be determined according to the following formulae:

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

$$Q_{R\,min} = C_R \cdot r_{1,2\,min} \quad [\text{Nm}]$$

$$r_{1,2min} = \frac{0,1}{A}(c_1 \cdot A_1 + c_2 \cdot A_2) \quad [\text{m}]$$

for ahead condition

The greater value is to be taken.

3. Scantlings of the Rudder Stock

3.1 Rudder stock diameter

3.1.1

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

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

Q_R : see [2.1.2], [2.2.2] and [2.2.3]

The related torsional stress is:

$$\tau_t = \frac{68}{k_r} \quad \left[\text{N/mm}^2\right]$$

k_r : see [1.4.2] and [1.4.3]

3.1.2

The diameter of the rudder stock determined according to [3.1.1] is decisive for the steering gear, the stopper and the locking device.

3.1.3

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 0.9 D_t. The length of the edge of the quadrangle for the auxiliary tiller must not be less than 0.77 D_t and the height not less than 0.8 D_t.

3.1.4

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.

3.2 Strengthening of rudder stock

3.2.1

If the rudder is so arranged that additional bending stresses occur in the rudder stock, the stock diameter has to be suitably increased. The increased diameter is, where applicable, decisive for the scantlings of the coupling.

For the increased rudder stock diameter the equivalent stress of bending and torsion is not to exceed the following value:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} \leq \frac{118}{k_r} \quad \left[N/mm^2\right]$$

Bending stress:

$$\sigma_b = \frac{10{,}2 \cdot M_b}{D_1^3} \quad \left[N/mm^2\right]$$

M_b : bending moment at the neck bearing, in Nm

Torsional stress:

$$\tau = \frac{5{,}1 \cdot Q_R}{D_1^3} \quad \left[N/mm^2\right]$$

D_1 : increased rudder stock diameter, in cm

The increased rudder stock diameter may be determined by the following formula:

$$D_1 = 0{,}1 \cdot D_t \sqrt[6]{1 + \frac{4}{3}\left(\frac{M_b}{Q_R}\right)^2}$$

Q_R : see [2.1.2], [2.2.2] and [2.2.3]

D_t : see [3.1.1]

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.

3.3 Analysis

3.3.1 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 3 to Fig 5 as outlined in [3.3.2] and [3.3.3].

3.3.2 Data for the analysis

$l_{10} - l_{50}$: lengths of the individual girders of the system [m]

$I_{10} - I_{50}$: moments of inertia of these girders [cm4]

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

Load on rudder body (general):

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

Load on semi-spade rudders:

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

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

C_R, C_{R1}, C_{R2} see 2.1 and 2.2

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

for the support in the sole piece (Fig 3):

$$Z = \frac{6{,}18 \cdot I_{50}}{\ell_{50}^3} \quad [\mathrm{kN/m}]$$

for the support in the rudder horn (Fig 4):

$$Z = \frac{1}{f_b + f_t} \quad [\mathrm{kN/m}]$$

f_b : unit displacement of rudder horn, in m, due to a unit force of 1 kN acting in the centre of support

$$= \frac{1{,}3 \cdot d^3 \cdot 10^8}{3 \cdot E \cdot I_n} \quad [\mathrm{m/kN}]$$

$$= 0{,}21 \frac{d^3}{I_n} \quad [\mathrm{m/kN}] \text{ (guidance value for steel)}$$

I_n : moment of inertia of rudder horn, in cm^4, around the x-axis at d/2 (see also Fig 4)

f_t : unit displacement due to a torsional moment of the amount 1, in kN.m

$$= \frac{d \cdot e^2}{G \cdot J_t}$$

$$= \frac{d \cdot e^2 \cdot \Sigma u_i / t_i}{3{,}17 \cdot 10^8 \cdot F_T^2} \quad [\mathrm{m/kN}] \text{ for steel}$$

G : modulus of rigity

= $7{,}92 \cdot 10^7$, in kN/m², for steel

J_t : torsional moment of inertia, in m^4

F_T : mean sectional area of rudder horn, in m²

u_i : breadth, in mm, of the individual plates forming the mean horn sectional area

t_i : plate thickness within the individual breadth ui, in mm

e, d : distances, in m, according to Fig 4

K_{11}, K_{22}, K_{12} : rudder horn compliance constants calculated for rudder horn with 2-conjugate elastic supports (Fig 5)

The 2-conjugate elastic supports are defined in terms of horizontal displacements, y_i, by the following equations:

at the lower rudder horn bearing:

$$y_1 = - K_{12} F_{A2} - K_{22} F_{A1}$$

at the upper rudder horn bearing:

$$y_2 = - K_{11} F_{A2} - K_{12} F_{A1}$$

where

y_1, y_2 : Horizontal displacements, in m, at the lower and upper rudder horn bearings, respectively

F_{A1}, F_{A2} : Horizontal support forces, in kN, at the lower and upper rudder horn bearings, respectively

K_{11}, K_{22}, K_{12}: obtained, in m/kN, from the following formulae:

$$K_{11} = 1,3 \cdot \frac{\lambda^3}{3EJ_{1h}} + \frac{e^2 \cdot \lambda}{GJ_{th}}$$

$$K_{12} = 1,3 \cdot \left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2 \cdot (d-\lambda)}{2EJ_{1h}}\right] + \frac{e^2 \cdot \lambda}{GJ_{th}}$$

$$K_{22} = 1,3 \cdot \left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2 \cdot (d-\lambda)}{EJ_{1h}} + \frac{\lambda \cdot (d-\lambda)^2}{EJ_{1h}} + \frac{(d-\lambda)^3}{3EJ_{2h}}\right] + \frac{e^2 \cdot d}{GJ_{th}}$$

where:

d : Height of the rudder horn, in m, defined in Fig 5. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the lower rudder horn pintle

λ : Length, in m, as defined in Fig 5. This length is measured downwards from the upper rudder horn end, at the point of curvature transition, till 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, in m, as defined in Fig 5 (value taken at z = d/2)

J_{1h} : Moment of inertia of rudder horn about the x axis, in 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 5)

J_{2h} Moment of inertia of rudder horn about the x axis, in 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 5)

J_{th} : Torsional stiffness factor of the rudder horn, in m^4.

- For any thin wall closed section:

$$J_{th} = \frac{4F_T^2}{\sum_i \frac{u_i}{t_i}}$$

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m^2

u_i : Length, in mm, of the individual plates forming the mean horn sectional area

t_i : Thickness, in 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.

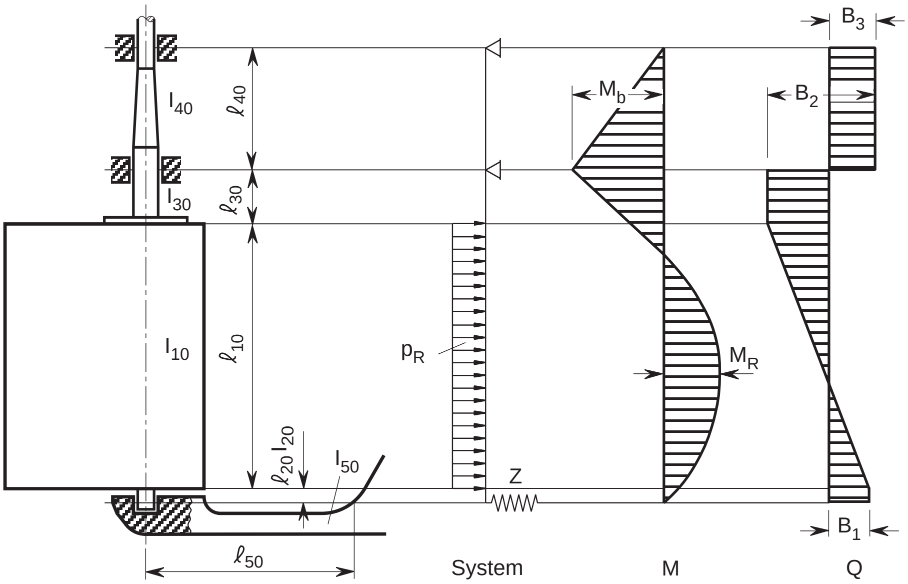


Figure 3: Rudder supported by sole piece

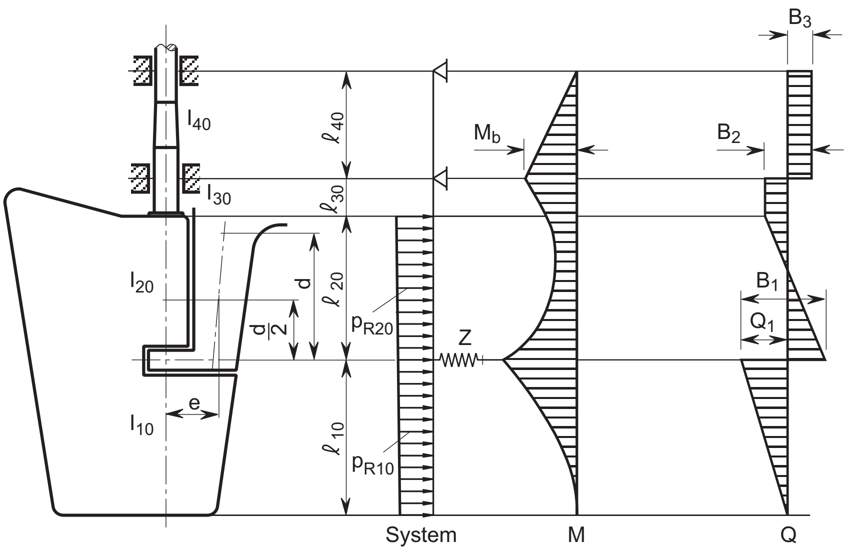


Figure 4: Semi-spade rudder (with 1-elastic support)

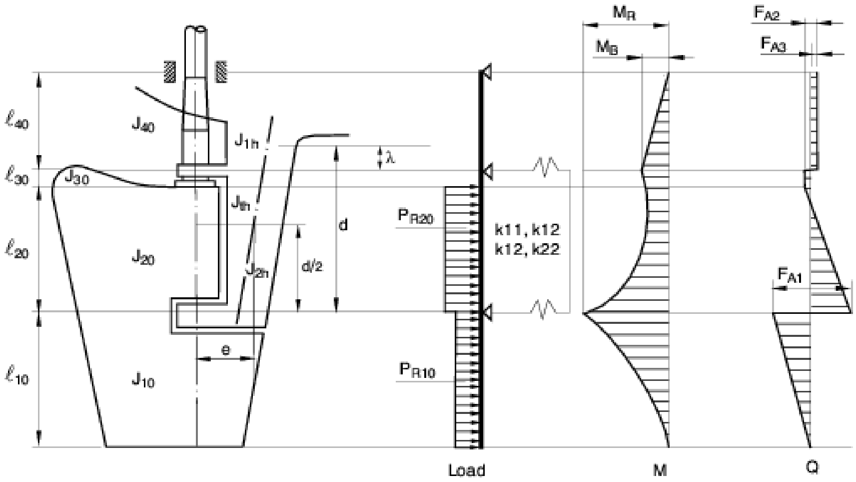


Figure 5: Semi-spade rudder (with 2-conjugate elastic supports)

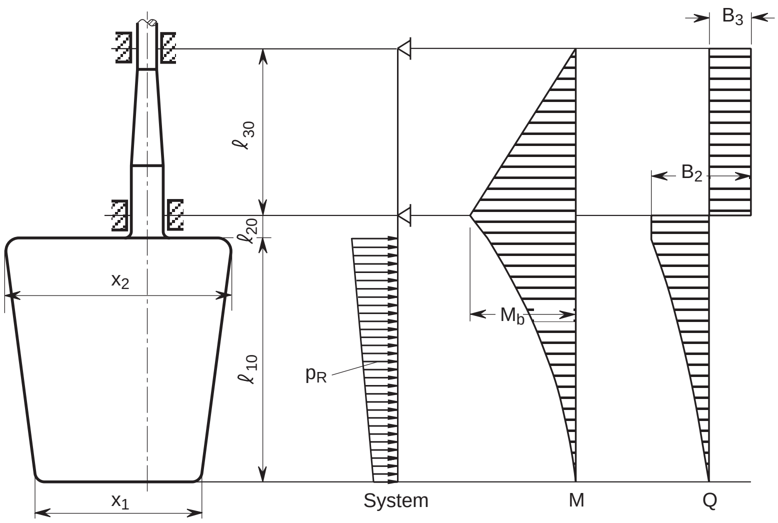


Figure 6: Spade rudder

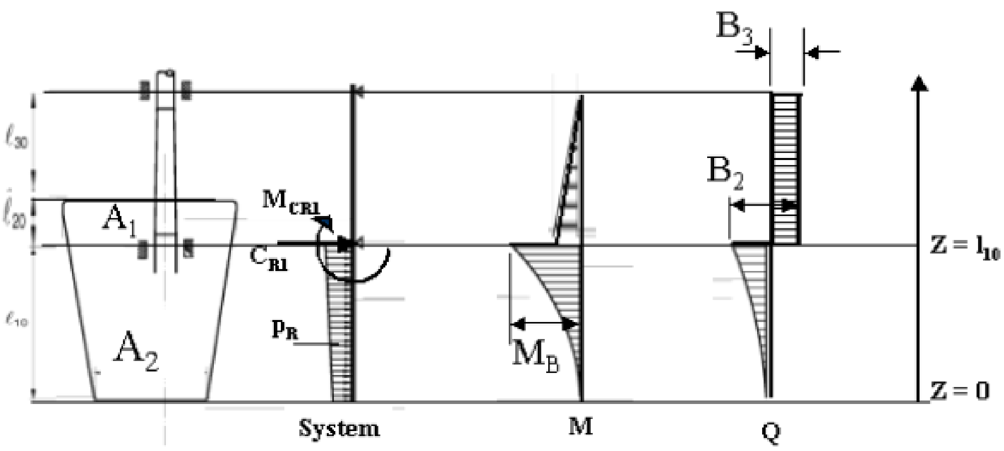


Figure 7: Spade rudders with rudder trunks

3.3.3 Moments and forces to be evaluated

a) The bending moment M_R and the shear force Q_1 in the rudder body, the bending moment M_b in the neck bearing and the support forces B_1, B_2, B_3 are to be evaluated.

The so evaluated moments and forces are to be used for the stress analyses required by [3.2], [5], [9.1]. and [9.2].

a) For spade rudders (see Fig 6) the moments and forces may be determined by the following formulae:

$$M_b = C_R \left(\ell_{20} + \frac{\ell_{10}\ (2\,x_1 + x_2)}{3\ (x_1 + x_2)} \right) \quad [Nm]$$

$$B_3 = \frac{M_b}{\ell_{30}} \quad [N]$$

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

b) For spade rudders with rudders trunks (see Fig 7) the moments and forces may be determined by the following formulae:

M_R is the greatest of the following values:

- $C_{R2} \,.\, (l_{10} – CG_{2Z})$
- $C_{R1} \,.\, (CG_{1Z} – l_{10})$

Where :

C_{R1} : rudder force over the rudder blade area A_1

C_{R2} : rudder force over the rudder blade area A_2

CG_{1Z} : vertical position of the center of gravity of the rudder blade area A_1

CG_{2Z} : vertical position of the center of gravity of the rudder blade area A_2

$M_B = C_{R2} \,.\, (l_{10} – CG_{2Z})$
$B_3 = (M_B + M_{CR1})/(l_{20} + l_{30})$
$B_2 = C_R + B_3$

3.4 Rudder trunk

3.4.1

Where the rudder stock is arranged in a trunk in such a way that the trunk is stressed by forces due to rudder action, the scantlings of the trunk are to be as such that the equivalent stress due to bending and shear does not exceed $0.35 \cdot R_{eH}$ of the material used.

3.4.2

In case where the rudder stock is fitted with a rudder trunk welded in such a way the rudder trunk is loaded by the pressure induced on the rudder blade, as given in [2.1.1], the bending stress in the rudder trunk, in N/mm^2, is to be in compliance with the following formula:

$\sigma \leq 80 / k$

where k, the material for the rudder trunk, is not to be taken less than 0,7.

For the calculation of the bending stress, the span to be considered is the distance between the mid-height of the lower rudder stock bearing and the point where the trunk is clamped into the shell or the bottom of the skeg.

3.4.3
The steel grade used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0,23% on laddle analysis and a carbon equivalent CEQ not exceeding 0,41.

3.4.4
The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration.

The fillet shoulder radius r is to be as large as practicable and to comply with the following formulae:

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

$r = 0,1\ D_1$ when $\sigma < 40 / k$ N/mm^2,

without being less than 30 mm,

where D_1 is defined in [3.2.1].

The radius may be obtained by grinding. If disk 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.

3.4.5
Before welding is started, a detailed welding procedure specification is to be submitted to the Society covering the weld preparation, welding positions, welding parameters, welding consumables, preheating, post weld heat treatment and inspection procedures. This welding procedure is to be supported by approval tests in accordance with the applicable requirements of materials and welding sections of the rules.

The manufacturer is to maintain records of welding, subsequent heat treatment and inspections traceable to the welds. These records are to be submitted to the Surveyor.

3.4.6
Non destructive tests are to be conducted at least 24 hours after completion of the welding. The welds are to be 100% magnetic particle tested and 100% ultrasonic tested. The welds are to be free from cracks, lack of fusion and incomplete penetration. The non destructive tests reports are to be handed over to the Surveyor.

3.4.7
Rudder trunks in materials other than steel are to be specially considered by the Society.

3.4.8
The thickness of the shell or of the bottom plate is to be compatible with the trunk thickness.

4. Rudder Couplings

4.1 General

4.1.1
The couplings are to be designed in such a way as to enable them to transmit the full torque of the rudder stock.

4.1.2

The distance of the bolt axis from the edges of the flange is not to be less than 1.2 times the diameter of the bolt. In horizontal couplings, at least 2 bolts are to be arranged forward of the stock axis.

4.1.3

The coupling bolts are to be fitted bolts. The bolts and nuts are to be effectively secured against loosening.

4.1.4

For spade rudders horizontal couplings according to [4.2]. are permissible only where the required thickness of the coupling flanges t_f is less than 50 mm, otherwise cone couplings according to [4.4] and [4.5], as applicable, are to be applied. For spade rudders of the high lift type, only cone couplings according to [4.4] and [4.5], as applicable, are permitted.

4.2 Horizontal couplings

4.2.1

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

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

D : rudder stock diameter according to [6], in 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, in mm

kr : material factor for the rudder stock as given in [1.4.2]

kb : material factor for the bolts analogue to [1.4.2]

4.2.2

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

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

t_{fmin} $= 0,9 \cdot d_b$

k_f : material factor for the coupling flanges analogue to [1.4.2]

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 $0,67 \cdot d_b$.

4.2.3

The coupling flanges are to be equipped with a fitted key according to DIN 6885 or equivalent standard for relieving the bolts.

The fitted key may be dispensed with if the diameter of the bolts is increased by 10 %.

4.2.4

Horizontal coupling flanges shall either be forged together with the rudder stock or be welded to the rudder stock as outlined in [10.1.3].

4.2.5
For the connection of the coupling flanges with the rudder body see also [10].

4.3 Vertical couplings

4.3.1
The diameter of the coupling bolts is not to be less than:

$$d_b = \frac{0{,}81 \cdot D}{\sqrt{n}} \sqrt{\frac{k_b}{k_r}} \quad [\text{mm}]$$

D, k_b, k_r, n see [4.2.1], where n is not to be less than 8.

4.3.2
The first moment of area of the bolts about the centre of the coupling is not to be less than:

$$S = 0{,}00043\, D^3 \quad [\text{cm}^3]$$

4.3.2
The thickness of the coupling flanges is not to be less than:

$$t_f = d_b \quad [\text{mm}]$$

The width of material outside the bolt holes is not to be less than $0{,}67 \cdot d_b$.

4.4 Cone Couplings with key

4.4.1
Cone couplings should have a taper c on diameter of $1:8 - 1:12$. $c = (d_0 - d_u)/l$ according to Figure 1: .

The cone shapes should fit very exact. The nut is to be carefully secured, e.g. by a securing plate as shown in Figure 1: .

4.4.2
The coupling length l should, in general, not be less than $1{,}5 \cdot d_0$.

4.4.3
For couplings between stock and rudder a key is to be provided, the shear area of which, in cm², is not to be less than:

$$a_s = \frac{17{,}55 Q_F}{d_k R_{eH1}}$$

Q_F : design yield moment of rudder stock, in Nm according to [6].

d_k : diameter of the conical part of the rudder stock, in mm, at the key

R_{eH1} : minimum nominal upper yield point of the key material, in N/mm²

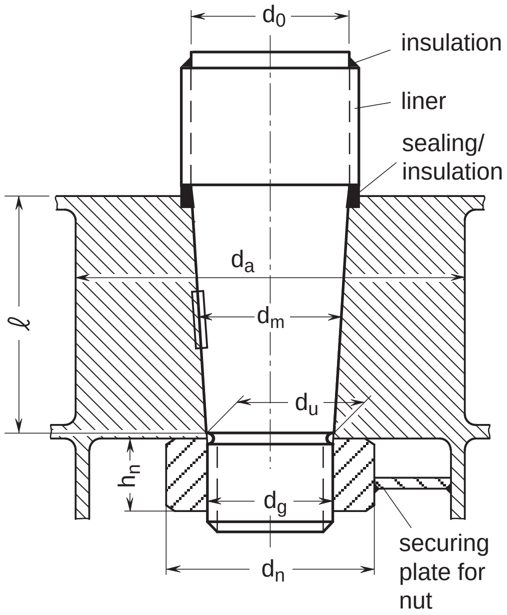


Figure 8:

4.4.4

The effective surface area, in cm², of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than:

$$a_k = \frac{5Q_F}{d_k R_{eH2}}$$

R_{eH2} : minimum nominal upper yield point of the key, stock or coupling material, in [N/mm²], whichever is less.

4.4.5

The dimensions of the slugging nut are to be as follows, see Figure 11:

- height:

$$h_n = 0{,}6 \cdot d_g$$

- outer diameter (the greater value to be taken):

$$d_n = 1{,}2 \cdot d_u \quad \text{or} \quad d_n = 1{,}5 \cdot d_g$$

- external thread diameter:

$$d_g = 0{,}65 \cdot d_0$$

4.4.6

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 [4.5.3] for a torsional moment $Q'_F = 0{,}5 \cdot Q_F$.

4.5 Cone couplings with special arrangements for mounting and dismounting the couplings

4.5.1

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, $c \approx 1:2$ to $\approx 1:20$.

4.5.2

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 Figure 1: .

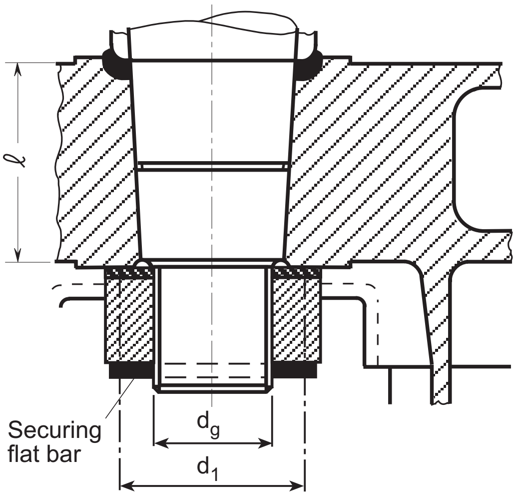


Figure 9:

Note: A securing flat bar will be regarded as an effective securing device of the nut, if its shear area is not less than:

$$A_s = \frac{P_s \cdot \sqrt{3}}{R_{eH}} \quad [mm^2]$$

Ps : shear force as follows

$$= \frac{P_e}{2} \cdot \mu_1 \left(\frac{d_1}{d_g} - 0{,}6 \right) \quad [N]$$

P_e : push-up force according to [4.5.3], in N

μ_1 : frictional coefficient between nut and rudder body, normally $\mu_1 = 0{,}3$

d_1 : mean diameter of the frictional area between nut and rudder body

d_g : thread diameter of the nut

R_{eH} : yield point, in N/mm², of the securing flat bar material

4.5.3 Push-up pressure and push-up length

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.

Push-up pressure

The push-up pressure is not to be less than the greater of the two following values:

$$p_{req1} = \frac{2 \cdot Q_F \cdot 10^3}{d_m^2 \cdot \ell \cdot \pi \cdot \mu_0} \quad \left[N/mm^2\right]$$

$$p_{req2} = \frac{6 \cdot M_b \cdot 10^3}{\ell^2 \cdot d_m} \quad \left[N/mm^2\right]$$

Q_F : design yield moment of rudder stock according to [6], in Nm

d_m : mean cone diameter, in mm

l : cone length, in mm

μ_0 $\approx$ 0,15 (frictional coefficient)

M_b : bending moment in the cone coupling (e.g. in case of spade rudders), in N.m

It has to be proved that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure is to be determined by the following formula:

$$p_{perm} = \frac{0{,}8 \cdot R_{eH}\left(1 - \alpha^2\right)}{\sqrt{3 + \alpha^4}}$$

R_{eH} : yield point [N/mm²] of the material of the gudgeon

$\alpha = \frac{d_m}{d_a}$ (see Fig. 14.6)

The outer diameter of the gudgeon should not be less than:

$$d_a = 1{,}5 \cdot d_m \quad [mm]$$

Push-up length

The push-up length is not to be less than:

$$\Delta\ell_1 = \frac{p_{req} \cdot d_m}{E\left(\frac{1 - \alpha^2}{2}\right)c} + \frac{0{,}8 \cdot R_{tm}}{c} \quad [mm]$$

R_{tm} : mean roughness [mm]

$\approx$ 0,01 mm

c : taper on diameter according to [4.5.1]

E : Young's modulus ($2{,}06 \cdot 10^5$ N/mm²)

The push-up length is, however, not to be taken greater than:

$$\Delta\ell_2 = \frac{1{,}6 \cdot R_{eH} \cdot d_m}{\sqrt{3 + \alpha^4}\ E \cdot c} + \frac{0{,}8 \cdot R_{tm}}{c} \quad [mm]$$

Note: In case of hydraulic pressure connections the required push-up force Pe for the cone may be determined by the following formula:

$$P_e = p_{req} \cdot d_m \cdot \pi \cdot \ell\left(\frac{c}{2} + 0{,}02\right) \quad [N]$$

The value 0,02 is a reference for the friction coefficient using oil pressure. It varies and depends on the mechanical treatment and roughness of the details to be fixed.

Where due to the fitting procedure a partial push-up effect caused by the rudder weight is given, this may be taken into account when fixing the required push-up length, subject to approval by the classification society.

4.5.4 Push-up pressure for pintle bearings

The required push-up pressure for pintle bearings is to be determined by the following formula:

$$p_{req} = 0,4 \frac{B_1 \cdot d_0}{d_m^2 \cdot \ell} \quad \left[N/mm^2\right]$$

B_1 : supporting force in the pintle bearing, in N, see also Figure 1:

d_m, l : see [4.5.3

d_0 : pintle diameter [mm] according to Figure 1:

5. Rudder Body, Rudder Bearings

5.1 Strength of rudder body

5.1.1

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.

5.1.2

The strength of the rudder body is to be proved by direct calculation according to [3.3]

5.1.3

For rudder bodies without cut-outs the permissible stress are limited to:

bending stress due to M_R:

$$\sigma_b = 110 \quad \left[N/mm^2\right]$$

shear stress due to Q_1:

$$\tau_t = 50 \quad \left[N/mm^2\right]$$

equivalent stress due to bending and shear:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} = 120 \quad \left[N/mm^2\right]$$

M_R, Q_1 see [3.3.3] and Figure 1: and Figure 1: .

In case of openings in the rudder plating for access to cone coupling or pintle nut the permissible stresses according to [5.1.4] apply. Smaller permissible stress values may be required if the corner radii are less than $0,15 \cdot h_o$, where h_o = height of opening.

5.1.4

In rudder bodies with cut-outs (semi-spade rudders) the following stress values are not to be exceeded:

bending stress due to M_R:

$$\sigma_b = 90 \quad \left[N/mm^2\right]$$

shear stress due to Q_1:

$$\tau = 50 \quad \left[N/mm^2\right]$$

torsional stress due to Mt:

$$\tau_t = 50 \quad \left[N/mm^2\right]$$

equivalent stress due to bending and shear and equivalent stress due to bending and torsion:

$$\sigma_{v1} = \sqrt{\sigma_b^2 + 3\tau^2} = 120 \quad \left[N/mm^2\right]$$

$$\sigma_{v2} = \sqrt{\sigma_b^2 + 3\tau_t^2} = 100 \quad \left[N/mm^2\right]$$

$$M_R = C_{R2} \cdot f_1 + B_1 \frac{f_2}{2} \quad [Nm]$$

Q_1 = C_{R2} , in N

f_1, f_2 : see Figure 1:

The torsional stress may be calculated in a simplified manner as follows:

$$\tau_t = \frac{M_t}{2 \cdot \ell \cdot h \cdot t} \quad \left[N/mm^2\right]$$

$$M_t = C_{R2} \cdot e \quad [Nm]$$

C_{R2} : partial rudder force, in N of the partial rudder area A_2 below the cross section under consideration

e : lever for torsional moment, in 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 Figure 1: . The centre of pressure is to be assumed at $0{,}33 \cdot c_2$ aft of the forward edge of area A_2, where c_2 = mean breadth of area A_2).

h, l, t : in cm, see Figure 1:

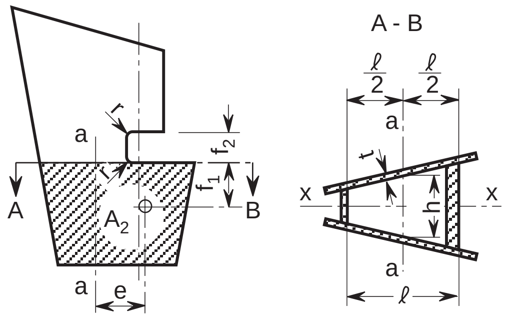


Figure 10:

The distance l between the vertical webs should not exceed $1{,}2 \cdot h$.

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.

Note: It is recommended to keep the natural frequency of the fully immersed rudder and of local structural components at least 10 % above the exciting frequency of the propeller (number of revolutions □ number of blades) or if relevant above higher order.

5.2 Rudder plating

5.2.1

The thickness of the rudder plating, in mm, is to be determined according to the following formula:

$$t_P = 1{,}74a\sqrt{p_R k} + 2{,}5$$

where:

$$p_R = 10 \cdot \mathbf{T} + \frac{C_R}{10^3 \cdot A} \quad \left[kN/m^2\right]$$

a : the smaller unsupported width of a plate panel, in m

The influence of the aspect ratio of the plate panels may be taken into account according to Ch 3.

However, the thickness is to be not less than the thickness t2 of the shell plating at the ends according to Ch. 6 Sec.1.

Regarding dimensions and welding [10.1.1] has to be observed in addition.

5.2.2

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.

5.2.3

The thickness of the webs is not to be less than 70 % of the thickness of the rudder plating according to [5.2.1], but not less than:

$$t_{min} = 8\sqrt{k} \quad [mm]$$

Webs exposed to seawater must be dimensioned according to [5.2.1].

5.3 Connections of rudder blade structure with solid parts in forged or cast steel

5.3.1 - General

Solid parts in forged or cast steel which ensure the housing of the rudder stock or of the pintle are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

5.3.2 - 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 which is connected with the solid part where the rudder stock is housed, which is made by vertical web plates and rudder plating, is to be not less than that obtained, in cm^3, from the following formula:

- $$w_S = c_S d_1^3 \left(\frac{H_E - H_X}{H_E}\right)^2 \frac{k}{k_1} 10^{-4}$$

where:

c_S : Coefficient, to be taken equal to:

- c_s = 1,0 if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate
- c_S = 1,5 if there is an opening in the considered cross-section of the rudder

D_1 : Rudder stock diameter, in mm, defined in [3.2.1]

H_E : Vertical distance, in m, between the lower edge of the rudder blade and the upper edge of the solid part

H_X : Vertical distance, in m, between the considered cross-section and the upper edge of the solid part

k, k_1 : Material factors, defined for the rudder blade plating and the rudder stock, respectively.

5.3.3 - Calculation of the actual section modulus of the connection with the rudder stock housing

The actual section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed is to be calculated with respect to the symmetrical axis of the rudder.

The breadth of the rudder plating to be considered for the calculation of this actual section modulus is to be not greater than that obtained, in m, from the following formula:

$$b = s_V + 2\frac{H_X}{m}$$

where:

s_V : Spacing, in m, between the two vertical webs (see Fig 6)

H_X : Distance defined in [5.3.2]

m : Coefficient to be taken, in general, equal to 3.

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate, they are to be deducted (see Fig 11).

5.3.4 - Thickness of horizontal web plates

In the vicinity of the solid parts, the thickness of the horizontal web plates, as well as that of the rudder blade plating between these webs, is to be not less than the greater of the values obtained, in mm, from the following formulae:

$t_H = 1,2\ t_P$

$$t_H = 0,045\frac{d_S^2}{s_H}$$

where:

t_P : Defined in [5.2.1]

d_S : Diameter, in mm, to be taken equal to:

- D_1 for the solid part connected to the rudder stock
- d_A for the solid part connected to the pintle

D_1 : Rudder stock diameter, in mm, defined in [3.2.1]

d_A : Pintle diameter, in mm, defined in [5.5.1]

s_H : Spacing, in mm, between the two horizontal web plates.

Different thickness may be accepted when justified on the basis of direct calculations submitted to the Society for approval.

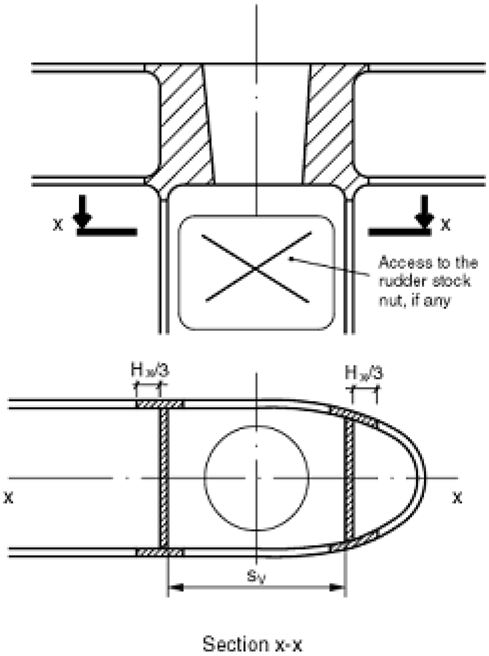


Figure 11: Cross-section of the connection between rudder blade structure and rudder stock housing

5.3.5 - Thickness of side plating and vertical web plates welded to the solid part

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, in mm, from Tab 2.

Table 2:

Type of rudder	Thickness of vertical web plates, in mm		Thickness of rudder plating, in mm	
	Rudder blade without opening	At opening boundary	Rudder blade without opening	Area with opening
Rudder supported by sole piece (Fig 3)	1,2 t_P	1,6 t_P	1,2 t_P	1,4 t_P
Semi-spade and spade rudders (Figs. 4 to 6)	1,4 t_P	2,0 t_P	1,3 t_P	1,6 t_P
t_P : Defined in [5.2.1]				

5.3.6 - Solid part protrusions

The solid parts are to be provided with protrusions. Vertical and horizontal web plates of the rudder are to be butt welded to these protrusions.

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 the other web plates.

5.3.7

If the torque is transmitted by a prolonged shaft extended into the rudder, the latter must have the diameter D_t or D_1, whichever is greater, at the upper 10 % of the intersection length. Downwards it may be tapered to 0,6 D_t, in spade rudders to 0,4 times the strengthened diameter, if sufficient support is provided for.

5.4 Rudder bearings

5.4.1

In way of bearings liners and bushes are to be fitted. Their minimum thickness is

t_{min} = 8 mm for metallic materials and synthetic material

= 22 mm for lignum material

Where in case of small ships bushes are not fitted, the rudder stock is to be suitably increased in diameter in way of bearings enabling the stock to be re-machined later.

5.4.2

An adequate lubrication is to be provided.

5.4.3

The bearing forces result from the direct calculation mentioned in [3.3]. 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 Ch 9, Sec 2, Fig 11

5.4.4

The projected bearing surface A_b (bearing height x external diameter of liner) is not to be less than

$$A_b = \frac{B}{q} \quad \left[mm^2\right]$$

B : support force [N]

q : permissible surface pressure according to Table 1:

5.4.5

Stainless and wear resistant steels, bronze and hot-pressed bronze-graphit materials have a considerable difference in potential to non-alloyed steel. Respective preventive measures are required.

5.4.6

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.

Table 3:

Bearing material	q [N/mm²]
lignum vitae	2,5
white metal, oil lubricated	4,5
synthetic material [1]	5,5
steel [2], bronze and hot-pressed bronze-graphite materials	7,0

1 Synthetic materials to be of approved type.

Surface pressures exceeding 5,5 N/mm² may be accepted in accordance with bearing manufacturer's specification and tests, but in no case more than 10 N/mm².

2 Stainless and wear resistant steel in an approved combination with stock liner. Higher surface pressures than 7 N/mm² may be accepted if verified by tests.

The wall thickness of pintle bearings in sole piece and rudder horn shall be approximately ¼ of the pintle diameter.

5.5 Pintles

5.5.1

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:

$$d = 0,35\sqrt{B_1 \cdot k_r} \quad [mm]$$

B_1 : support force, in N

k_r : see [1.4.2]

5.5.2

The thickness of any liner or bush shall not be less than:

$$t = 0,01\sqrt{B_1} \quad [mm]$$

or the values in [5.4.1] respectively.

5.5.3

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

5.5.4

The pintles are to be arranged in such a manner as to prevent unintentional loosening and falling out.

For nuts and threads the requirements of [4.4.5] and [4.5.2] apply accordingly.

5.6 Guidance values for bearing clearances values for bearing clearances

5.6.1

For metallic bearing material the bearing clearanceis to be not less:

$$\frac{d_b}{1000} + 1{,}0 \quad [mm]$$

d_b : inner diameter of bush

5.6.2
If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties.

5.6.3
The clearance is not to be taken less than 1,5 mm on diameter. In case of self lubricating bushes going down below this value can be agreed to on the basis of the manufacturer's specification.

6. Design Yield Moment of Rudder Stock

6.1 General

6.1.1
The design yield moment of the rudder stock is to be determined by the following formula:

$$Q_F = 0{,}02664 \frac{D_t^3}{k_r} \quad [Nm]$$

Dt : stock diameter [mm] according to [3.1]

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 $1{,}145 \cdot D_t$.

7. Stopper, Locking Device

7.1 Stopper

7.1.1
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.

7.2 Locking device

7.2.1
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 [6] Where the ship's speed exceeds 12 knots, the design yield moment need only be calculated for a stock diameter based on a speed v0 = 12 knots.

7.3

7.3.1

Regarding stopper and locking device see also the applicable requirements of the Society's Rules for Machinery Installations.

8. Propeller Nozzles

8.1 General

8.1.1

The following requirements are applicable to propeller nozzles having an inner diameter of up to 5 m. Nozzles with larger diameters will be specially considered.

8.1.2

Special attention is to be given to the support of fixed nozzles at the hull structure.

8.2 Design pressure

8.2.1

The design pressure for propeller nozzles is to be determined by the following formula:

$$p_d = c \cdot p_{d0} \quad \left[kN/m^2 \right]$$

$$p_{d0} = \varepsilon \frac{N}{A_p} \quad \left[kN/m^2 \right]$$

N : maximum shaft power, in kW

A_p : propeller disc area, in m²

$= D^2 \frac{\pi}{4}$

D : propeller diameter, in m

ε : factor according to the following formula:

$$\varepsilon = 0,21 - 2 \cdot 10^{-4} \frac{N}{A_p}$$

ε_{min} = 0,10

c = 1,0 in zone 2 (propeller zone)

= 0,5 in zones 1 and 3

= 0,35 in zone 4

see Fig 12

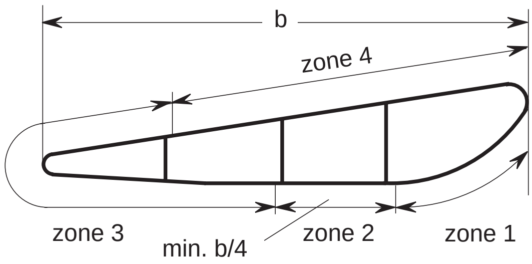


Figure 12:

8.3 Plate thickness

8.3.1

The thickness of the nozzle shell plating is not to be less than:

$$t = 5 \cdot a \sqrt{p_d} + t_K \quad [mm]$$

$$t_{min} = 7{,}5 \text{ mm}$$

a : spacing of ring stiffeners, in m

t_k : corrosion allowance, in mm

8.3.2

The web thickness of the internal stiffening rings shall not be less than the nozzle plating for zone 3, however, in no case be less than 7,5 mm.

8.4 Section modulus

8.4.1

The section modulus of the cross section shown in Fig 12 around its neutral axis is not to be less than:

$$W = n \cdot d^2 \cdot b \cdot v_0^2 \quad \left[cm^3\right]$$

d : inner diameter of nozzle, in m

b : length of nozzle, in m

n = 1,0 for rudder nozzles

= 0,7 for fixed nozzles

8.5 Welding

8.5.1

The inner and outer nozzle shell plating is to be welded to the internal stiffening rings as far as practicable by double continuous welds. Plug welding is only permissible for the outer nozzle plating.

9. Rudder horn and solepiece scantlings

9.1 Sole piece

9.1.1

The section modulus of the sole piece related to the z-axis is not to be less than:

$$W_z = \frac{B_1 \cdot x \cdot k}{80} \quad [cm^3]$$

B_1 : see [3.3]

For rudders with two supports the support force is approximately $B_1 = C_R/2$, when the elasticity of the sole piece is ignored.

x : distance of the respective cross section from the rudder axis, in m

xmin $= 0,5 \cdot \ell_{50}$

xmax $= l_{50}$

l_{50} : see Fig 13 and [3.3.2]

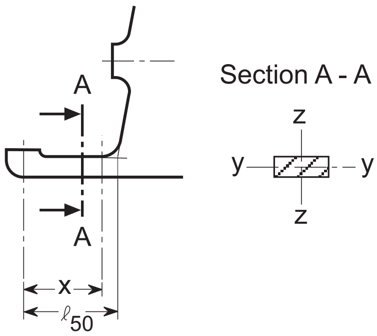


Figure 13:

9.1.2

The section modulus related to the y-axis is not to be less than:

- where no rudder post or rudder axle is fitted

$$W_y = \frac{W_z}{2}$$

- where a rudder post or rudder axle is fitted

$$W_y = \frac{W_z}{3}$$

9.1.3

The sectional area at the location $x = l_{50}$ is not to be less than:

$$A_s = \frac{B_1}{48}\, k \quad [mm^2]$$

9.1.4

The equivalent stress taking into account bending and shear stresses at any location within the length l_{50} is not to exceed:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} = \frac{115}{k} \quad [N/mm^2]$$

$$\sigma_b = \frac{B_1 \cdot x}{W_z} \quad [N/mm^2]$$

$\tau = \frac{B_1}{A_s}$ $\left[N/mm^2\right]$

9.2 Rudder horn of semi spade rudders (case of 1-elastic support)

9.2.1

The distribution of the bending moment, shear force and torsional moment is to be determined according to the following formulae:

- bending moment: Mb = $B_1 \cdot z$ [Nm]

  Mbmax = $B_1 \cdot d$ [Nm]
- shear force: Q = B_1 [N]
- torsional moment: MT = $B_1 \cdot e_{(z)}$ [Nm]

For determining preliminary scantlings the flexibility of the rudder horn may be ignored and the supporting force B_1 be calculated according to the following formula:

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

b, c, d, e(z) and z see Fig 14 and Fig 15.

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

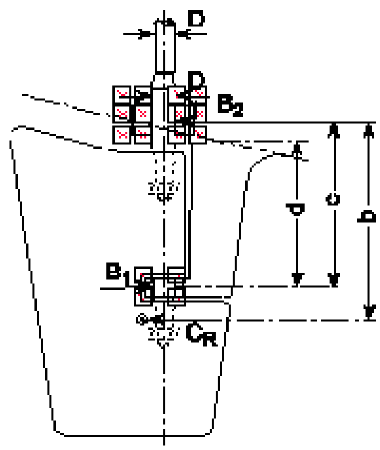


Figure 14:

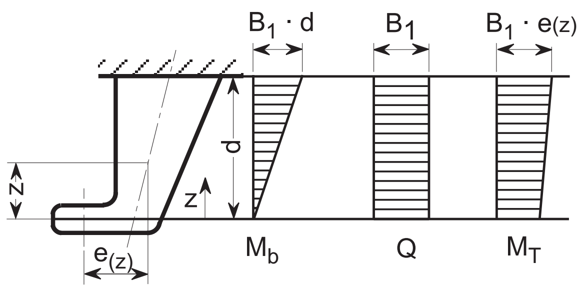


Figure 15:

9.2.2

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:

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

9.2.3

At no cross section of the rudder horn the shear stress due to the shear force Q is to exceed the value:

$$\tau = \frac{48}{k} \quad \left[N/mm^2\right]$$

The shear stress is to be determined by the following formula:

$$\tau = \frac{B_1}{A_h} \quad \left[N/mm^2\right]$$

A_h : effective shear area of the rudder horn, in mm^2, in y-direction

9.2.4

The equivalent stress at any location (z) of the rudder horn shall not exceed the following value:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\left(\tau^2 + \tau_T^2\right)} = \frac{120}{k} \quad \left[N/mm^2\right]$$

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

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

A_T : sectional area, in mm² enclosed by the rudder horn at the location considered

t_h : thickness of the rudder horn plating, in mm.

9.2.5

When determining the thickness of the rudder horn plating the provisions of [5.2] to[5.4] are to be complied with. The thickness is, however, not to be less than:

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

9.2.6

The rudder horn plating is to be effectively connected to the aft ship structure, e.g. by connecting the plating to longitudinal girders, in order to achieve a proper transmission of forces, see Fig 16.

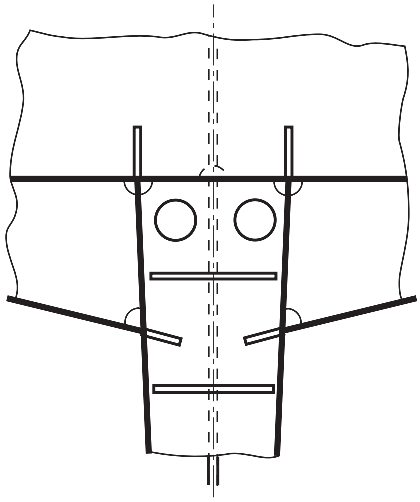


Figure 16:

9.2.7

Transverse webs of the rudder horn are to be led into the hull up to the next deck in a sufficient number and must be of adequate thickness.

9.2.8

Strengthened plate floors are to be fitted in line with the transverse webs in order to achieve a sufficient connection with the hull. The thickness of these plate floors is to be increased by 50 per cent above the bottom thickness determined according to Ch 6, Sec 1.

9.2.9

The centre line bulkhead (wash-bulkhead) in the after peak is to be connected to the rudder horn.

9.2.10

Where the transition between rudder horn and shell is curved, about 50 % of the required total section modulus of the rudder horn is to be formed by the webs in a Section A - A located in the centre of the transition zone, i.e. 0,7 r above the beginning of the transition zone. See Fig. 17.

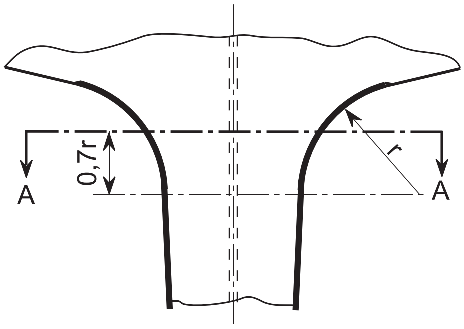


Figure 17:

9.3 Rudder horn of semi spade rudders (case of 2-conjugate elastic supports)

9.3.1 - Bending moment

The bending moment acting on the generic section of the rudder horn is to be obtained, in N.m, from the following formulae:

between the lower and upper supports provided by the rudder horn:

$M_H = F_{A1}\, z \quad (F_{A1} = B_1)$

above the rudder horn upper-support:

$M_H = F_{A1}\, z + F_{A2}\,(z - d_{lu}) \quad (F_{A1} = B_1 \text{ and } F_{A2} = B_2)$

where:

F_{A1} : Support force at the rudder horn lower-support, in N, to be obtained according to Fig 5

F_{A2} : Support force at the rudder horn upper-support, in N, to be obtained according to Fig 5

z : Distance, in m, defined in Fig 19, to be taken less than the distance d, in m, defined in the same figure

d_{lu} : Distance, in m, between the rudder-horn lower and upper bearings (according to Fig 18, $d_{lu} = d - \lambda$).

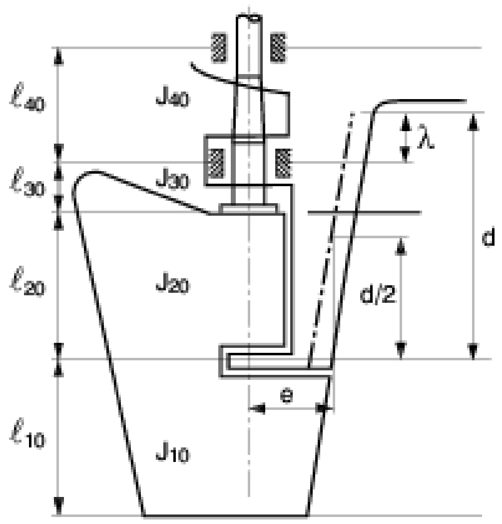


Figure 18: Geometrical parameters for the calculation of the bending moment in rudder horn

9.3.2 - Shear force

The shear force Q_H acting on the generic section of the rudder horn is to be obtained, in N, from the following formulae:

between the lower and upper rudder horn bearings:

$Q_H = F_{A1}$

above the rudder horn upper-bearing:

$Q_H = F_{A1} + F_{A2}$

where:

F_{A1}, F_{A2} : Support forces, in N

9.3.3 - Torque

The torque acting on the generic section of the rudder horn is to be obtained, in N.m, from the following formulae:

between the lower and upper rudder horn bearings:

$$M_T = F_{A1}\, e_{(z)}$$

above the rudder horn upper-bearing:

$$M_T = F_{A1}\, e_{(z)} + F_{A2}\, e_{(z)}$$

where:

F_{A1}, F_{A2} : Support forces, in N

$e_{(z)}$: Torsion lever, in m, defined in Fig 19.

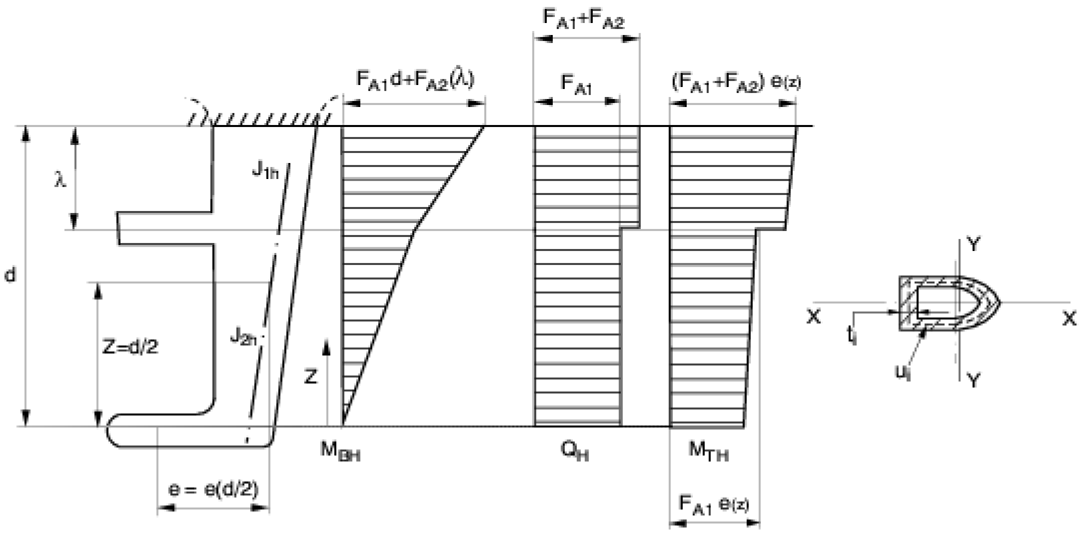


Figure 19: Rudder horn geometry

9.3.4 - Shear stress calculation

a) 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, in N/mm^2, to be obtained from the following formula:

$$\tau_S = \frac{F_{A1}}{A_H}$$

t_T : Torsional stress, in N/mm^2, to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^3}{2F_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case-by-case basis

b) 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, in N/mm^2, to be obtained from the following formula:

$$\tau_S = \frac{F_{A1} + F_{A2}}{A_H}$$

τ_T : Torsional stress, in N/mm^2, to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^3}{2F_T t_H}$$

For solid rudder horn, t_T is to be considered by the Society on a case-by-case basis

where:

F_{A1}, F_{A2} : Support forces, in N

A_H : Effective shear sectional area of the rudder horn, in mm2, in y-direction

M_T : Torque, in N.m

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m2

t_H : Plate thickness of rudder horn, in mm. For a given cross section of the rudder horn, the maximum value of t_T, is obtained at the minimum value of t_H .

9.3.5 - Bending stress calculation

For the generic section of the rudder horn within the length d, defined in Fig 13, the following stresses are to be calculated:

σ_B : Bending stress, in N/mm^2, to be obtained from the following formula:

$$\sigma_B = \frac{M_H}{W_X}$$

M_H : Bending moment at the section considered, in N.m

W_X : Section modulus, in cm^3, around the horizontal axis X (see Fig 19).

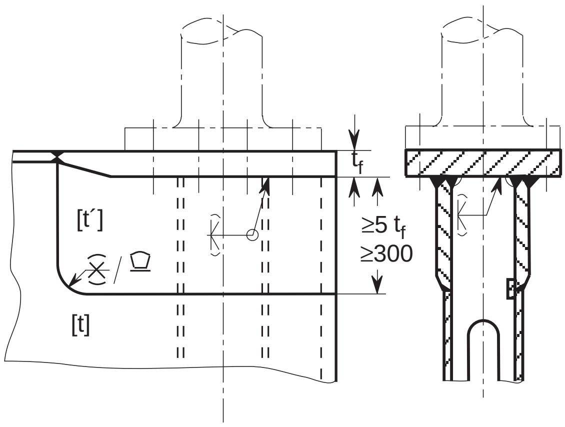
9.3.6 - General remarks

Above requirements [9.2.5] to [9.2.10] also apply to rudder horn with 2-conjugate elastic supports.

10. Rudder coupling flanges

10.1.1

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 Ch 11, Sec 1 (see Fig 20). See also [4.1.4] and [4.2.4].



t = plate thickness in accordance with Section 14, E.3.1 [mm]

t_f = actual flange thickness in [mm]

$t' = \frac{t_f}{3} + 5$ [mm] where $t_f < 50$mm

$t' = 3\sqrt{t_f}$ [mm] where $t_f \geq 50$mm

Figure 20: Horizontal rudder coupling flanges

10.1.2

Allowance shall be made for the reduced strength of the coupling flange in the thickness direction (see Ch 11, Sec 1). In case of doubt, proof by calculation of the adequacy of the welded connection shall be produced.

10.1.3

The welded joint between the rudder stock (with thickened collar, see Ch 11, Sec 1) and the flange shall be made in accordance with Fig. 21.

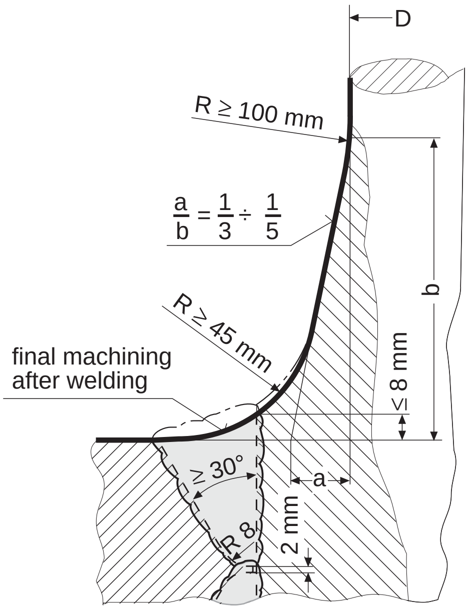


Figure 21: Welded joint between rudder stock and coupling flange

11. Azimuth propulsion system

11.1 General

11.1.1 Arrangement

The azimuth propulsion system is constituted by the following sub-systems (see Fig 22):

- the steering unit
- the bearing
- the hull supports
- the rudder part of the system
- the pod, which contains the electric motor in the case of a podded propulsion system.

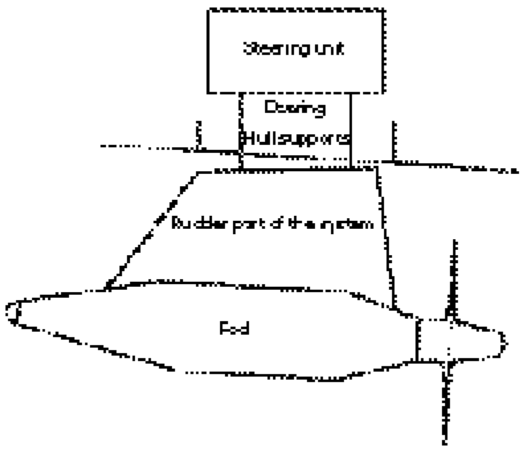


Figure 22: Azimuth propulsion system

11.1.2 Application

The requirements of this Article apply to the scantlings of the hull supports, the rudder part and the pod.

The steering unit and the bearing are to comply with the relevant requirements of the Society's Rules.

11.1.3 Operating conditions

The maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed is to be specified by the Designer. Such maximum angle is generally to be less than 35° on each side.

In general, orientations greater than this maximum angle may be considered by the Society for azimuth propulsion systems during manoeuvres, provided that the orientation values together with the relevant speed values are submitted to the Society for approval.

11.2 Arrangement

11.2.1 Plans to be submitted

In addition to the plans showing the structural arrangement of the pod and the rudder part of the system, the plans showing the arrangement of the azimuth propulsion system supports are to be submitted to the Society for approval. The scantlings of the supports and the maximum loads which act on the supports are to be specified in these drawings.

11.2.2 Locking device

The azimuth propulsion system is to be mechanically lockable in a fixed position, in order to avoid rotations of the system and propulsion in undesirable directions in the event of damage.

11.3 Design loads

11.3.1

The lateral pressure to be considered for scantling of plating and ordinary stiffeners of the azimuth propulsion system is to be determined for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed.

- The total force which acts on the azimuth propulsion system is to be obtained by integrating the lateral pressure on the external surface of the system.
- The calculations of lateral pressure and total force are to be submitted to the Society for information.

11.4 Plating

11.4.1 Plating of the rudder part of the azimuth propulsion system

The thickness of plating of the rudder part of the azimuth propulsion system is to be not less than that obtained, in mm, from the formulae in [5.2.1], in which the term C_R/A is to be replaced by the lateral pressure calculated according to [11.3].

11.4.2 Plating of the pod

The thickness of plating of the pod is to be not less than that obtained, in mm, from the formulae in Ch 6, Sec 1, [3.2.1], where the lateral pressure is to be calculated according to [11.3].

11.4.3 Webs

The thickness of webs of the rudder part of the azimuth propulsion system is to be determined according to [5.2.3], where the lateral pressure is to be calculated according to [11.3].

11.5 Ordinary stiffeners

11.5.1 Ordinary stiffeners of the pod

The scantlings of ordinary stiffeners of the pod are to be not less than those obtained from the formulae in Ch 6, Sec 2, where the lateral pressure is to be calculated according to [11.3].

11.6 Primary supporting members

11.6.1 Analysis criteria

The scantlings of primary supporting members of the azimuth propulsion system are to be obtained by the Designer through direct calculations, to be carried out according to the following requirements:

- the structural model is to include the pod, the rudder part of the azimuth propulsion system, the bearing and the hull supports
- the boundary conditions are to represent the connections of the azimuth propulsion system to the hull structures
- the loads to be applied are those defined in [11.6.2].
- The direct calculation analyses (structural model, load and stress calculation, strength checks) carried out by the Designer are to be submitted to the Society for information.

11.6.2 Loads

The following loads are to be considered by the Designer in the direct calculation of the primary supporting members of the azimuth propulsion system:

- gravity loads
- buoyancy

- maximum loads calculated for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed
- maximum loads calculated for the possible orientations of the system greater than the maximum angleat the relevant speed (see [11.1.3])
- maximum loads calculated for the crash stop of the ship obtained through inversion of the propeller rotation
- maximum loads calculated for the crash stop of the ship obtained through a 180□ rotation of the pod.

11.6.3 Strength check

It is to be checked that the Von Mises equivalent stress □E in primary supporting members, calculated, in N/mm2, for the load cases defined in [11.6.2], is in compliance with the following formula:

$\sigma_E \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable stress, in N/mm^2, to be taken equal to the lesser of the following values:

- 0,275 R_m
- 0,55 R_{eH}

R_m : Tensile strength, in N/mm^2, of the material, defined in [1.4.2]

R_{eH} : Minimum yield stress, in N/mm^2, of the material, defined in [1.4.2]

11.7 Hull supports of the azimuth propulsion system

11.7.1 Analysis criteria

The scantlings of hull supports of the azimuth propulsion system are to be obtained by the Designer through direct calculations, to be carried out in accordance with the requirements in [11.6.1].

11.7.2 Loads

The loads to be considered in the direct calculation of the hull supports of the azimuth propulsion system are those specified in [11.6.2].

11.7.3 Strength check

It is to be checked that the Von Mises equivalent stress □E in hull supports, in N/mm2, calculated for the load cases defined in [11.6.2], is in compliance with the following formula:

$\sigma_E \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable stress, in N/mm^2, equal to:

$$\sigma_{ALL} = 65 / k_r$$

k_r : Material factor, defined in [1.4.2]

Values of σ_E greater than σ_{ALL} may be accepted by the Society on a case-by-case basis, depending on the localisation of σ_E and on the type of direct calculation analysis.

Welcome JBP

Section 2 - BULWARKS AND GUARD RAILS

1. General

1.1 Introduction

1.1.1

The requirements of this Section apply to the arrangement of bulwarks and guard rails provided at boundaries of the freeboard deck, superstructure decks and tops of the first tier of deckhouses located on the freeboard deck.

1.2 General

1.2.1

Efficient bulwarks or guard rails are to be fitted at the boundaries of all exposed parts of the freeboard deck and superstructure decks directly attached to the freeboard deck, as well as the first tier of deckhouses fitted on the freeboard deck and the superstructure ends.

1.2.2

The height of the bulwarks or guard rails is to be at least 1 m from the deck. However, where their height would interfere with the normal operation of the ship, a lesser height may be accepted, if adequate protection is provided and subject to any applicable statutory requirement.

1.2.3

Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

1.2.4

In type B-100 ships, open rails on the weather parts of the freeboard deck for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with Ch 9, Sec 6, [5.5.2] are to be fitted.

1.2.5

In ships with bulwarks and trunks of breadth not less than 0,6 B, which are included in the calculation of freeboard, open rails on the weather parts of the freeboard deck in way of the trunk for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with Ch 9, Sec 6, [5.3.1] are to be fitted.

1.2.6

In ships having superstructures which are open at either or both ends, adequate provision for freeing the space within such superstructures is to be provided.

1.2.7

The freeing port area in the lower part of the bulwarks is to be in compliance with the applicable requirements of Ch 9, Sec 6, [5].

2. Bulwarks

2.1 General

2.1.1

As a rule, plate bulwarks are to be stiffened at the upper edge by a suitable bar and supported either by stays or plate brackets spaced not more than 2,0 m apart.

Bulwarks are to be aligned with the beams located below or are to be connected to them by means of local transverse stiffeners.

As an alternative, the lower end of the stay may be supported by a longitudinal stiffener.

2.1.2

In type B-60 and B-100 ships, the spacing forward of 0,07 L from the fore end of brackets and stays is to be not greater than 1,2 m.

2.1.3

Where bulwarks are cut completely, the scantlings of stays or brackets are to be increased with respect to those given in [2.2].

2.1.4

As a rule, bulwarks are not to be connected either to the upper edge of the sheerstrake plate or to the stringer plate.

Failing this, the detail of the connection will be examined by the Society on a case-by-case basis.

2.2 Scantlings

2.2.1

The gross thickness of bulwarks on the freeboard deck not exceeding 1100 mm in height is to be not less than:

- 6,0 mm for [90] m < L ≤ 120 m
- 6,5 mm for 120 m < L ≤ 150 m
- 7,0 mm for L > 150 m.

Where the height of the bulwark is equal to or greater than 1800 mm, its thickness is to be equal to that calculated for the side of a superstructure situated in the same location as the bulwark.

For bulwarks between 1100 mm and 1800 mm in height, their thickness is to be calculated by linear interpolation.

2.2.2

Bulwark plating and stays are to be adequately strengthened in way of eyeplates used for shrouds or other tackles in use for cargo gear operation, as well as in way of hawserholes or fairleads provided for mooring or towing.

2.2.3
At the ends of partial superstructures and for the distance over which their side plating is tapered into the bulwark, the latter is to have the same thickness as the side plating; where openings are cut in the bulwark at these positions, adequate compensation is to be provided either by increasing the thickness of the plating or by other suitable means.

2.2.4
The gross section modulus of stays in way of the lower part of the bulwark is to be not less than the value obtained, in cm^3, from the following formula:

$Z = 80\, s\, h_B^2$

where:

s : Spacing of stays, in m

h_B : Height of bulwark, in m, measured between its upper edge and the deck.

The actual section of the connection between stays and deck structures is to be taken into account when calculating the above section modulus.

To this end, the bulb or face plate of the stay may be taken into account only where welded to the deck; in this case the beam located below is to be connected by double continuous welding.

For stays with strengthening members not connected to the deck, the calculation of the required minimum section modulus is considered by the Society on a case-by-case basis.

At the ends of the ship, where the bulwark is connected to the sheerstrake, an attached plating having a width not exceeding 600 mm may also be included in the calculation of the actual gross section modulus of stays.

2.2.5
Openings in bulwarks are to be arranged so that the protection of the crew is to be at least equivalent to that provided by the horizontal courses in [3.1.2].

For this purpose, vertical rails or bars spaced approximately 230 mm apart may be accepted in lieu of rails or bars arranged horizontally.

2.2.6
In the case of ships intended for the carriage of timber deck cargoes, the specific provisions of the freeboard regulations are to be complied with.

3. Guard rails

3.1

3.1.1
Where guard rails are provided, the upper edge of sheerstrake is to be kept as low as possible.

3.1.2
The opening below the lowest course is to be not more than 230 mm. The other courses are to be not more than 380 mm apart.

3.1.3

In the case of ships with rounded gunwales or sheerstrake, the stanchions are to be placed on the flat part of the deck.

3.1.4

Fixed, removable or hinged stanchions are to be fitted about 1,5 m apart. At least every third stanchion is to be supported by a bracket or stay.

Removable or hinged stanchions are to be capable of being locked in the upright position.

3.1.5

Wire ropes may only be accepted in lieu of guard rails in special circumstances and then only in limited lengths. Wires are to be made taut by means of turnbuckles.

3.1.6

Chains may only be accepted in short lengths in lieu of guard rails if they are fitted between two fixed stanchions and/or bulwarks.

Chapter 10 – Hull outfitting

Welcome JBP

Section 3 - EQUIPMENT

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

EN : Equipment Number defined in [2.1]

R_{eH} : Minimum yield stress, in N/mm^2 , of the material, defined in Ch 3, Sec 1, [2]

R_m : Tensile strength, in N/mm^2, of the material, defined in Ch 3, Sec 1, [2].

1. General

1.1 General

1.1.1

The requirements in this Section apply to temporary mooring of a ship within or near harbour, or in a sheltered area, when the ship is awaiting a berth, the tide, etc.

Therefore, the equipment complying with the requirements in this Section is not intended for holding a ship off fully exposed coasts in rough weather or for stopping a ship which is moving or drifting.

1.1.2

The equipment complying with the requirements in this Section is intended for holding a ship in good holding ground, where the conditions are such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors is to be significantly reduced.

1.1.3

The Equipment Number (EN) formula for anchoring equipment required here under is based on an assumed current speed of 2.5 m/s, wind speed of 25 m/s and a scope of chain cable between 6 and 10, the scope being the ratio between length of chain paid out and water depth.

1.1.4

It is assumed that under normal circumstances a ship will use one anchor only.

2. Equipment number

2.1 Equipment number

2.1.1 General

All ships are to be provided with equipment in anchors and chain cables (or ropes according to [3.3.5]), to be obtained from Tab 1, based on their Equipment Number EN.

In general, stockless anchors are to be adopted.

For ships with EN greater than 16000, the determination of the equipment will be considered by the Society on a case by case basis.

Table 1: Equipment

Equipment number EN A < EN ≤ B		Stockless anchors		Stud link chain cables for anchors			
		N (1)	Mass per anchor, in kg	Total length, in m	Diameter, in mm		
A	B				Q1	Q2	Q3
50	70	2	180	220,0	14,0	12,5	
70	90	2	240	220,0	16,0	14,0	
90	110	2	300	247,5	17,5	16,0	
110	130	2	360	247,5	19,0	17,5	
130	150	2	420	275,0	20,5	17,5	
150	175	2	480	275,0	22,0	19,0	
175	205	2	570	302,5	24,0	20,5	
205	240	3	660	302,5	26,0	22,0	20,5
240	280	3	780	330,0	28,0	24,0	22,0
280	320	3	900	357,5	30,0	26,0	24,0
320	360	3	1020	357,5	32,0	28,0	24,0
360	400	3	1140	385,0	34,0	30,0	26,0
400	450	3	1290	385,0	36,0	32,0	28,0
450	500	3	1440	412,5	38,0	34,0	30,0
500	550	3	1590	412,5	40,0	34,0	30,0
550	600	3	1740	440,0	42,0	36,0	32,0
600	660	3	1920	440,0	44,0	38,0	34,0
660	720	3	2100	440,0	46,0	40,0	36,0
720	780	3	2280	467,5	48,0	42,0	36,0
780	840	3	2460	467,5	50,0	44,0	38,0
840	910	3	2640	467,5	52,0	46,0	40,0
910	980	3	2850	495,0	54,0	48,0	42,0
980	1060	3	3060	495,0	56,0	50,0	44,0
1060	1140	3	3300	495,0	58,0	50,0	46,0
1140	1220	3	3540	522,5	60,0	52,0	46,0
1220	1300	3	3780	522,5	62,0	54,0	48,0
1300	1390	3	4050	522,5	64,0	56,0	50,0
1390	1480	3	4320	550,0	66,0	58,0	50,0
1480	1570	3	4590	550,0	68,0	60,0	52,0
1570	1670	3	4890	550,0	70,0	62,0	54,0
1670	1790	3	5250	577,5	73,0	64,0	56,0
1790	1930	3	5610	577,5	76,0	66,0	58,0
1930	2080	3	6000	577,5	78,0	68,0	60,0
2080	2230	3	6450	605,0	81,0	70,0	62,0
2230	2380	3	6900	605,0	84,0	73,0	64,0
2380	2530	3	7350	605,0	87,0	76,0	66,0
2530	2700	3	7800	632,5	90,0	78,0	68,0
2700	2870	3	8300	632,5	92,0	81,0	70,0
2870	3040	3	8700	632,5	95,0	84,0	73,0
3040	3210	3	9300	660,0	97,0	84,0	76,0
3210	3400	3	9900	660,0	100,0	87,0	78,0
3400	3600	3	10500	660,0	102,0	90,0	78,0
3600	3800	3	11100	687,5	105,0	92,0	81,0
3800	4000	3	11700	687,5	107,0	95,0	84,0
4000	4200	3	12300	687,5	111,0	97,0	87,0
4200	4400	3	12900	715,0	114,0	100,0	87,0
4400	4600	3	13500	715,0	117,0	102,0	90,0

(1) See [3.2.4].

Equipment number EN A < EN ≤ B		Stockless anchors		Stud link chain cables for anchors			
		N **(1)**	Mass per anchor, in kg	Total length, in m	Diameter, in mm		
A	B				Q1	Q2	Q3
4600	4800	3	14100	715,0	120,0	105,0	92,0
4800	5000	3	14700	742,5	122,0	107,0	95,0
5000	5200	3	15400	742,5	124,0	111,0	97,0
5200	5500	3	16100	742,5	127,0	111,0	97,0
5500	5800	3	16900	742,5	130,0	114,0	100,0
5800	6100	3	17800	742,5	132,0	117,0	102,0
6100	6500	3	18800	742,5		120,0	107,0
6500	6900	3	20000	770,0		124,0	111,0
6900	7400	3	21500	770,0		127,0	114,0
7400	7900	3	23000	770,0		132,0	117,0
7900	8400	3	24500	770,0		137,0	122,0
8400	8900	3	26000	770,0		142,0	127,0
8900	9400	3	27500	770,0		147,0	132,0
9400	10000	3	29000	770,0		152,0	132,0
10000	10700	3	31000	770,0			137,0
10700	11500	3	33000	770,0			142,0
11500	12400	3	35500	770,0			147,0
12400	13400	3	38500	770,0			152,0
13400	14600	3	42000	770,0			157,0
14600	16000	3	46000	770,0			162,0

(1) See [3.2.4].

2.1.2 Equipment Number for ships with perpendicular superstructure front bulkheads

The Equipment Number EN is to be obtained from the following formula:

EN = ? 2/3 + 2 h B + 0,1 A

where:.

Δ : Moulded displacement of the ship, in t, to the summer load waterline,

h : Effective height, in m, from the summer load waterline to the top of the uppermost house, to be obtained in accordance with the following formula:

$$h = a + \Sigma hn$$

When calculating h, sheer and trim are to be disregarded,

a : Freeboard amidships from the summer load waterline to the upper deck, in m,

dP : Height, in m, at the centreline of tier "n" of superstructures or deckhouses having a breadth greater than B/4. Where a house having a breadth greater than B/4 is above a house with a breadth of B/4 or less, the upper house is to be included and the lower ignored,

A : Area, in m2 , in profile view, of the parts of the hull, superstructures and houses above the sum-mer load waterline which are within the length LE and also have a breadth greater than B/4,

LE : Equipment length, in m, equal to L without being taken neither less than 96% nor greater than 97% of the total length of the summer load waterline.

Fixed screens or bulwarks 1,5 m or more in height are to be regarded as parts of houses when determining h and A. In particular, the hatched area shown in Fig 1 is to be included.

The height of hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A.

3. Equipment

3.1 General

3.1.1

All anchoring equipment, towing bitts, mooring bollards, fairlead cleats and eyebolts are to be so constructed and attached to the hull that, in use up to design loads, the integrity of the craft will not be impaired.

3.1.2

The anchoring arrangement is to be such as to prevent the cable from being damaged and fouled. Adequate arrangement is to be provided to secure the anchor under all operational conditions.

3.2 Anchors

3.2.1 General

The scantlings of anchors are to be in compliance with the following requirements.

Anchors are to be constructed and tested in compliance with approved plans.

3.2.2 Ordinary anchors

The required mass for each anchor is to be obtained from Tab 1.

The individual mass of a main anchor may differ by ±7% from the mass required for each anchor, provided that the total mass of anchors is not less than the total mass required in Tab 1.

The mass of the head of an ordinary stockless anchor, including pins and accessories, is to be not less than 60% of the total mass of the anchor.

Where a stock anchor is provided, the mass of the anchor, excluding the stock, is to be not less than 80% of the mass required in Tab 1 for a stockless anchor. The mass of the stock is to be not less than 25% of the mass of the anchor without the stock but including the connecting shackle.

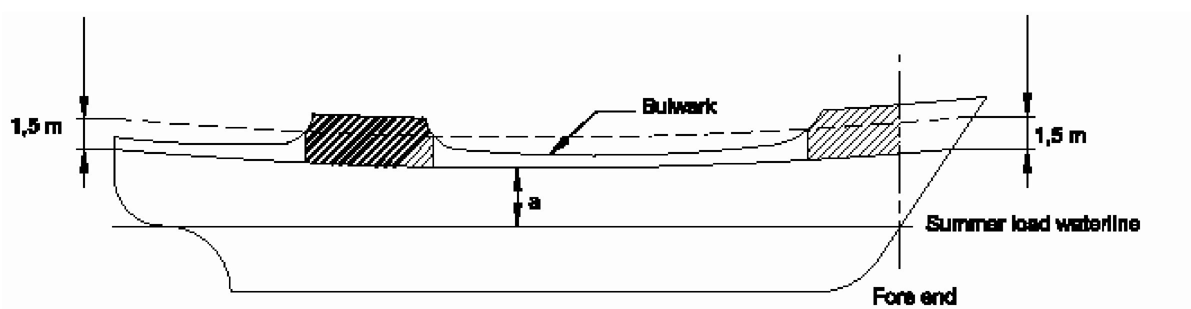


Figure 1: Ships with perpendicular front bulkhead - Effective area of bulwarks or fixed screen to be included in the Equipment Number

3.2.3 High and very high holding power anchors

High holding power (HHP) and very high holding power (VHHP) anchors, i.e. anchors for which a holding power higher than that of ordinary anchors has been proved according to the applicable requirements of the Society's Rules for Materials, do not require prior adjustment or special placement on the sea bottom.

Where HHP or VHHP anchors are used as bower anchors, the mass of each anchor is to be not less than 75% or 50%, respectively, of that required for ordinary stockless anchors in Tab 1.

The mass of VHHP anchors is to be, in general, less than or equal to 1500 kg.

3.2.4 Third anchor

Where three anchors are provided, two are to be connected to their own chain cables and positioned on board always ready for use.

The third anchor is intended as a spare and is not required for the purpose of classification.

3.2.5 Test for high holding power anchors approval

For approval and/or acceptance as a HHP anchor, comparative tests are to be performed on various types of sea bottom.

Such tests are to show that the holding power of the HHP anchor is at least twice the holding power of an ordinary stockless anchor of the same mass.

For approval and/or acceptance as a HHP anchor of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least two anchors of different sizes are to be tested. The mass of the maximum size to be approved is to be not greater than 10 times the maximum size tested. The mass of the smallest is to be not less than 0,1 times the minimum size tested.

3.2.6 Test for very high holding power anchors approval

For approval and/or acceptance as a VHHP anchor, comparative tests are to be performed at least on three types of sea bottom: soft mud or silt, sand or gravel and hard clay or similar compounded material. Such tests are to show that the holding power of the VHHP anchor is to be at least four times the holding power of an ordinary stockless anchor of the same mass or at least twice the holding power of a previously approved HHP anchor of the same mass. The holding power test load is to be less than or equal to the proof load of the anchor, specified in the applicable requirements of the Society's Rules for Materials.

For approval and/or acceptance as a VHHP anchor of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least three anchors of different sizes are to be tested. relevant to the bottom, middle and top of the mass range.

3.2.7 Specification for test on high holding power and very high holding power anchors

Tests are generally to be carried out from a tug. Shore based tests may be accepted by the Society on a case-by-case basis.

Alternatively, sea trials by comparison with a previous approved anchor of the same type (HHP or VHHP) of the one to be tested may be accepted by the Society on a case-by-case basis.

For each series of sizes, the two anchors selected for testing (ordinary stockless and HHP anchors for testing HHP anchors, ordinary stockless and VHHP anchors or, when ordinary stockless anchors are not available, HHP and VHHP anchors for testing VHHP anchors) are to have the same mass.

The length of chain cable connected to each anchor, having a diameter appropriate to its mass, is to be such that the pull on the shank remains practically horizontal. For this purpose a value of the ratio between the length of the chain cable paid out and the water depth equal to 10 is considered normal. A lower value of this ratio may be accepted by the Society on a case-by-case basis.

Three tests are to be carried out for each anchor and type of sea bottom.

The pull is to be measured by dynamometer; measurements based on the RPM/bollard pull curve of tug may, however, be accepted instead of dynamometer readings.

Note is to be taken where possible of the stability of the anchor and its ease of breaking out.

3.3 Chain cables for anchors

3.3.1 Material

The chain cables are classified as grade Q1, Q2 or Q3 depending on the type of steel used and its manufacture.

The characteristics of the steel used and the method of manufacture of chain cables are to be approved by the Society for each manufacturer. The material from which chain cables are manufactured and the completed chain cables themselves are to be tested in accordance with the applicable requirements of the Society's Rules for Materials.

Chain cables made of grade Q1 may not be used with high holding power and very high holding power anchors.

3.3.2 Scantlings of stud link chain cables

The mass and geometry of stud link chain cables, including the links, are to be in compliance with the requirements in the applicable requirements of the Society's Rules for Materials.

The diameter of stud link chain cables is to be not less than the value in Tab 1.

3.3.3 Studless link chain cables

For ships with EN less than 90, studless short link chain cables may be accepted by the Society as an alternative to stud link chain cables, provided that the equivalence in strength is based on proof load, defined in the applicable requirements of the Society's Rules for Materials and that the steel grade of the studless chain is equivalent to the steel grade of the stud chains it replaces, as defined in [3.3.1].

3.3.4 Chain cable arrangement

Chain cables are to be made by lengths of 27,5 m each, joined together by Dee or lugless shackles.

The total length of chain cable, required in Tab 1, is to be divided in approximately equal parts between the two anchors ready for use.

Where different arrangements are provided, they are considered by the Society on a case-by-case basis.

Where the ship may anchor in areas with current speed greater than 2,5 m/s, the Society may require a length of heavier chain cable to be fitted between the anchor and the rest of the chain in order to enhance anchor bedding.

3.3.5 Wire ropes

As an alternative to the stud link or short link chain cables mentioned, wire ropes may be used in the following cases:

- wire ropes for both the anchors, for ship length less than 30 m,

- wire rope for one of the two anchors, for ship length between 30 m and 40 m.

The wire ropes above are to have a total length equal to 1,5 times the corresponding required length of stud link chain cables, obtained from Tab 1, and a minimum breaking load equal to that given for the corresponding stud link chain cable (see [3.3.2]).

A short length of chain cable is to be fitted between the wire rope and the anchor, having a length equal to 12,5m or the distance from the anchor in the stowed position to the winch, whichever is the lesser.

3.4 Attachment pieces

3.4.1 General

Where the lengths of chain cable are joined to each other by means of shackles of the ordinary Dee type, the anchor may be attached directly to the end link of the first length of chain cable by a Dee type end shackle.

A detachable open link in two parts riveted together may be used in lieu of the ordinary Dee type end shackle; in such case the open end link with increased diameter, defined in [3.4.2], is to be omitted.

Where the various lengths of chain cable are joined by means of lugless shackles and therefore no special end and increased diameter links are provided, the anchor may be attached to the first length of chain cable by a special pear-shaped lugless end shackle or by fitting an attachment piece.

3.4.2 Scantlings

The diameters of the attachment pieces, in mm, are to be not less than the values indicated in Tab 2.

Attachment pieces may incorporate the following items between the increased diameter stud link and the open end link:

- swivel, having diameter = 1,2 d
- increased stud link, having diameter = 1,1 d

Where different compositions are provided, they will be considered by the Society on a case-by-case basis.

Table 1: Diameters of attachment pieces

Attachment piece	Diameter, in mm
End shackle	1,4 d
Open end link	1,2 d
Increased stud link	1,1 d
Common stud link	d
Lugless shackle	d
Note 1: d : diameter, in mm, of the common link.	

3.4.3 Material

Attachment pieces, joining shackles and end shackles are to be of such material and design as to provide strength equivalent to that of the attached chain cable, and are to be tested in accordance with the applicable requirements of the applicable requirements of the Society's Rules for Materials.

3.4.4 Spare attachment pieces

A spare pear-shaped lugless end shackle or a spare attachment piece is to be provided for use when the spare anchor is fitted in place.

3.5 Towlines and mooring lines

3.5.1 General

The towlines having the characteristics defined in Tab 3 are intended as those belonging to the ship to be towed by a tug or another ship.

3.5.2 Materials

Towlines and mooring lines may be of wire, natural or synthetic fibre or a mixture of wire and fibre.

The breaking loads defined in Tab 3 refer to steel wires or natural fibre ropes.

Steel wires and fibre ropes are to be tested in accordance with the applicable requirements in the applicable requirements of the Society's Rules for Materials.

3.5.3 Steel wires

Steel wires are to be made of flexible galvanised steel and are to be of types defined in Tab 4.

Where the wire is wound on the winch drum, steel wires to be used with mooring winches may be constructed with an independent metal core instead of a fibre core. In general such wires are to have not less than 186 threads in addition to the metallic core.

Table 1: Towlines and mooring lines

Equipment number EN A< EN ≤ B		Towline (1)		Mooring lines		
A	B	Minimum length, in m	Breaking load, in kN	N (2)	Length of each line, in m	Breaking load, in kN
50	70	180	98,1	3	80	34
70	90	180	98,1	3	100	37
90	110	180	98,1	3	110	39
110	130	180	98,1	3	110	44
130	150	180	98,1	3	120	49
150	175	180	98,1	3	120	54
175	205	180	112	3	120	59
205	240	180	129	4	120	64
240	280	180	150	4	120	69
280	320	180	174	4	140	74
320	360	180	207	4	140	78
360	400	180	224	4	140	88
400	450	180	250	4	140	98
450	500	180	277	4	140	108
500	550	190	306	4	160	123
550	600	190	338	4	160	132
600	660	190	371	4	160	147
660	720	190	406	4	160	157
720	780	190	441	4	170	172
780	840	190	480	4	170	186
840	910	190	518	4	170	201
910	980	190	550	4	170	216
980	1060	200	603	4	180	230

(1) The towline is not compulsory. It is recommended for ships having length not greater than 180 m.
(2) See [3.5.7].

Equipment number EN A< EN ≤ B		Towline (1)		Mooring lines		
A	B	Minimum length, in m	Breaking load, in kN	N (2)	Length of each line, in m	Breaking load, in kN
1060	1140	200	647	4	180	250
1140	1220	200	692	4	180	270
1220	1300	200	739	4	180	284
1300	1390	200	786	4	180	309
1390	1480	200	836	4	180	324
1480	1570	220	889	5	190	324
1570	1670	220	942	5	190	333
1670	1790	220	1024	5	190	353
1790	1930	220	1109	5	190	378
1930	2080	220	1168	5	190	402
2080	2230	240	1259	5	200	422
2230	2380	240	1356	5	200	451
2380	2530	240	1453	5	200	481
2530	2700	260	1471	6	200	481
2700	2870	260	1471	6	200	490
2870	3040	260	1471	6	200	500
3040	3210	280	1471	6	200	520
3210	3400	280	1471	6	200	554
3400	3600	280	1471	6	200	588
3600	3800	300	1471	6	200	612
3800	4000	300	1471	6	200	647
4000	4200	300	1471	7	200	647
4200	4400	300	1471	7	200	657
4400	4600	300	1471	7	200	667
4600	4800	300	1471	7	200	677
4800	5000	300	1471	7	200	686
5000	5200	300	1471	8	200	686
5200	5500	300	1471	8	200	696
5500	5800	300	1471	8	200	706
5800	6100	300	1471	9	200	706
6100	6500			9	200	716
6500	6900			9	200	726
6900	7400			10	200	726
7400	7900			11	200	726
7900	8400			11	200	735
8400	8900			12	200	735
8900	9400			13	200	735
9400	10000			14	200	735
10000	10700			15	200	735
10700	11500			16	200	735
11500	12400			17	200	735
12400	13400			18	200	735
13400	14600			19	200	735
14600	16000			21	200	735

(1) The towline is not compulsory. It is recommended for ships having length not greater than 180 m.
(2) See [3.5.7].

Table 2: Steel wire composition

Breaking load B_L, in kN	Steel wire components		
	Number of threads	Ultimate tensile strength of threads, in N/mm^2	Composition of wire
$B_L < 216$	72	1420 ÷ 1570	6 strands with 7-fibre core
$216 < B_L < 490$	144	1570 ÷ 1770	6 strands with 7-fibre core
$B_L > 490$	216 or 222	1770 ÷ 1960	6 strands with 1-fibre core

3.5.4 Number of mooring lines

When the breaking load of each mooring line is greater than 490kN, either a greater number of mooring lines than those required in Tab 3 having lower strength or a lower number of mooring lines than those required in Tab 3 having greater strength may be used, provided the total breaking load of all lines aboard the ship is greater than the value defined in Tab 3.

In any case, the number of lines is to be not less than 6 and the breaking load of each line is to be greater than 490kN.

3.5.5 Length of mooring lines

The length of individual mooring lines may be reduced by up to 7% of the length defined in Tab 3, provided that the total length of mooring lines is greater than that obtained by adding the lengths of the individual lines defined in Tab 3.

3.5.6 Equivalence between the breaking loads of synthetic and natural fibre ropes

Generally, fibre ropes are to be made of polyamide or other equivalent synthetic fibres.

The equivalence between the breaking loads of synthetic fibre ropes B_{LS} and of natural fibre ropes B_{LN} is to be obtained, in kN, from the following formula:

$$B_{LS} = 7{,}4\,\delta\,B_{LN}^{8/9}$$

where:

δ : Elongation to breaking of the synthetic fibre rope, to be assumed not less than 30%.

3.6 Hawse pipes

3.6.1

Hawse pipes are to be built according to sound marine practice.

Their position and slope are to be so arranged as to create an easy lead for the chain cables and efficient housing for the anchors, where the latter are of the retractable type, avoiding damage to the hull during these operations.

For this purpose chafing lips of suitable form with ample lay-up and radius adequate to the size of the chain cable are to be provided at the shell and deck. The shell plating in way of the hawse pipes is to be reinforced as necessary.

3.6.2

In order to obtain an easy lead of the chain cables, the hawse pipes may be provided with rollers. These rollers are to have a nominal diameter not less than 10 times the size of the chain cable where they are provided with full imprints, and not less than 12 times its size where provided with partial imprints only.

3.6.3

All mooring units and accessories, such as timbler, riding and trip stoppers are to be securely fastened to the Surveyor's satisfaction.

3.7 Windlass

3.7.1 General

The windlass, which is generally single, is to be power driven and suitable for the size of chain cable and the mass of the anchors.

In mechanically propelled ships of less than 200 t gross tonnage, a hand-operated windlass may be fitted. In such case it is to be so designed as to be capable of weighing the anchors in a reasonably short time.

The windlass is to be fitted in a suitable position in order to ensure an easy lead of the chain cables to and through the hawse pipes. The deck in way of the windlass is to be suitably reinforced.

3.7.2 Assumptions for the calculation of the continuous duty pull

The calculation of the continuous duty pull P_C that the windlass unit prime mover is to be able to supply is based on the following assumptions:

- ordinary stockless anchors,
- wind force equal to 6 on Beaufort Scale,
- water current velocity 3 knots,
- anchorage depth 100 m,
- PC includes the influences of buoyancy and hawse pipe efficiency; the latter is assumed equal to 70%,
- the anchor masses assumed are those defined in the applicable requirements of the Society's Rules for Materials, excluding tolerances,
- only one anchor is assumed to be raised at a time.

Owing to the buoyancy, the chain masses assumed are smaller than those defined in the applicable requirements of the Society's Rules for Materials, and are obtained, per unit length of the chain cable, in kg/m, from the following formula:

$m_L = 0,0218\ d^2\ d$

where d is the chain cable diameter, in mm.

3.7.3 Calculation of the continuous duty pull

According to the assumptions in [3.7.2], the windlass unit prime mover is to be able to supply for a least 30 minutes a continuous duty pull PC to be obtained, in kN, from Tab 5.

Table 1: Continuous duty pull

Material of chain cables	Continuous duty pull, in kN
Mild steel	$P_C = 0,0375\ d^2$
High tensile strength steel	$P_C = 0,0425\ d^2$
Very high tensile strength steel	$P_C = 0,0475\ d^2$
Note 1: d : chain cable diameter, in mm.	

3.7.4 Temporary overload capacity

The windlass unit prime mover is to provide the necessary temporary overload capacity for breaking out the anchor.

The temporary overload capacity, or short term pull, is to be not less than 1,5 times the continuous duty pull P_C and it is to be provided for at least two minutes.

The speed in this overload period may be lower than the nominal speed specified in [3.7.5].

3.7.5 Nominal hoisting speed

The nominal speed of the chain cable when hoisting the anchor and cable, to be assumed as an average speed, is to be not less than 0,15 m/s.

The speed is to be measured over two shots of chain cable during the entire trip; the trial is to commence with 3 shots (82,5 m) of chain fully submerged.

3.7.6 Windlass brake

A windlass brake is to be provided having sufficient capacity to stop the anchor and chain cable when paying out the latter with safety, in the event of failure of the power supply
to the prime mover. Windlasses not actuated by steam are also to be provided with a non-return device.

A windlass with brakes applied and the cable lifter declutched is to be able to withstand a pull of 45% of the breaking load of the chain without any permanent deformation of the stressed parts or brake slip.

3.7.7 Chain stoppers

Where a chain stopper is fitted, it is to be able to withstand a pull of 80% of the breaking load of the chain.

Where a chain stopper is not fitted, the windlass is to be able to withstand a pull of 80% of the breaking load of the chain without any permanent deformation of the stressed part or brake slip.

3.7.8 Green sea loads

For ships of length 80 m or more, where the height of the exposed deck in way of the item is less than 0,1L or 22 m above the summer load waterline, whichever is the lesser, the securing devices of windlasses located within the forward quarter length of the ship are to resist green sea forces.

The green sea pressure and associated areas are to be taken equal to (see Fig 2):

- 200 kN/m^2 normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction,
- 150 kN/m^2 parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of f times the projected area in this direction,

where:

f = 1+ B/H, but not greater than 2,5

B : Width of windlass measured parallel to the shaft axis,

H : Overall height of windlass.

Where mooring winches are integral with the anchor wind-lass, they are to be considered as part of the windlass.

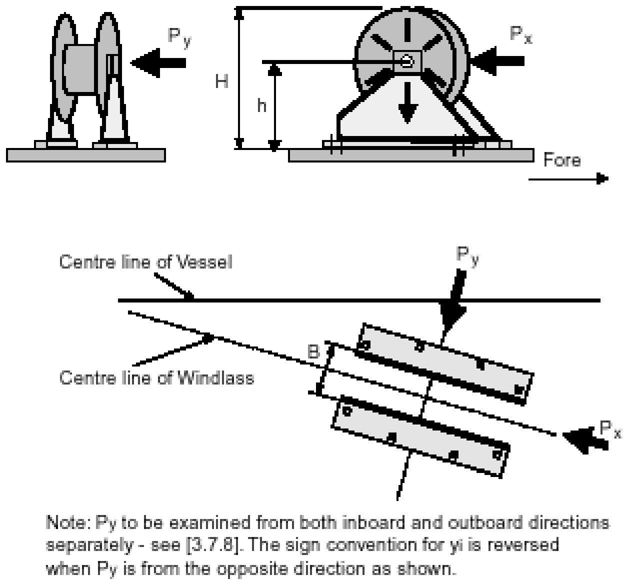


Figure 1: Direction of Forces and Weight *(1/1/2004)*

3.7.9 Forces in the securing devices of windlasses due to green sea loads

Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated by considering the green sea loads specified in [3.7.8].

The windlass is supported by N bolt groups, each containing one or more bolts (see also Fig 3).

The axial force R_i in bolt group (or bolt) i, positive in tension, is to be obtained, in kN, from the following formulae:

$$R_{xi} = P_x h_{xi} A_i / I_x$$

$$R_{yi} = P_y h_{yi} A_i / I_y$$

$$R_i = R_{xi} + R_{yi} - R_{si}$$

where:

Px : Force, in kN, acting normal to the shaft axis

Py : Force, in kN, acting parallel to the shaft axis, either inboard or outboard, whichever gives the greater force in bolt group i

H : Shaft height, in cm, above the windlass mounting

xi, yi : x and y co-ordinates, in cm, of bolt group i from the centroid of all N bolt groups, positive in the direction opposite to that of the applied force

Ai : Cross-sectional area, in cm 2 , of all bolts in group i

Ix = ΣAi xi2 for N bolt groups

Iy = ΣA i yi2 for N bolt groups

R I : Static reaction, in kN, at bolt group i, due to weight of windlass.

Shear forces F_{xi} , F_{yi} applied to the bolt group i, and the resultant combined force F_i are to be obtained, in kN, from the following formulae:

$$F_{xi} = (P_i - \alpha g M) / N$$

$$F_{yi} = (P_y - \alpha g M) / N$$

$$F_i = (F_{xi}^2 + F_{yi}^2)^{0,5}$$

where:

α : Coefficient of friction, to be taken equal to 0,5

M : Mass, in t, of windlass

N : Number of bolt groups.

Axial tensile and compressive forces and lateral forces calculated according to these requirements are also to be considered in the design of the supporting structure.

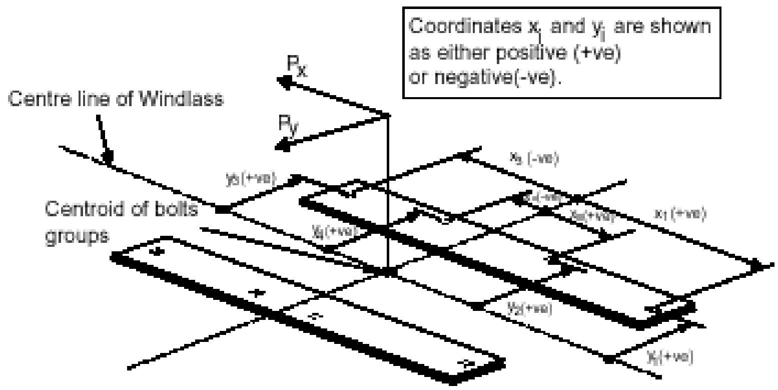


Figure 1: Sign Convention

3.7.10 Strength criteria for windlass subject to anchor and chain loads

The stresses on the parts of the windlass, its frame and stopper are to be less than the yield stress of the material used.

For the calculation of the above stresses, special attention is to be paid to:

- stress concentrations in keyways and other stress raisers,
- dynamic effects due to sudden starting or stopping of the prime mover or anchor chain,
- calculation methods and approximation.

3.7.11 Strength criteria for securing devices of windlass

Tensile axial stresses in the individual bolts in each bolt group i are to be calculated according to the requirements specified in [3.7.9]. The horizontal forces F_{xi} and F_{yi} , to be calculated according to the requirements specified in [3.7.9], are normally to be reacted by shear chocks.

Where "fitted" bolts are designed to support these shear forces in one or both directions, the equivalent Von Mises stress σ, in N/mm^2 , in the individual bolt is to comply with following formula:

$$\sigma \leq 0,5\ \sigma_{BPL}$$

where σ_{BPL} is the stress in the bolt considered as being loaded by the proof load.

Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculations.

3.7.12 Connection with deck

The windlass, its frame and the stoppers are to be efficiently bedded to the deck.

3.8 Chain stoppers

3.8.1

A chain stopper is generally to be fitted between the windlass and the hawse pipe in order to relieve the windlass of the pull of the chain cable when the ship is at anchor. A chain stopper is to be capable of withstanding a pull of 80% of the breaking load of the chain cable. The deck at the chain stopper is to be suitably reinforced.

For the same purpose, a piece of chain cable may be used with a rigging screw capable of supporting the weight of the anchor when housed in the hawse pipe or a chain tensioner. Such arrangements are not to be considered as chain stoppers.

3.8.2

Where the windlass is at a distance from the hawse pipes and no chain stoppers are fitted, suitable arrangements are to be provided to lead the chain cables to the windlass.

3.9 Chain locker

3.9.1

The capacity of the chain locker is to be adequate to stow all chain cable equipment and provide an easy direct lead to the windlass.

3.9.2

Where two chains are used, the chain lockers are to be divided into two compartments, each capable of housing the full length of one line.

3.9.3

The inboard ends of chain cables are to be secured to suitably reinforced attachments in the structure by means of end shackles, whether or not associated with attachment pieces.

Generally, such attachments are to be able to withstand a force not less than 15% of the breaking load of the chain cable.

In an emergency, the attachments are to be easily released from outside the chain locker.

3.9.4

Where the chain locker is arranged aft of the collision bulkhead, its boundary bulkheads are to be watertight and a drainage system is to be provided.

3.10 Fairleads and bollards

3.10.1

Fairleads and bollards of suitable size and design are to be fitted for towing, mooring and warping operations.

4. Shipboard fittings and supporting hull structures associated with towing and mooring

4.1 Towing

4.1.1 Application

These requirements apply to all classed sea-going ships of 500 GT and above. The strength of shipboard fittings i.e. bollard/fairlead/chocks used for normal and emergency operations at bow, sides and stern and their supporting structures are to comply with the following requirements

4.1.2 Arrangement

Shipboard fittings for towing are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the towing load.

4.1.3 Load considerations

The design load to be used are specified below:

- Not less than twice the maximum breaking strength of the tow line anticipated to be used throughout the service life of the ship is to be applied.
- *Where the maximum breaking strength of the tow line is not provided then, at a minimum, 1,5 times the breaking strength of the tow line for the ship's corresponding EN, as specified in Table 3, is to be applied.*

4.1.4 Deck fittings

The size of deck fittings is to be in accordance with a standard (e.g. ISO3913 Shipbuilding Welded Steel Bollards) recognized by the Society. The design load used to assess deck fittings and their attachment to the ship are to be in accordance with [4.1.3].

4.1.5 Supporting hull structure: Arrangement

Arrangement of the reinforced members (carling) beneath is to consider any variation of direction (laterally and vertically) of the towing forces (which is to be not less than the Design Load as [4.1.3] acting through the arrangement of connection to the towing fittings.

4.1.6 Supporting hull structure: Acting point of towing force

The acting point of the towing force on deck fittings is to be taken at the attachment point of a towing line.

4.1.7 Supporting hull structure: Allowable stress

The allowable bending stress is to be taken equal to R_{eH} of the material used.

The allowable shearing stress is to be taken as the 0,6 R_{eH} of the material used.

4.1.8 Safe Working Load (SWL)

The SWL is not to exceed one half of the design load per [4.1.3].

The SWL of each fitting that is designed for normal and emergency use with tugs is to be marked (by weld bead) on the deck fittings for towing.

The SWL is to be noted in the General Arrangement drawing or other information available on board for the guidance of Master.

4.1.9 Emergency Towing Arrangement

Ships subject to SOLAS Reg. II-1/3-4 are to comply with that regulation and MSC.35(63) as may be amended.

4.2 Mooring

4.2.1 Application

Mooring equipment is to be in accordance with the requirements in [4.1].

However when mooring equipment is only used for mooring, the requirements in [4.2] can be substituted for the corresponded requirements in [4.1].

4.2.2 Load considerations

The design load to be used are specified below:

- Not less than twice the maximum breaking strength of the mooring line anticipated to be used throughout the service life of the ship is to be applied.
- Where the maximum breaking strength of the tow line is not provided then, at a minimum, 1,5 times the breaking strength of the tow line for the ship's corresponding EN, as specified in Table 3, is to be applied.

Welcome JBP

Section 1 – WELDING

1. General

1.1 Application

1.1.1

The requirements of this Section apply to the preparation, execution and inspection of welded connections in hull structures.

They are to be complemented by the criteria given in the Society's rules or guide for welding.

1.1.2

Welding of hull parts is to be carried out by approved welders only.

1.1.3

Welding procedures and welding consumables approved for the types of connection and parent material in question are to be used.

1.1.4

Welding of connections is to be executed according to the approved plans.

1.1.5

The quality standard adopted by the shipyard is to be submitted to the Society and it applies to all welded connections unless otherwise specified on a case by case basis.

1.1.6

Completed weld joints are to be to the satisfaction of the attending Surveyor.

1.1.7

Non-destructive examination (NDE) for weld is to be carried out at the position indicated by the test plan in order to ensure that the welds are free from cracks and internal harmful imperfections and defects.

1.2 Welding consumables and procedures

1.2.1

Welding consumables adopted are to be approved by the Society. The requirements for the approval of welding procedure are given in IACS UR/W17, W23 and W26 or the Society's rules or guide for welding.

1.2.2

The welding procedures adopted are to be approved by the Society. The requirements for the approval of welding consumable are given in the Society's rules or guide for welding.

1.2.3
Suitable welding consumables are to be selected depending on the kind and grade of materials. The requirements of the selection of welding consumables are given in the Society's rules or guide for welding.

1.3 Welders and NDE operators

1.3.1 Welders
Manual and semi-automatic welding is to be performed by welders certified by the Society as specified in the rules or guide for welding.

1.3.2 Automatic welding operators
Personnel manning automatic welding machines and equipment are to be competent and sufficiently trained and certified by the Society as specified in the rules or guide for welding.

1.3.3 NDE operator
NDE is to be carried out by qualified personnel certified by the Society or by recognized bodies in compliance with appropriate standards.

1.4 Documentation to be submitted

1.4.1
The welding application plan to be submitted for approval shall contain the necessary data relevant to the fabrication by welding of the structures, kinds of welding procedure applied, welding position, etc.

1.4.2
The NDE plan to be submitted for approval shall contain the necessary data relevant to the locations and number of examinations, welding procedure(s) applied, method of NDE applied, etc.

2. Types of welded connections

2.1 General

2.1.1
The type of connections and the edge preparation are to be appropriate to the welding procedure adopted.

2.2 Butt welding

2.2.1 General
In general, butt connections of plating are to be full penetration, welded on both sides except where special welding procedures approved by the Society is applied.

2.2.2 Welding of plates with different thicknesses
In the case of welding of plates with a difference in gross thickness equal to or greater than 4 mm, the thicker plate is normally to be tapered. The taper shall have a length of not less than 4 times the difference in gross thickness.

2.2.3 Edge preparation, root gap

Edge preparations and root gaps are to be in accordance with the adopted welding procedure and relevant bevel preparation.

2.3 Tee or cross joints

2.3.1 General

The connections of primary supporting members and stiffener webs to plating as well as plating abutting on another plating, are normally to be made by fillet welding as shown Fig 1.

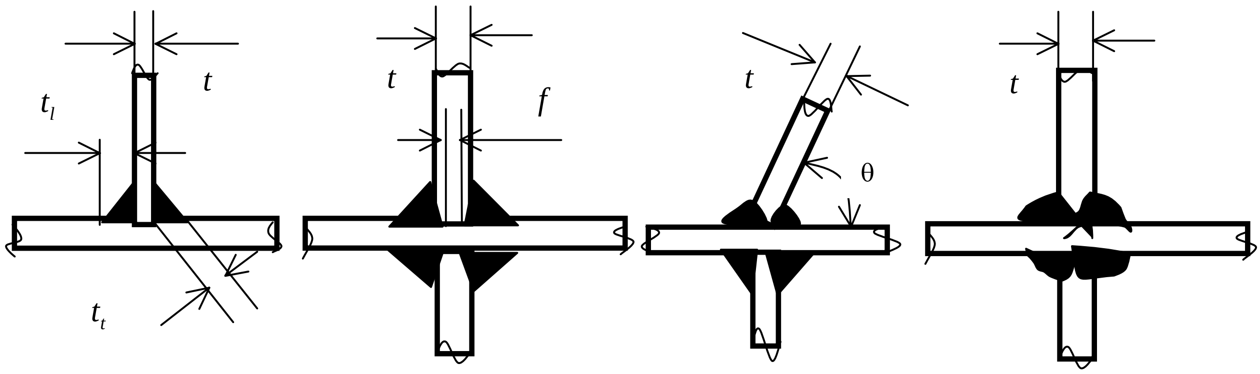


Figure 1: Tee or Cross joints

t : As-built thickness of abutting plate, in mm

f : Unwelded root face, in mm. In general, $f \le t/3$ (In the sketch the arrow "f" indicating the unwelded root face should be placed inwards)

t_l : Leg length of fillet weld, in mm

t_t : Throat thickness, in mm

2.4 Full penetration welds

2.4.1 Application

Full penetration welds are in any case to be used in the following connections:

- Rudder horns and shaft brackets to shell structure
- Vertical corrugated bulkhead to inner bottom plating that are situated in the cargo area and arranged without lower stool
- Vertical corrugated bulkhead to top plating of lower stool
- Pillars to plating member, in case the stress acting on the pillar is tension
- For bulk carriers:
  - (1) In case where shedder plates are fitted at the lower end of corrugate bulkhead, the shedder plates are to be welded to the corrugation and the top plate of the lower stool by one side penetration welds or equivalent.
  - (2) The lower stool side plating is to be connected to the lower stool top plating and the inner bottom plating by full penetration welds. Deep penetration welds may be accepted.

(3) The supporting floors are to be connected to the inner bottom plating by full penetration welds. Deep penetration welds may be accepted.

2.4.2 Edge preparation

Generally, adequate groove angle between 40 and 60 degrees and root opening is to be taken and back gouging for both side welding is required.

2.5 Fillet welds

2.5.1 Kinds and size of fillet welds and their applications

Kinds and size of fillet welds for thickness of abutting plating up to 50 mm are classed into 4 categories as given in Tab 1 and their application to hull construction is to be as required by Tab.2

Table 1: Kinds and sizes of fillet welds

Class	Kinds of fillet welds	Actual gross thickness of abutting plate, t, in mm	Leg length of Fillet weld, in mm [1]	Length of fillet welds, in mm	Pitch, in mm
F0	Double continuous weld		$0.7t$		
F1	Double continuous weld	$t \le 10$	$0.50t + 1.0$		
		$10 \le t < 20$	$0.4t + 2.0$		
		$20 \le t$	$0.3t + 4.0$		
F2	Double continuous weld	$t \le 10$	$0.4t + 1.0$		
		$10 \le t < 20$	$0.3t + 2.0$		
		$20 \le t$	$0.2t + 4.0$		
F3	Double continuous weld	$t \le 10$	$0.30t + 1.0$		
		$10 \le t < 20$	$0.2t + 2.0$		
		$20 \le t$	$0.1t + 4.0$		
F4	Intermittent weld		Same as F1	75	300

Note:

1) Leg length of fillet welds is made fine adjustments corresponding to the corrosion addition t_c specified in Table 1 Chapter 3 Section 3 as follows.

tc > 3 + 0.5 mm

tc < 1 -0.5 mm

For zone “ a “ of side frame as shown in Ch 3, Sec 6 Fig 16 , the weld throat is to be 0.44 t.

For zone “ b “ of side frame as shown in Ch 3, Sec 6 Fig 16, the weld throat is to be 0.4 t.

Where t is as-built thickness of the thinner of two connected members.

Table 2: Application of fillet welds

Hull area	Connection: Of	Connection: To		Kinds of fillet welds
General, unless otherwise specified in the table	Watertight plate	Boundary plating		F1
	Brackets at ends of members			F1
	Ordinary stiffener	Deep tank bulkheads		F3
		Cut-out in way of primary supporting members		F2
	Web of ordinary stiffener	Plating		F4
		Face plates of built-up stiffeners	At ends (15% of span)	F2
			Elsewhere	F4
	End of Primary supporting members and ordinary stiffeners	Deck plate, shell plate, inner bottom plate, bulkhead plate		F0
Bottom and double bottom	Ordinary stiffener			F3
	Center girder	Shell plates in strengthened bottom forward		F1
		Inner bottom plate and shell plate except the above		F2
	Side girder including intercostal plate			F3
				F3
				F3
	Floor	Shell plates and inner bottom plates	For two frame spaces at the ends	F2
		Center girder and side girders in way of hopper tanks		F2
		Elsewhere		F3
	Bracket on center girder	Center girder, inner bottom and shell plates		F2
	Web stiffener	Floor and girder		F3
Side and inner side in double side structure	Web of primary supporting members	Side plating, inner side plating and web of primary supporting members		F2
Side frame of single side structure	Side frame and end bracket	Side shell plate		F1
	Tripping bracket	Side shell plate and side frame		F1
Deck	Strength deck, $t \geq 13$	Side shell plating within 0.6 L midship		Deep penetration
		Elsewhere		F1
	Strength deck, $t < 13$	Side shell plating		F1
	Other deck	Side shell plating		F2
		Ordinary stiffeners		F4
	ordinary stiffener and intercostal girder	Deck plating		F3
	Hatch coamings	Deck plating	At corners of hatchways for 15 % of the hatch length	F1
			Elsewhere	F2
	Web stiffeners	Coaming webs		F4

Hull area	Connection			Kinds of fillet welds
	Of	To		
Bulkheads	Non-watertight bulkhead structure	Boundaries	Swash bulkheads	F3
	Ordinary stiffener	Bulkhead plating	At ends (25% of span), where no end brackets are fitted	F1
Primary supporting members	Web plate and girder plate	Shell plating, deck plating, inner bottom plating, bulkhead	At end (15 % of span)	F1
			Elsewhere	F2
		Face plate	In tanks, and located within 0.125 L from fore peak	F2
			Face area exceeds 65 cm^2	F2
			Elsewhere	F3
After peak	Internal members	Boundaries and each other		F2
Seating	Girder and bracket	Bed plate	In way of main engine, thrust bearing, boiler bearers and main generator engines	F1
		Girder plate	In way of main engine and thrust bearing	F1
		Inner bottom plate and shell	In way of main engine and thrust bearing	F2
Super-structure	External bulkhead	Deck		F1
Pillar	Pillar	Heal and head		F1
Ventilator	Coaming	Deck		F1
Rudder	Rudder frame	Vertical frames forming main piece		F1
		Rudder plate		F3
		Rudder frames except above		F2

2.5.2 Intermittent welds

Where double continuous fillet welds in lieu of intermittent welds are applied, leg length of fillet welds is to be of class F2.

2.5.3 Size of fillet weld for abutting plating with small angle

Where the angle between an abutting plate and the connected plate is not 90 degrees as shown in Figure 11.2, the size of fillet welds for the side of larger angle is to be increased in accordance with the following formula.

$$t_l' = t_l \frac{1}{\sqrt{2}\sin\left(\frac{\varphi}{2}\right)}$$

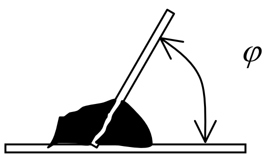


Figure 2: Connecting angle

2.5.4 Deep penetration welds

When deep penetration welds are applied, established by a welding procedure test, the required leg length of fillet welds may be reduced by 15% of that required in Table 11.1.

2.6 Lap joint welds

2.6.1 General

Lap joint welds may be adopted in very specific cases subject to the approval of the Society. Lap joint welds may be adopted for the followings:

- peripheral connections of doublers
- internal structural elements subject to very low stresses

2.6.2 Fillet welds

Lap joints are to have the fillet size of class F1.

2.7 Slot welds

2.7.1 General

Slot welds may be adopted in very specific cases subject to the approval of the Society. However, slot welds of doublers on the outer shell and strength deck is not permitted within 0.6 L amidships.

2.7.2 Size of fillet welds

The slot welds are to have adequate shape to permit a thoroughly fused bead to be applied all around the bottom edge of the opening. The size of fillet welds is to be class F1 and spacing of slots is to be as determined by the Society on a case by case basis.

3. Inspection and checks

To be completed

Chapter 11 – Construction and welding

Welcome JBP

Section 2 – TESTING OF COMPARTMENT

1. General

1.1 Definitions

1.1.1

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

1.1.2

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

1.1.3

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

1.1.4

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

1.1.5

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

1.1.6

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

1.2 Application

1.2.1

The following requirements determine the testing conditions for:

- tanks, including independent tanks,
- watertight or weathertight structures.

1.2.2

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

1.2.3
Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion so that any subsequent work not impair the strength and tightness of the structure.

2. Testing methods

2.1 Structural testing

2.1.1
Structural testing may be carried out after application of the shop primer.

2.1.2
Structural testing may be carried out after the protective coating has been applied, provided that one of the following two conditions is satisfied:

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

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

2.1.3
In absence of leak testing, protective coating should be applied after the structural testing of:

- all erection welds, both manual and automatic,
- all manual fillet weld connections on tank boundaries and manual penetration welds.

2.2 Leak testing

2.2.1
Where leak testing is carried out, in accordance with Table 1, an air pressure of 0.15 10^5 Pa is to be applied during the test.

2.2.2
Prior to inspection, it is recommended that the air pressure in the tank is raised to 0.20 10^5 Pa and kept at this level for about 1 hour to reach a stabilized state, with a minimum number of personnel in the vicinity of the tank, and then lowered to the test pressure.

2.2.3
Individual Societies may accept that the test is conducted after the pressure has reached a stabilized state at 0.20 10^5 Pa, without lowering pressure, provided they are satisfied of the safety of the personnel involved in the test.

2.2.4
Welds are to be coated with an efficient indicating liquid.

2.2.5
A U-tube filled with water up to a height corresponding to the test pressure is to be fitted to avoid overpressure of the compartment tested and verify the test pressure. The U-tube should have a cross section larger than that of the pipe supplying air.

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

2.2.6

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

2.2.7

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

2.3 Hose testing

2.3.1

When hose testing is required to verify the tightness of the structures, as defined in Table 1, the minimum pressure in the hose, at least equal to $2.0\ 10^5$ Pa, is to be applied at a maximum distance of 1.5 m. The nozzle diameter is not to be less than 12 mm.

2.4 Hydropneumatic testing

2.4.1

When hydropneumatic testing is performed, the same safety precautions as for leak testing are to be adopted.

2.5 Other testing methods

2.5.1

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

3. Testing requirements

3.1 General

3.1.1

General testing requirements for testing are given in Table 1.

Table 1: General testing requirements

Item number	Structural to be tested	Type of testing	Structural test pressure	Remarks
1	Double bottom tanks	Structural testing [1]	The greater of the following: • head of water up to the top of overflow • head of water up to the margin line	Tank boundaries tested from at least one side
2	Double side tanks	Structural testing [1]	The greater of the following: • head of water up to the top of overflow • 2.4 m head of water above highest point of tank	Tank boundaries tested from at least one side
3	Tank bulkheads, deep tanks	Structural testing [1]	The greater of the following: [2] • head of water up to the top of overflow • 2.4 m head of water above highest point of tank • setting pressure of the safety relief valves, where relevant	Tank boundaries tested from at least one side
	Fuel oil bunkers	Structural testing		
4	Ballast holds in bulk carrier	Structural testing [1]	The greater of the following: • head of water up to the top of overflow • 0.90 m head of water above top of hatch	
5	Fore peak and after peak used as tank	Structural testing	The greater of the following: • head of water up to the top of overflow • 2.4 m head of water above highest point of tank	Tank of the after peak carried out after the stern tube has been fitted
	Fore peak not used as tank	Refer to SOLAS Ch. II.1 Reg.14		
	Aft peak not used as tank	Leak testing		
6	Cofferdams	Structural testing [3]	The greater of the following: • head of water up to the top of overflow • 2.4 m head of water above highest point of tank	
7	Watertight bulkheads	Refer to SOLAS Ch.II.1 Reg.14[4]		
8	Watertight doors below freeboard or bulkhead deck	Refer to SOLAS Ch. II.1 Reg.18		
9	Double plate rudder	Leak testing		
10	Shaft tunnel clear of deep tanks	Hose testing		
11	Shell doors	Hose testing		

Item number	Structural to be tested	Type of testing	Structural test pressure	Remarks
12	Watertight hatchcovers of tanks in bulk carriers	Hose testing		
	Watertight hatchcovers of tanks in combination carriers	Structural testing [1]	The greater of the following: • 2.4 m head of water above highest point of tank • setting pressure of the safety relief valves, where relevant	At least every 2nd hatch cover are to be tested
13	Watertight hatchcovers and closing appliances	Hose testing		
14	Chain locker (if aft of collision bulkhead)	Structural testing	Head of water up to the top	
15	Independent tanks	Structural testing	Head of water up to the top of overflow, but not less than 0.9 m	
16	Ballast ducts	Structural testing	Ballast pump maximum pressure	

Note:

1) Leak or hydropneumatic testing may be accepted under the conditions specified in 2.2, provided that at least one tank for each type is structurally tested, to be selected in connection with the approval of the design. In general, structural testing need not be repeated for subsequent vessels of series of identical newbuildings. This relaxation does not apply to cargo space boundaries in tankers and combination carriers and tanks for segregated cargoes or pollutants. If the structural test reveals weakness or severe faults not detected by the leak test, all tanks are to be structurally tested.
2) Where applicable, the highest point of tank is to be measured to the deck and excluding hatches. In holds for liquid cargo or ballast with large hatch covers, the highest point of tanks is to be taken at the top of hatch.
3) Leak or hydropneumatic testing may be accepted under the conditions specified in 2.2 when, at the Society discretion, the latter is considered significant also in relation to the construction techniques and the welding procedures adopted.
4) When hose test cannot be performed without damaging possible outfitting (machinery, cables, switchboards, insulation, etc.) already installed, it may be replaced, at the Society discretion, by a careful visual inspection of all the crossings and weld joints; where necessary, dye penetrant test or ultrasonic test may be required.

Chapter 12 – Ships in Operation Renewal Criteria

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SECTION UNDER DEVELOPMENT

Section 1 - MAINTENANCE OF CLASS, THICKNESS MEASUREMENTS

1. General

1.1 Aim of the Chapter

1.1.1

The survey requirements for the maintenance of class of bulk carriers are given in UR Z 10.2 for single side skin bulk carriers and UR Z 10.5 for double side skin bulk carriers.

Thickness measurements are a major part of surveys to be carried out for the maintenance of class, and the analysis of

these measurements is a prominent factor in the determination and extent of the repairs and renewals of the ship's structure.

1.1.2

This Chapter is intended to provide Owners, companies performing thickness measurements and the Society's Surveyors with a uniform means with a view to fulfilling Rule requirements for thickness measurements. In particular, it will enable all the above-mentioned parties to carry out:

- the planning and preparation
- the determination of extent and location, and
- the analysis

of the thickness measurements, in cooperation.

1.1.3

This Chapter also takes into account specific requirements for thickness measurements relevant to close-up surveys within the scope of the Enhanced Survey Program (ESP) of single side skin bulk carriers and double side skin bulk carriers.

1.2 Definition

1.2.1 General corrosion

The status of corrosion mentioned below is to be treated as uniform corrosion

(1) Corrosion extending throughout frame

(2) Corrosion extending through the width of the plate (line corrosion in frames, floors, and beams, and linear corrosion in the area between floors, frames and beams)

(3) Pitting and local corrosion extending for more than 70% of the area of the plate (refer to the figure 1 below)

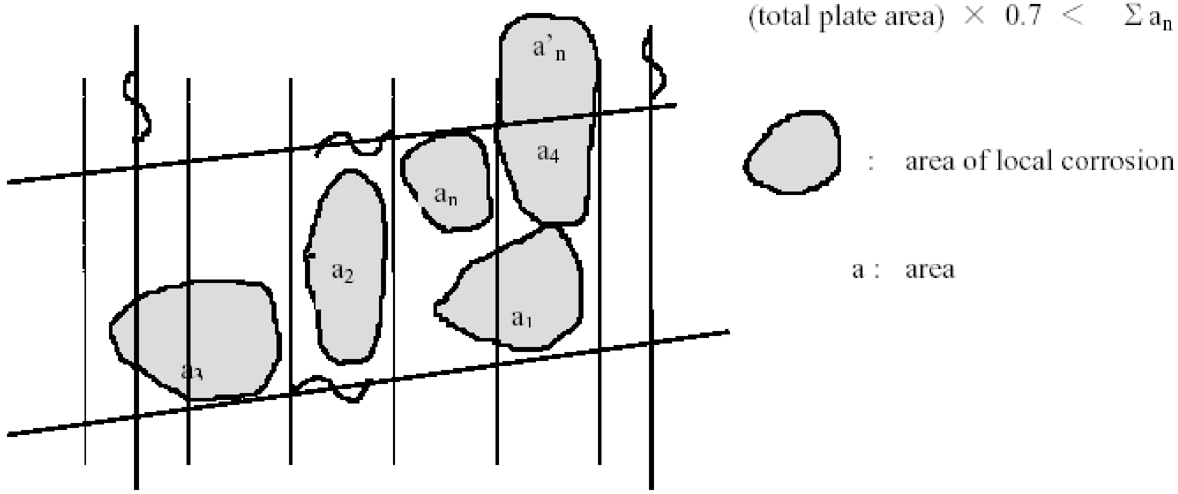
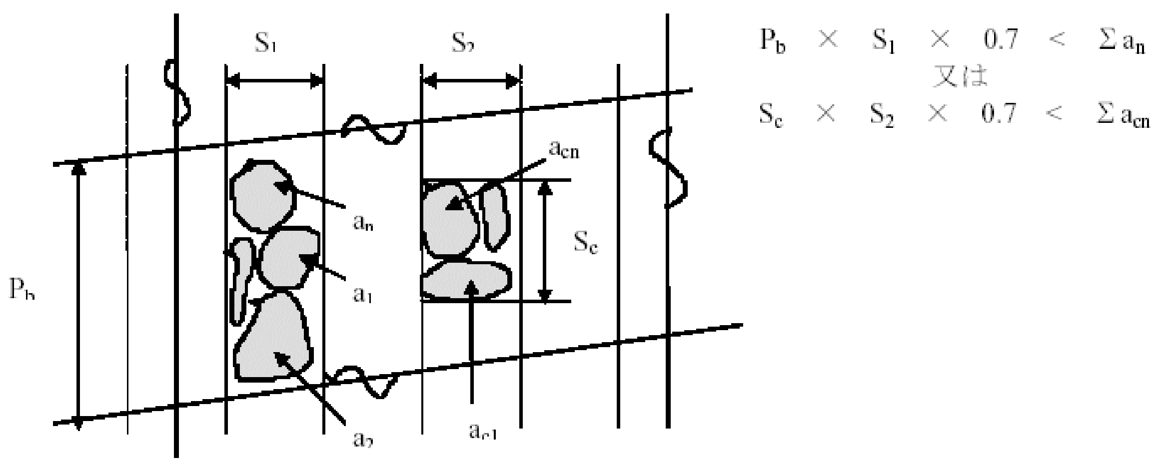


Figure 1: General corrosion (Uniform corrosion)

1.2.2 Local corrosion

Local corrosion is defined as the corrosion other than general corrosion such as pitting corrosion and grovving. However, if the status of local corrosion is corresponding to the case shown in Figure 2, this local corrosion is treated as the general corrosion.



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SECTION UNDER DEVELOPMENT

Section 2 - REQUIREMENTS FOR THICKNESS MEASUREMENTS AND ACCEPTANCE CRITERIA

1. General

1.1

Separate Articles of this section provide the following information:

- references to rule requirements and some additional information on the extent of the thickness measurements to be performed during surveys (see [2.1] and [2.2])
- locations of the measurements for the main parts of the ship (see [2.3])
- how to analyse the results of thickness measurements (see [3]).

Tables are also given to detail the above items. The sketches are given as an example to illustrate the requirements.

2. Rule requirements for the extent of measurements and the determination of locations

2.1 General

2.1.1

For the maintenance of class, thickness measurements may be required during annual, intermediate and class renewal surveys.

Tab 1 gives the references to the minimum requirements for thickness measurements related to the different types of surveys.

Some additional explanations are also given about the wording used in the Rules as well as the general principles of the required thickness measurements during class renewal surveys.

Table 1:References to rule requirements related to thickness measurements

TYPE OF SURVEY		
CLASS RENEWAL	INTERMEDIATE	ANNUAL
Outside the cargo length area: UR Z 7, 2.2.11 and UR Z 7 Table 1:systematic measurements and suspect areas. Where substantial corrosion is found (UR Z 7,2.2.12), the extent of thickness measurements may be increased to the Surveyor's satisfaction, using UR Z 7,Table 2 as guidance	**Outside the cargo length area:** Thickness measurements to be taken if deemed necessary by the Surveyor. Where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction, using UR Z 7, Table 2 as guidance	**Outside the cargo length area:** UR Z 7, 3.2.3 and 3.2.4: areas of substantial corrosion identified at previous class renewal or intermediate surveys; Where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction, using UR Z 7, Table 2 as guidance

TYPE OF SURVEY		
CLASS RENEWAL	INTERMEDIATE	ANNUAL
Within the cargo length area:	**Within the cargo length area:**	**Within the cargo length area:**
a) single side skin bulk carriers: UR Z 10.2, 2.4 and 5: planning and general requirements UR Z 10.2, Table I: measurements of elements subjected to close-up survey UR Z 10.2, Table II: extent of systematic thickness measurements UR Z 10.2 Table VIII according to the different locations, where substantial corrosion is found	a) single side skin bulk carriers: Ships 10 years of age or less: UR Z 10.2, 4.2.2.3 for cargo holds UR Z 10.2, 4.2.2.1 and 4.2.2.3 for salt ballast tanks UR Z 10.2, Table VIII, according to the different locations, where substantial corrosion is found Ships over 10 years of age: See references given for class renewal survey	a) single side skin bulk carriers: UR Z 10.2, 3.2.4.1 c) and 3.2.4.2 c) for cargo holds and when deemed necessary by the Surveyor UR Z 10.2, 3.2.5.1 for salt ballast tanks and when deemed necessary by the Surveyor UR Z 10.2 Table VIII according to the different locations, where substantial corrosion is found
b) double side skin bulk carriers: UR Z 10.5, 2.4 and 5: planning and general requirements UR Z 10.5, Table I: measurements of elements subjected to close-up survey UR Z 10.5, Table II: extent of systematic thickness measurements UR Z 10.5 Table III according to the different locations, where substantial corrosion is found	b) double side skin bulk carriers: Ships 10 years of age or less: UR Z 10.5, 4.2.2.3 and Table IV for cargo holds UR Z 10.5, 4.2.2.1, 4.2.2.3 and Table IV for salt ballast tanks UR Z 10.5, Table III, according to the different locations, where substantial corrosion is found Ships over 10 years of age: See references given for class renewal survey	b) double side skin bulk carriers: UR Z 10.5 3.2.4.1 b) and 3.2.4.2 b) for cargo holds and when deemed necessary by the Surveyor UR Z 10.5,3.2.5.1 for salt ballast tanks and when deemed necessary by the Surveyor UR Z 10.5 Table III according to the different locations, where substantial corrosion is found

2.2 Class renewal survey.

2.2.1

The thickness measurements required by the Rules consist of:

- systematic thickness measurements in order to assess the overall and local strength of the ship
- thickness measurements as indicated in the program of close-up survey
- measurements of elements considered as suspect areas.
- additional measurements on areas determined as affected by substantial corrosion.

2.2.2

For the determination of close-up surveys and relevant thickness measurements as well as the areas considered as suspect areas, reference is to be made to the relevant Sections of the following IACS Unified Requirements:

- for the hull structure and piping systems in way of cargo holds, cofferdams, pipe tunnels, void spaces, fuel oil tanks within the cargo length area and all ballast tanks:
  - UR Z 10.2 (Hull Surveys of Single Skin Bulk Carriers) or
  - UR Z 10.5 (Hull Surveys of Double Skin Bulk Carriers)
- for the remainder of the ship outside the cargo length area :
  - UR Z 7.

2.3 Number and locations of measurements

2.3.1 Number of measurements

Considering the extent of thickness measurements as required by the Rules and indicated in [2.1] and [2.2], the locations of the points to be measured are given for the most important items of the structure.

2.3.2 Locations of measurements

Tab 2 provides explanations and/or interpretations for the application of those requirements indicated in the Rules which refer to both systematic thickness measurements related to the calculation of global hull girder strength and specific measurements connected to close-up surveys.

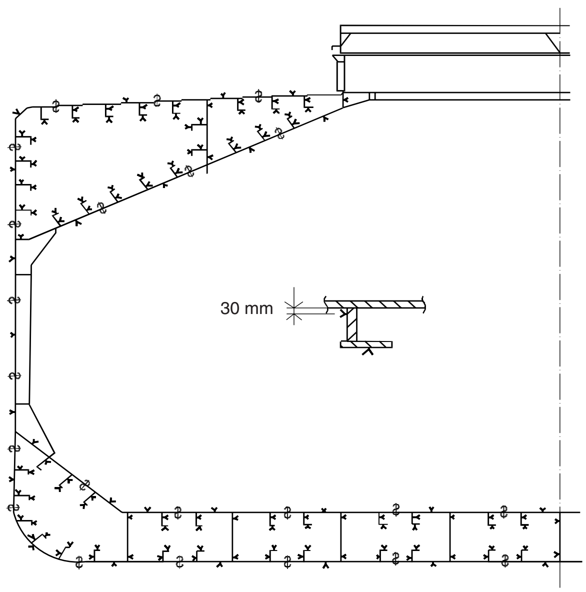
Figures are provided to facilitate the explanations and/or interpretations given in the table. These figures show typical arrangements of single side skin bulk carriers and of double side skin bulk carriers.

Table 2: Interpretations of rule requirements for the locations and number of points to be measured

ITEM	INTERPRETATION	FIGURE
Selected plates on deck, tank top, bottom, double bottom and wind-and-water	«Selected» means at least a single point on one out of three plates, to be chosen on representative areas of average corrosion	
All deck, tank top and bottom plates and wind-and-water strakes	At least two points on each plate to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion	
Transverse section	Single side skin bulk carrier: A Transverse Section includes all longitudinal members such as plating, longitudinals and girders at the deck, side, bottom; inner bottom and hopper side plating, longitudinal bulkhead and bottom plating in top wing tanks. Double side skin bulk carrier: A Transverse Section includes all longitudinal members such as plating, longitudinals and girders at the deck, sides, bottom, inner bottom, hopper sides, inner sides and top wing inner sides.	Fig 1 for single side skin bulk carriers FIG to be provided later
Cargo hold hatch covers and coamings		Fig 2
Selected internal structure such as floors and longitudinals, transverse frames, web frames, deck beams, girders	The internal structural items to be measured in each space internally surveyed are to be at least 10% outside the cargo length area	
Transverse section of deck plating outside line of cargo hatch openings	Two single points on each deck plate (to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion) between the ship sides and hatch coamings in the transverse section concerned	
Areas of deck plating inside line of hatch openings	«Selected» means at least a single point on one out of three plates, to be chosen on representative areas of average corrosion «All deck plating» means at least two points on each plate to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion	Extent of areas is shown as (E) in UR Z 10.2 Annex II, sheet 14, for single side skin bulk carriers and UR Z 10.5 Fig.1 for double side skin bulk carriers

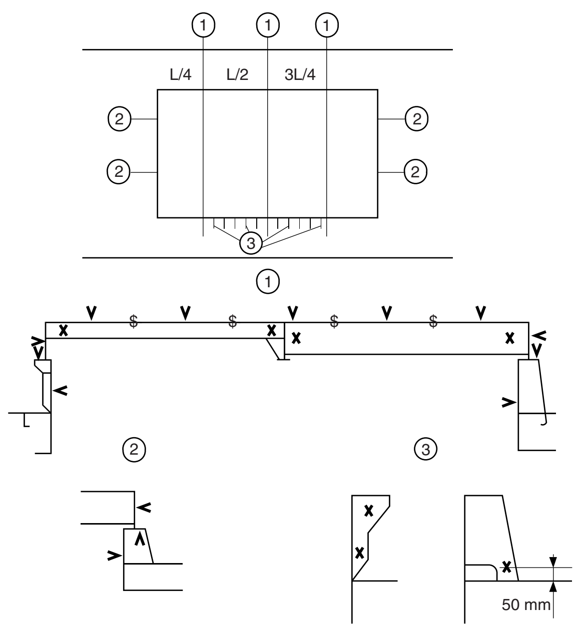
ITEM	INTERPRETATION	FIGURE
Side shell frames in cargo holds for single side skin bulk carriers	25% of frames: one out of four frames should preferably be chosen throughout the cargo hold length on each side «Selected frames» means at least 3 frames on each side of cargo holds	Extent of areas is shown as (A) in UR Z 10.2 Annex II, sheet 14, for single side skin bulk carriers. Locations of points are given in Fig 3 for single side skin bulk carriers
Transverse frame in double skin tank		
Transverse bulkheads in cargo holds	Includes bulkhead plating, stiffeners and girders, including internal structure of upper and lower stools, where fitted. Two selected bulkheads: one is to be the bulkhead between the two foremost cargo holds and the second may be chosen in other positions	Areas of measurements are shown as (C) in UR Z 10.2 Annex II, sheet 14, for single side skin bulk carriers and UR Z 10.5 Fig.1 for double side skin bulk carriers. Locations of points are given in Fig 4.
One transverse bulkhead in each cargo hold	This means that the close-up survey and related thickness measurements are to be performed on one side of the bulkhead; the side is to be chosen based on the outcome of the overall survey of both sides. In the event of doubt, the Surveyor may also require (possibly partial) close-up survey on the other side	Areas of measurements are shown as (C) in UR Z 10.2 Annex II, sheet 14, for single side skin bulk carriers and UR Z 10.5 Fig.1 for double side skin bulk carriers. Locations of points are given in Fig 4.
Transverse bulkheads in one topside/side ballast tank	The ballast tank is to be chosen based on the history of ballasting among those prone to have the most severe conditions	Locations of points are given in Fig 5
Transverse webs in ballast tanks	Either of the representative tanks of each type (i.e. topside or hopper or side tank) is to be chosen in the forward part «Associated plating and longitudinals» means adjacent plating and longitudinals of deck, bottom, side shell, slope, hopper and longitudinal bulkhead, as applicable	Extent of areas is shown as (B) in UR Z 10.2 Annex II, sheet 14, for single side skin bulk carriers and as (A) in UR Z 10.5 Fig.1 for double side skin bulk carriers. Locations of points are given in Fig 3.

Figure 1: Transverse section of a single side skin bulk carrier



Measurements are to be taken on both port and starboard sides of the selected transverse section

Figure 2: Locations of measurements on hatch covers and coamings



(1) Three sections at L/4, L/2, 3L/4 of hatch cover length, including:

- one measurement of each hatch cover plate and skirt plate
- measurements of adjacent beams and stiffeners
- one measurement of coaming plates and coaming flange, each side

(2) Measurements of both ends of hatch cover skirt plate, coaming plate and coaming flange

(3) One measurement of one out of three hatch coaming brackets and bars, on both sides and both ends

Figure 3: Locations of measurements on structural members in cargo holds and ballast tanks of single side skin bulk carriers

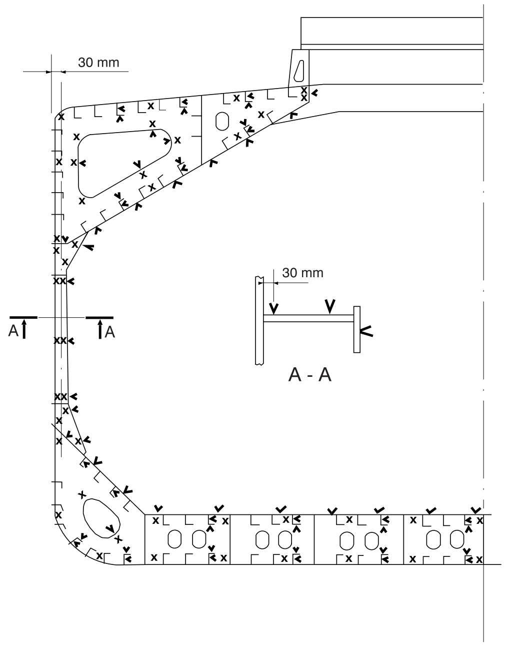
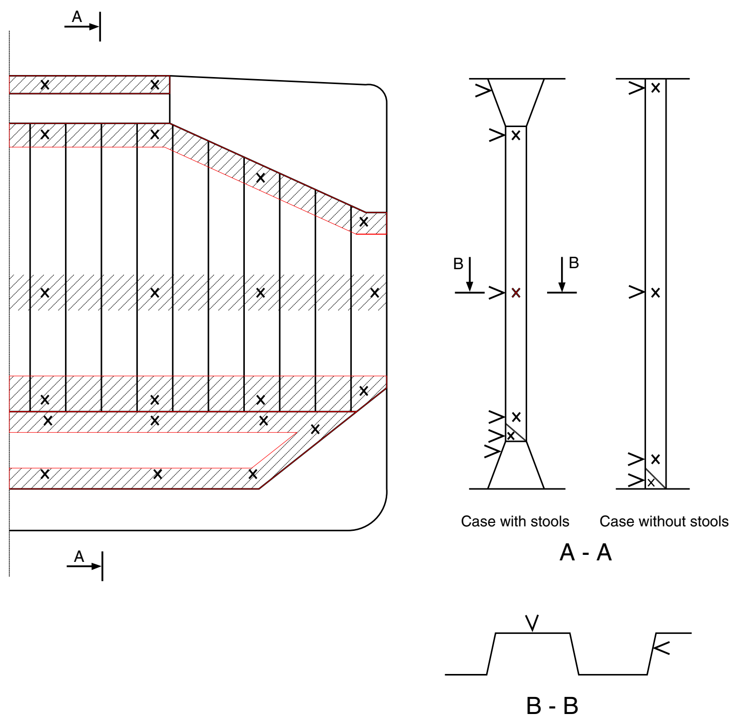
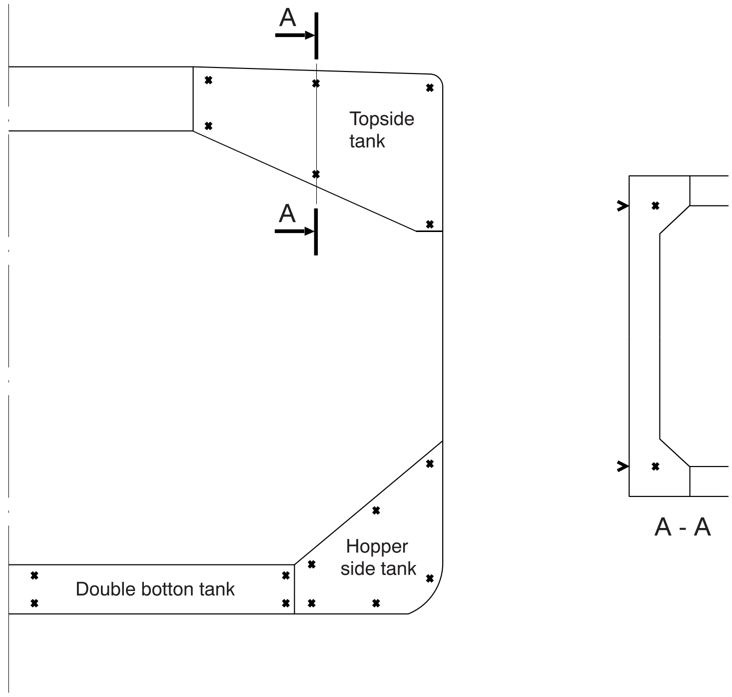


Figure 4: Locations of measurements on cargo hold transverse bulkheads



Measurements to be taken in each shaded area as per views A - A and B – B

Figure 5: Locations of measurements on transverse bulkheads of topside, hopper, double hull and double bottom tanks of bulk carriers



Measurements to be taken in each vertical section as per view A - A

3. Acceptance Criteria

3.1 Definitions

Item: an item is defined as an individual element such as a plate, a stiffener, a web, etc…

t_w: actual wastage, in mm, on the considered item.

$t_{renewal}$: Renewal Thickness; minimum allowable thickness, in mm, used during the Ship In Operation phase, below which renewal of structural members must be made.

$t_{reserve}$: Thickness in Reserve; Rule specified corrosion addition thickness, in mm, to account for anticipated thickness diminution that may occur during the assumed inspection interval of 2.5 year after the thickness measurement ($t_{reserve}$ = 0.5 mm).

$t_{wastage\_allowance}$: Thickness for Wastage Allowance, thickness, in mm, allowable thickness diminution used during the Ship In Operation phase.

t_c : Corrosion addition, in mm, defined in Ch 3, Sec3

t_{as_built} : The actual thickness, in mm, provided at the newbuilding stage, including $t_{voluntary\_addition}$, if any.

$t_{voluntary\_addition}$: Thickness for voluntary addition; the thickness, in mm, voluntarily added as the Owner's extra margin for corrosion wastage in addition to t_c .

t_{gauged}: gauged thickness, in mm, on one item, i.e average thickness on one item using the various measurements taken on this same item and carried out for periodical surveys during the Ship in Operation phase.

Deck zone: the deck zone includes all the following items contributing to the hull girder strength above the level corresponding to 0.9 D above the base line:

- Strength deck plating,
- deck stringer,
- sheer strake
- side shell plating
- top side tank sloped plating, including horizontal and vertical strakes;
- all the longitudinals connected to the above mentioned platings

Bottom zone: the bottom zone includes the following items contributing to the hull girder strength up to the level of the double bottom excluding the hopper plates :

- keel plate
- bottom plating
- Bilge plate
- bottom girders
- Double bottom plating
- all the longitudinals connected to the above mentioned platings

Neutral axis zone: the neutral axis zone includes the following plating only :

- Side shell plating above the double bottom level up to the strength deck
- inner hull plating, if any, between the hopper and the top side tank.

3.2 Local criteria

3.2.1 Wastage allowance

For each item, the wastage allowance that specifies the corrosion limit is to be within the corrosion addition in order to keep the structural strength at the intended safety level at any time during the ship's life, and is given by the following formula:

$t_{wastage\_allowance} = t_c - t_{reserve} + t_{voluntary\_addition}$

The actual wastage on the considered item is the thickness diminution determined during the Ship in Operation phase and is given by the following formula:

$t_w = t_{as\_built} - t_{gauged}$

3.2.2 Renewal thickness

For each item, with respect to general corrosion, steel renewal is required when the gauged thickness t_{gauged} is less than the renewal thickness , as specified in the following formula:

$t_{gauged} < t_{renewal}$,

where:

$t_{renewal} = t_{as\_built} - t_{wastage\_allowance}$

The same renewal criteria can be expressed either as:

$t_w > t_{wastage\_allowance}$

Where the gauged thickness t_{gauged} is such as:

$t_{renewal} < t_{gauged} < t_{as\_built} - t_c - t_{voluntary\_addition} + 2\, t_{reserve}$

coating, applied in accordance with the coating manufacturer's requirements or annual gauging may be adopted as an alternative to the steel renewal. The coating is to be maintained in goo condition.

The minimum remaining thickness in pits or grooves is to be greter than :

- 75% of the as built thickness, for pitting or grooving in the frame and end brackets webs and flanges
- 70% of the as built thickness, for pitting or grooving in the side shell, hopper tank and topside tank plating attached to the each side frame, over a width up to 30 mm from each side of it.

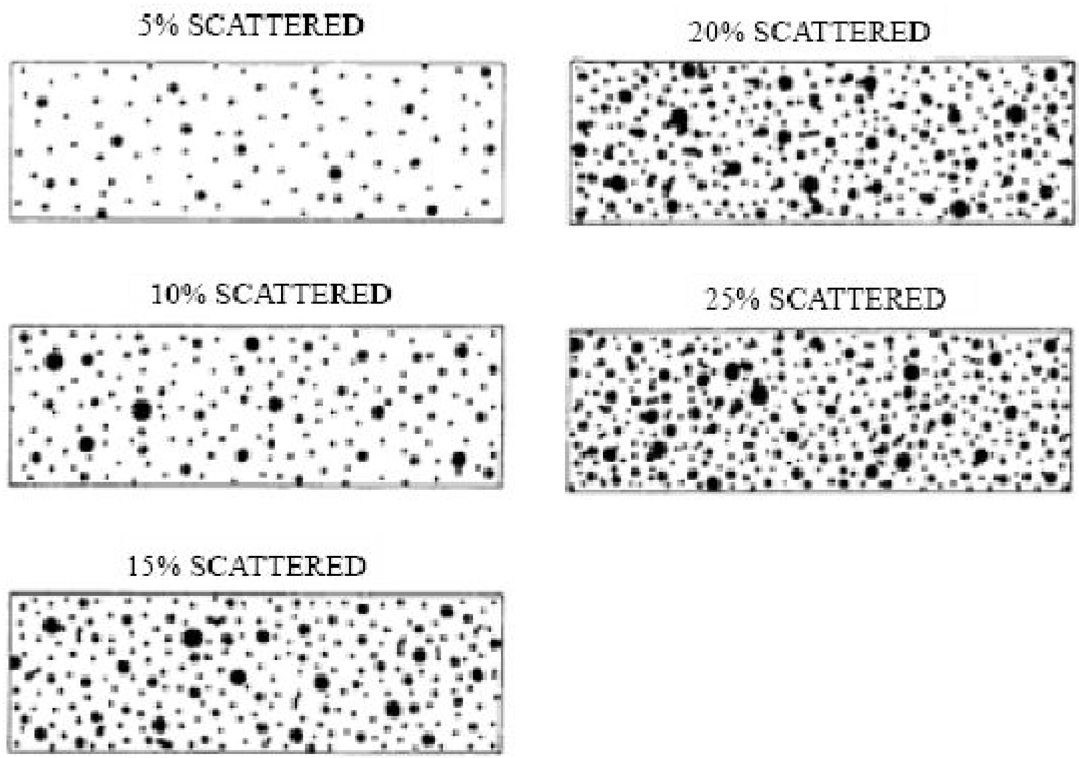


Figure 6: Pitting intensity diagrams (from 5% to 25% intensity)

3.3 Global strength criteria

3.3.1 Renewal thickness

The global strength criteria is defined by the assessment of the bottom zone, deck zone and neutral axis zone, as detailed below.

a) bottom zone and deck zone:

The current hull girder section modulus determined with the thickness measurements is not to be less than 90% of the section modulus calculated according to Ch 5 with the gross offered thicknesses.

Alternatively, the current sectional areas of the bottom zone and of the deck zone which are the sum of the gauged items area of the considered zones, are not to be less than 90% of the sectional area of the corresponding zones determined with the gross offered thicknesses.

b) neutral axis zone:

The current sectional area of the neutral axis zone, the sum of the gauged platings area of this zone, is not to be less than 85% of the gross offered sectional area of the neutral axis zone.

Notes

Usually, as the offered thicknesses (gross and/or the net values as defined in Ch 3, Sec 2) have been used in direct strength analysis, the assessment is to be made on the basis of the offered hull girder section modulus or, alternatively on the basis of the offered sectional area.

If the actual wastage of all items, of a given transverse section, which contribute to the hull girder strength is less than 10% for the deck and bottom zones and 15% for the neutral axis zone, the global strength criteria of this transverse section is automatically satisfied and its checking is no more required.

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