Rules for the Classification of Steel Ships

PART B – Hull and Stability

NR 467.B1 DT R12 E **January 2020**

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BUREAU VERITAS MARINE & OFFSHORE

GENERAL CONDITIONS

1. INDEPENDENCE OF THE SOCIETY AND APPLICABLE TERMS

1.1 The Society shall remain at all times an independent contractor and neither the Society nor any of its officers, employees, servants, agents or subcontractors shall be or act as an employee, servant or agent of any other party hereto in the performance of the Services.

1.2 The operations of the Society in providing its Services are exclusively conducted by way of random inspections and do not, in any circumstances, involve monitoring or exhaustive verification.

1.3 The Society acts as a services provider. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty. The Society is not and may not be considered as an underwriter, broker in Unit's sale or chartering, expert in Unit's valuation, consulting engineer, controller, naval architect, designer, manufacturer, shipbuilder, repair or conversion yard, charterer or shipowner; none of them above listed being relieved of any of their expressed or implied obligations as a result of the interventions of the Society.

1.4 The Society only is qualified to apply and interpret its Rules.

1.5 The Client acknowledges the latest versions of the Conditions and of the applicable Rules applying to the Services' performance.

1.6 Unless an express written agreement is made between the Parties on the applicable Rules, the applicable Rules shall be the Rules applicable at the time of entering into the relevant contract for the performance of the Services.

1.7 The Services' performance is solely based on the Conditions. No other terms shall apply whether express or implied.

2. DEFINITIONS

2.1 **"Certificate(s)"** means classification or statutory certificates, attestations and reports following the Society's intervention.

2.2 **"Certification"** means the activity of certification in application of national and international regulations or standards, in particular by delegation from different governments that can result in the issuance of a Certificate.

2.3 **"Classification"** means the classification of a Unit that can result or not in the issuance of a classification Certificate with reference to the Rules. Classification is an appraisement given by the Society to the Client, at a certain date, following surveys by its surveyors on the level of compliance of the Unit to the Society's Rules or to the documents of reference for the Services provided. They cannot be construed as an implied or express warranty of safety, fitness for the purpose, seaworthiness of the Unit or of its value for sale, insurance or chartering.

2.4 **"Client"** means the Party and/or its representative requesting the Services.

2.5 **"Conditions"** means the terms and conditions set out in the present document.

2.6 **"Industry Practice"** means international maritime and/or offshore industry practices.

2.7 **"Intellectual Property"** means all patents, rights to inventions, utility models, copyright and related rights, trade marks, logos, service marks, trade dress, business and domain names, rights in trade dress or get-up, rights in goodwill or to sue for passing off, unfair competition rights, rights in designs, rights in computer software, database rights, topography rights, moral rights, rights in confidential information (including know-how and trade secrets), methods and protocols for Services, and any other intellectual property rights, in each case whether capable of registration, registered or unregistered and including all applications for and renewals, reversions or extensions of such rights, and all similar or equivalent rights or forms of protection in any part of the world.

2.8 **"Parties"** means the Society and Client together.

2.9 **"Party"** means the Society or the Client.

2.10 **"Register"** means the public electronic register of ships updated regularly by the Society.

2.11 **"Rules"** means the Society's classification rules and other documents. The Society's Rules take into account at the date of their preparation the state of currently available and proven technical minimum requirements but are not a standard or a code of construction neither a guide for maintenance, a safety handbook or a guide of professional practices, all of which are assumed to be known in detail and carefully followed at all times by the Client.

2.12 **"Services"** means the services set out in clauses 2.2 and 2.3 but also other services related to Classification and Certification such as, but not limited to: ship and company safety management certification, ship and port security certification, maritime labour certification, training activities, all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board. The Services are carried out by the Society according to the applicable referential and to the Bureau Veritas' Code of Ethics. The Society shall perform the Services according to the applicable national and international standards and Industry Practice and always on the assumption that the Client is aware of such standards and Industry Practice.

2.13 **"Society"** means the classification society **'Bureau Veritas Marine & Offshore SAS'**, a company organized and existing under the laws of France, registered in Nanterre under number 821 131 844, or any other legal entity of Bureau Veritas Group as may be specified in the relevant contract, and whose main activities are Classification and Certification of ships or offshore units.

2.14 **"Unit"** means any ship or vessel or offshore unit or structure of any type or part of it or system whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submarines, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

3. SCOPE AND PERFORMANCE

3.1 Subject to the Services requested and always by reference to the Rules, the Society shall:

- review the construction arrangements of the Unit as shown on the documents provided by the Client;
- conduct the Unit surveys at the place of the Unit construction;
- class the Unit and enter the Unit's class in the Society's Register;
- survey the Unit periodically in service to note whether the requirements for the maintenance of class are met.

The Client shall inform the Society without delay of any circumstances which may cause any changes on the conducted surveys or Services.

3.2 The Society will not:

- declare the acceptance or commissioning of a Unit, nor its construction in conformity with its design, such activities remaining under the exclusive responsibility of the Unit's owner or builder;
- engage in any work relating to the design, construction, production or repair checks, neither in the operation of the Unit or the Unit's trade, neither in any advisory services, and cannot be held liable on those accounts.

4. RESERVATION CLAUSE

4.1 The Client shall always: (i) maintain the Unit in good condition after surveys; (ii) present the Unit for surveys; and (iii) inform the Society in due time of any circumstances that may affect the given appraisement of the Unit or cause to modify the scope of the Services.

4.2 Certificates are only valid if issued by the Society.

4.3 The Society has entire control over the Certificates issued and may at any time withdraw a Certificate at its entire discretion including, but not limited to, in the following situations: where the Client fails to comply in due time with instructions of the Society or where the Client fails to pay in accordance with clause 6.2 hereunder.

4.4 The Society may at times and at its sole discretion give an opinion on a design or any technical element that would 'in principle' be acceptable to the Society. This opinion shall not presume on the final issuance of any Certificate or on its content in the event of the actual issuance of a Certificate. This opinion shall only be an appraisal made by the Society which shall not be held liable for it.

5. ACCESS AND SAFETY

5.1 The Client shall give to the Society all access and information necessary for the efficient performance of the requested Services. The Client shall be the sole responsible for the conditions of presentation of the Unit for tests, trials and surveys and the conditions under which tests and trials are carried out. Any information, drawing, etc. required for the performance of the Services must be made available in due time.

5.2 The Client shall notify the Society of any relevant safety issue and shall take all necessary safety-related measures to ensure a safe work environment for the Society or any of its officers, employees, servants, agents or subcontractors and shall comply with all applicable safety regulations.

6. PAYMENT OF INVOICES

6.1 The provision of the Services by the Society, whether complete or not, involve, for the part carried out, the payment of fees thirty (30) days upon issuance of the invoice.

6.2 Without prejudice to any other rights hereunder, in case of Client's payment default, the Society shall be entitled to charge, in addition to the amount not properly paid, interests equal to twelve (12) months LIBOR plus two (2) per cent as of due date calculated on the number of days such payment is delinquent. The Society shall also have the right to withhold Certificates and other documents and/or to suspend or revoke the validity of Certificates.

6.3 In case of dispute on the invoice amount, the undisputed portion of the invoice shall be paid and an explanation on the dispute shall accompany payment so that action can be taken to solve the dispute.

7. LIABILITY

7.1 The Society bears no liability for consequential loss. For the purpose of this clause consequential loss shall include, without limitation:

- Indirect or consequential loss;
- Any loss and/or deferral of production, loss of product, loss of use, loss of bargain, loss of revenue, loss of profit or anticipated profit, loss of business and business interruption, in each case whether direct or indirect.

The Client shall defend, release, save, indemnify, defend and hold harmless the Society from the Client's own consequential loss regardless of cause.

7.2 Except in case of wilful misconduct of the Society, death or bodily injury caused by the Society's negligence and any other liability that could not be, by law, limited, the Society's maximum liability towards the Client is limited to one hundred and fifty per-cents (150%) of the price paid by the Client to the Society for the Services having caused the damage. This limit applies to any liability of whatsoever nature and howsoever arising, including fault by the Society, breach of contract, breach of warranty, tort, strict liability, breach of statute.

7.3 All claims shall be presented to the Society in writing within three (3) months of the completion of Services' performance or (if later) the date when the events which are relied on were first discovered by the Client. Any claim not so presented as defined above shall be deemed waived and absolutely time barred.

8. INDEMNITY CLAUSE

8.1 The Client shall defend, release, save, indemnify and hold harmless the Society from and against any and all claims, demands, lawsuits or actions for damages, including legal fees, for harm or loss to persons and/or property tangible, intangible or otherwise which may be brought against the Society, incidental to, arising out of or in connection with the performance of the Services (including for damages arising out of or in connection with opinions delivered according to clause 4.4 above) except for those claims caused solely and completely by the gross negligence of the Society, its officers, employees, servants, agents or subcontractors.

9. TERMINATION

9.1 The Parties shall have the right to terminate the Services (and the relevant contract) for convenience after giving the other Party thirty (30) days' written notice, and without prejudice to clause 6 above.

9.2 In such a case, the Classification granted to the concerned Unit and the previously issued Certificates shall remain valid until the date of effect of the termination notice issued, subject to compliance with clause 4.1 and 6 above.

9.3 In the event where, in the reasonable opinion of the Society, the Client is in breach, or is suspected to be in breach of clause 16 of the Conditions, the Society shall have the right to terminate the Services (and the relevant contracts associated) with immediate effect.

10. FORCE MAJEURE

10.1 Neither Party shall be responsible or liable for any failure to fulfil any term or provision of the Conditions if and to the extent that fulfilment has been delayed or temporarily prevented by a force majeure occurrence without the fault or negligence of the Party affected and which, by the exercise of reasonable diligence, the said Party is unable to provide against.

10.2 For the purpose of this clause, force majeure shall mean any circumstance not being within a Party's reasonable control including, but not limited to: acts of God, natural disasters, epidemics or pandemics, wars, terrorist attacks, riots, sabotages, impositions of sanctions, embargoes, nuclear, chemical or biological contaminations, laws or action taken by a government or public authority, quotas or prohibition, expropriations, destructions of the worksite, explosions, fires, accidents, any labour or trade disputes, strikes or lockouts.

11. CONFIDENTIALITY

11.1 The documents and data provided to or prepared by the Society in performing the Services, and the information made available to the Society, are treated as confidential except where the information:

- is properly and lawfully in the possession of the Society;
- is already in possession of the public or has entered the public domain, otherwise than through a breach of this obligation;
- is acquired or received independently from a third party that has the right to disseminate such information;
- is required to be disclosed under applicable law or by a governmental order, decree, regulation or rule or by a stock exchange authority (provided that the receiving Party shall make all reasonable efforts to give prompt written notice to the disclosing Party prior to such disclosure.

11.2 The Parties shall use the confidential information exclusively within the framework of their activity underlying these Conditions.

11.3 Confidential information shall only be provided to third parties with the prior written consent of the other Party. However, such prior consent shall not be required when the Society provides the confidential information to a subsidiary.

11.4 Without prejudice to sub-clause 11.1, the Society shall have the right to disclose the confidential information if required to do so under regulations of the International Association of Classifications Societies (IACS) or any statutory obligations.

12. INTELLECTUAL PROPERTY

12.1 Each Party exclusively owns all rights to its Intellectual Property created before or after the commencement date of the Conditions and whether or not associated with any contract between the Parties.

12.2 The Intellectual Property developed by the Society for the performance of the Services including, but not limited to drawings, calculations, and reports shall remain the exclusive property of the Society.

13. ASSIGNMENT

13.1 The contract resulting from to these Conditions cannot be assigned or transferred by any means by a Party to any third party without the prior written consent of the other Party.

13.2 The Society shall however have the right to assign or transfer by any means the said contract to a subsidiary of the Bureau Veritas Group.

14. SEVERABILITY

14.1 Invalidity of one or more provisions does not affect the remaining provisions.

14.2 Definitions herein take precedence over other definitions which may appear in other documents issued by the Society.

14.3 In case of doubt as to the interpretation of the Conditions, the English text shall prevail.

15. GOVERNING LAW AND DISPUTE RESOLUTION

15.1 These Conditions shall be construed and governed by the laws of England and Wales.

15.2 The Parties shall make every effort to settle any dispute amicably and in good faith by way of negotiation within thirty (30) days from the date of receipt by either one of the Parties of a written notice of such a dispute.

15.3 Failing that, the dispute shall finally be settled under the Rules of Arbitration of the Maritime Arbitration Chamber of Paris ("CAMP"), which rules are deemed to be incorporated by reference into this clause. The number of arbitrators shall be three (3). The place of arbitration shall be Paris (France). The Parties agree to keep the arbitration proceedings confidential.

16. PROFESSIONAL ETHICS

16.1 Each Party shall conduct all activities in compliance with all laws, statutes, rules, economic and trade sanctions (including but not limited to US sanctions and EU sanctions) and regulations applicable to such Party including but not limited to: child labour, forced labour, collective bargaining, discrimination, abuse, working hours and minimum wages, anti-bribery, anti-corruption, copyright and trademark protection, personal data protection (https://personaldataprotection.bureauveritas.com/privacypolicy).

Each of the Parties warrants that neither it, nor its affiliates, has made or will make, with respect to the matters provided for hereunder, any offer, payment, gift or authorization of the payment of any money directly or indirectly, to or for the use or benefit of any official or employee of the government, political party, official, or candidate.

16.2 In addition, the Client shall act consistently with the Bureau Veritas' Code of Ethics.
https://group.bureauveritas.com/group/corporate-social-responsibility

RULES FOR THE CLASSIFICATION OF SHIPS

Part B
Hull and Stability

Chapters **1 2 3 4 5 6 7 8 9 10 11**

January 2020

The English wording of these rules take precedence over editions in other languages.

Unless otherwise specified, these rules apply to ships for which contracts are signed after January 1st, 2020. The Society may refer to the contents hereof before January 1st, 2020, as and when deemed necessary or appropriate.

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Chapter 1
GENERAL

SECTION 1 APPLICATION

1 General

1.1 Structural requirements

1.1.1 Part B of the Rules contains the requirements for determination of the minimum hull scantlings, applicable to all types of seagoing monohull displacement ships of normal form, speed and proportions, made in welded steel construction, excluding ships covered by NR600 "Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m".

These requirements are to be integrated with those specified in Part D or Part E, for any individual ship type, and in Part F, as applicable, depending on the additional class notations assigned to the ships.

Note 1: NR600 is applicable for:

- cargo ships with length less than 65 m, and
- non cargo ships with length less than 90 m.

The wording "cargo ships" and "non-cargo ships" used in NR600 means:

- Cargo ships: ships liable to carry cargoes and having a deadweight greater than 30% of the total displacement. As a general rule, these ships are fitted with cargo holds, tanks and ballast tanks (i.e bulk or ore carriers, oil or chemical tanker, container ship, general cargo ship, ...) and the value of the block coefficient is greater than 0,75.
- Non-cargo ships: type of ships other than cargo ships defined here above.

Note 2: NR600 is not applicable for liquefied gas carriers, ships for dredging activities and any cargo ships with alternate light and heavy cargo loading conditions.

1.1.2 The requirements of Part B, Part D, Part E and Part F apply also to those steel ships in which parts of the hull, e.g. superstructures or movable decks, are built in aluminium alloys.

1.1.3 Ships whose hull materials are different than those given in [1.1.2] 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 Rules.

1.1.4 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 Rules is to be not less than that corresponding to the assigned freeboard.

1.1.5 Where scantlings are obtained from direct calculation procedures which are different from those specified in Part B, Chapter 7, adequate supporting documentation is to be submitted to the Society, as detailed in Ch 1, Sec 3.

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 Rules, even when the certification (especially the issuance of the Cargo Gear Register) of lifting appliances is not required.

1.2.3 The foundations of lifting appliances intended to be used at sea are to comply with the requirements of Part E, Chapter 8.

2 Rule application

2.1 Ship parts

2.1.1 General

For the purpose of application of the 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 of Part B are to be applied for the scantling and arrangement of ship parts according to Tab 1.

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

Part		Applicable Chapters and Sections
All parts		Part B, Chapter 1 Part B, Chapter 2 Part B, Chapter 3 Part B, Chapter 4 Part B, Chapter 5 Part B, Chapter 6 Part B, Chapter 8 **(1)**, excluding: • Ch 8, Sec 1 • Ch 8, Sec 2 Part B, Chapter 10 Part B, Chapter 11
Specific parts	Fore part	Ch 8, Sec 1
	Central part	Part B, Chapter 7
	Aft part	Ch 8, Sec 2
(1) See also [2.3].		

2.3 Rules applicable to other ship items

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

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

Item	Applicable Chapters and Sections
Machinery space	Ch 8, Sec 3
Superstructures and deckhouses	Ch 8, Sec 4
Bow doors and inner doors	Ch 8, Sec 5
Side shell doors and stern doors	Ch 8, Sec 6
Watertight and weathertight doors	Ch 8, Sec 12
Large hatch covers	Ch 8, Sec 7
Small hatches	Ch 8, Sec 8
Movable decks and inner ramp External ramps	Ch 8, Sec 9
Arrangement of hull and superstructures openings	Ch 8, Sec 10
Helicopter decks	Ch 8, Sec 11
Rudders	Ch 9, Sec 1
Other hull outfitting	Ch 9, Sec 2 Ch 9, Sec 3 Ch 9, Sec 4

3 Rounding off of scantlings

3.1

3.1.1 Plate thicknesses

The rounding off of plate thicknesses is to be obtained from the following procedure:

a) the net thickness (see Ch 4, Sec 2) is calculated in accordance with the rule requirements

b) corrosion addition t_C (see Ch 4, Sec 2) is added to the calculated net thickness, and this gross thickness is rounded off to the nearest half-millimetre

c) the rounded net thickness is taken equal to the rounded gross thickness, obtained in b), minus the corrosion addition t_C.

3.1.2 Stiffener section moduli

Stiffener section moduli as calculated in accordance with the rule requirements are to be rounded off to the nearest standard value; however, no reduction may exceed 3%.

SECTION 2 SYMBOLS AND DEFINITIONS

1 Units

1.1

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

Table 1 : Units

Designation	Usual symbol	Units
Ship's dimensions	see [2]	m
Hull girder section modulus	Z	m^3
Density	ρ	t/m^3
Concentrated loads	P	kN
Linearly distributed loads	q	kN/m
Surface distributed loads (pressures)	p	kN/m^2
Thicknesses	t	mm
Span of ordinary stiffeners and primary supporting members	ℓ	m
Spacing of ordinary stiffeners and primary supporting members	s	m
Bending moment	M	kN·m
Shear force	Q	kN
Stresses	σ, τ	N/mm^2
Section modulus of ordinary stiffeners and primary supporting members	w	cm^3
Sectional area of ordinary stiffeners and primary supporting members	A	cm^2

2 Symbols

2.1

2.1.1

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

L_1 : L, but to be taken not greater than 200 m

L_2 : L, but to be taken not greater than 120 m

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

L_S : Subdivision length, in m, defined in [3.3]

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

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

T : Moulded draught, in m, defined in [3.7]

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

C_B : Total block coefficient:

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

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 fore-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.

3.1.4 Ends of rule length

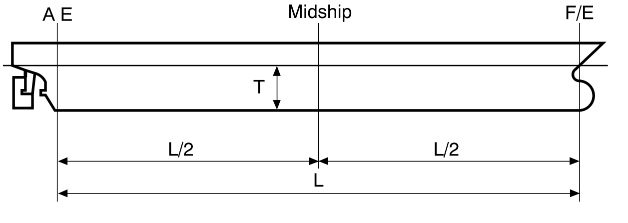
The fore end (FE) of the rule length L, see Fig 1, is the perpendicular to the summer load waterline at the forward side of the stem.

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

3.1.5 Midship

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

Figure 1 : Ends and midship



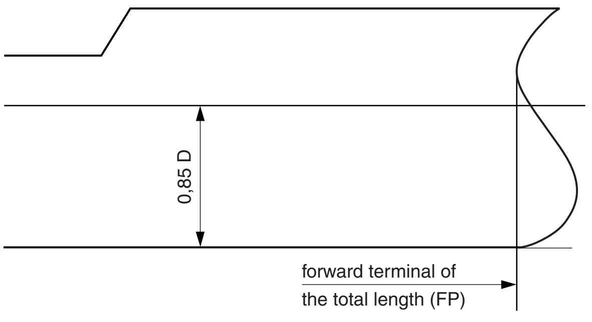
3.2 Load line length

3.2.1 *The load line length L_{LL} shall be taken as 96% of the total length on a waterline at 85% of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that be greater.*

3.2.2 *For ships without a rudder stock, the length L_{LL} is to be taken as 96% of the waterline at 85% of the least moulded depth.*

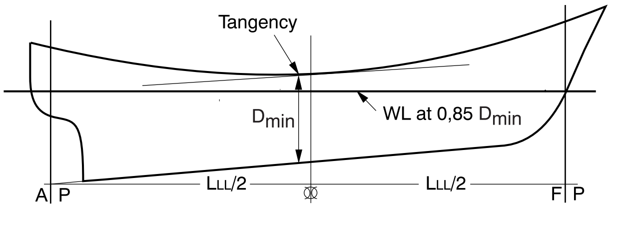
3.2.3 *Where the stem contour is concave above the waterline at 85% of the least moulded depth, both the forward terminal of the total length and the fore-side of the stem respectively is taken at the vertical projection to that waterline of the aftermost point of the stem contour (see Fig 2).*

Figure 2 : Concave stem contour Forward terminal of length



3.2.4 *In ship design with a rake of keel, the waterline on which this length is measured is parallel to the designed waterline at 85% of the least moulded depth D_{min} found by drawing a line parallel to the keel line of the ship (including skeg) tangent to the moulded sheer line of the freeboard deck. The least moulded depth is the vertical distance measured from the top of the keel to the top of the freeboard deck beam at side at the point of tangency (see Fig 3).*

Figure 3 : Length of ships with a rake of keel



3.3 Subdivision length

3.3.1 *The subdivision L_S of the ship is the greatest projected moulded length of that part of the ship at or below deck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision draught.*

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 uppermost continuous deck.

In the case of a ship with a solid bar keel, the moulded base line is to be taken at the intersection between the upper face of the bottom plating with the solid bar keel at the middle of length L.

3.6 Moulded depth

3.6.1 *The moulded depth D_1 is the vertical distance measured from the top of the keel to the top of the freeboard deck beam at side. Where the form at the lower part of the midship section is of a hollow character or where thick garboards are fitted, the distance is measured from the point where the line of the flat of the bottom continued inwards cuts the side of the keel.*

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

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

3.7 Moulded draught

3.7.1 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 waterline.

In the case of ships with a solid bar keel, the moulded base line is to be taken as defined in [3.5.1].

3.8 Lightweight

3.8.1 *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 and mediums required for the fixed fire-fighting systems (e.g. fresh water, CO_2, dry chemical powder, foam concentrate, etc.).

3.9 Deadweight

3.9.1 *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.*

3.10 Freeboard deck

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

3.11 Bulkhead deck

3.11.1 *The bulkhead deck in a passenger ship means the uppermost deck to which the main bulkheads and the ship's shell are carried watertight.*

The bulkhead deck may be a stepped deck.

In a cargo ship, the freeboard deck may be taken as the bulkhead deck.

3.12 Inner side

3.12.1 The inner side is the longitudinal bulkhead which limits the inner hull for ships fitted with double hull.

3.13 Superstructure

3.13.1 General

A superstructure is a decked structure connected to 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.

3.13.2 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 8, Sec 4
  - all front, side and aft openings are fitted with efficient weathertight means of closing.
- open, where it is not enclosed.

3.13.3 Bridge

A bridge is a superstructure which does not extend to either the forward or after perpendicular.

3.13.4 Poop

A poop is a superstructure which extends from the after perpendicular forward to a point which is aft of the forward perpendicular. The poop may originate from a point aft of the aft perpendicular.

3.13.5 Forecastle

A forecastle is a superstructure which extends from the forward perpendicular aft to a point which is forward of the after perpendicular. The forecastle may originate from a point forward of the forward perpendicular.

3.13.6 Full superstructure

A full superstructure is a superstructure which, as a minimum, extends from the forward to the after perpendicular.

3.14 Raised quarterdeck

3.14.1 *A raised quarterdeck is a partial superstructure of reduced height as defined in [3.19].*

It extends forward from the after perpendicular and has an intact front bulkhead (sidescuttles of the non-opening type fitted with efficient deadlights and bolted man hole covers).

Where the forward bulkhead is not intact due to doors and access openings, the superstructure is then to be considered as a poop.

3.15 Superstructure deck

3.15.1 *A superstructure deck is a deck forming the upper boundary of a superstructure.*

3.16 Deckhouse

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

3.17 Trunk

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

3.18 Well

3.18.1 *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 two or more sides by deck structures.*

3.19 Standard height of superstructure

3.19.1 *The standard height of superstructure is defined in Tab 2.*

Table 2 : Standard height of superstructure

Load line length L_{LL}, in m	Standard height h_S, in m	
	Raised quarter deck	All other superstructures
$L_{LL} \leq 30$	0,90	1,80
$30 < L_{LL} < 75$	$0,9 + 0,00667 (L_{LL} - 30)$	1,80
$75 \leq L_{LL} < 125$	$1,2 + 0,012 (L_{LL} - 75)$	$1,8 + 0,01 (L_{LL} - 75)$
$L_{LL} \geq 125$	1,80	2,30

3.20 Tiers of superstructures and deckhouses

3.20.1 The lowest tier is the tier located immediately above the freeboard deck.

The second tier is the tier located immediately above the lowest tier, and so on.

3.21 Type A and Type B ships

3.21.1 Type A ship

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.

3.21.2 Type B ship

All ships which do not come within the provisions regarding Type A ships stated in [3.21.1] 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.

3.21.3 Type B-60 ship

A Type B-60 ship is any Type B ship of over 100 metres in length which, fulfilling the requirements *reported in Ch 3, App 4, [4.4], 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.*

3.21.4 Type B-100 ships

A Type B-100 ship is any Type B ship of over 100 metres in length which, fulfilling the requirements *reported in Ch 3, App 4, [4.4], 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.*

3.22 Positions 1 and 2

3.22.1 Position 1

Position 1 includes:

- *exposed freeboard and raised quarter decks,*
- *exposed superstructure decks situated forward of 0,25 L_{LL} 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.*

3.22.2 Position 2

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_{LL} 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.*

3.23 Sister ship

3.23.1 A sister ship is a ship built by the same yard from the same plans.

4 Reference co-ordinate system

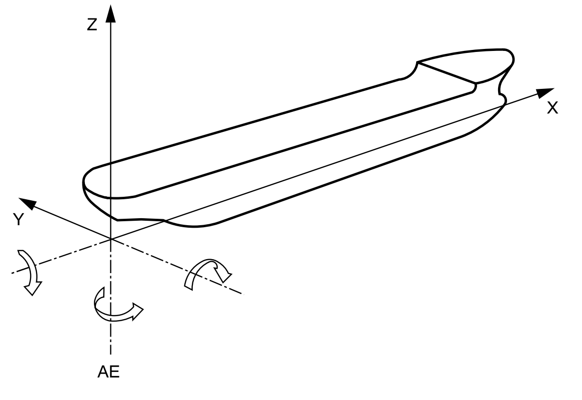
4.1

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 4):

- 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.

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

Figure 4 : Reference co-ordinate system



SECTION 3 DOCUMENTATION TO BE SUBMITTED

1 Documentation to be submitted for all ships

1.1 Ships surveyed by the Society during the construction

1.1.1 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.

The above plans and documents are to be supplemented by further documentation which depends on the service notation and, possibly, the additional class notation (see Pt A, Ch 1, Sec 2) assigned to the ship, as specified in [2].

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, [1.6].

1.1.2 Plans and documents to be submitted for information

In addition to those in [1.1.1], 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.

Table 1 : Plans and documents to be submitted for approval for all ships

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 Location and height of air vent outlets of various compartments 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
Loading manual and loading instruments	See Ch 10, Sec 2, [3]
Watertight subdivision bulkheads Watertight tunnels	Openings and their closing appliances, if any
Fore part structure	Location and height of air vent outlets of various compartments
Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures	
Aft part structure	Location and height of air vent outlets of various compartments
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

(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 9, Sec 1, [11].

Plan or document	Containing also information on
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)
Bow doors, stern doors and inner doors, if any, side doors and other openings in the side shell	Closing appliances Electrical diagrams of power control and position indication circuits for bow doors, stern doors, side doors, inner doors, television system and alarm systems for ingress of water
Hatch covers, if any	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
Movable decks and ramps, if any	
Windows and side scuttles, arrangements and details	
Scuppers and sanitary discharges	
Bulwarks and freeing ports	Arrangement and dimensions of bulwarks and freeing ports on the freeboard deck and superstructure deck
Helicopter decks, if any	General arrangement Main structure Characteristics of helicopters: maximum mass, distance between landing gears or landing skids, print area of wheels or skids, distribution of landing gear loads
Rudder and rudder horn **(1)**	Maximum ahead service speed
Sternframe or sternpost, sterntube Propeller shaft boss and brackets **(1)**	
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 outer doors and hatchways	
Plan of manholes	
Plan of access to and escape from spaces	
Plan of ventilation	Use of spaces
Plan of tank testing	Testing procedures for the various compartments Height of pipes for testing
Plan of watertight doors and scheme of relevant manoeuvring devices	Manoeuvring devices Electrical diagrams of power control and position indication circuits
Freeboard calculations	
Stability documentation	See Ch 3, Sec 1, [2.1]
Calculations relevant to intact stability and, where required, damage stability	
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
Emergency towing arrangement	See Ch 9, Sec 4, [3.3]

(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 9, Sec 1, [11].

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

1.2.1 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 [1.1]. 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.

2 Further documentation to be submitted for ships with certain service notations or additional class notations

2.1 General

2.1.1 Depending on the service notation and, possibly, the additional class notation (see Pt A, Ch 1, Sec 2) assigned to the ship, other plans or documents may be required to be submitted to the Society, in addition to those in [1.1]. They are listed in the relevant parts of the Rules applicable to these notations as defined in Pt A, Ch 1, Sec 2.

SECTION 4 CALCULATION PROGRAMMES

1 Programme for the Rule based scantling

1.1 General

1.1.1 Computer programmes, dealing with rule checking, are available to the clients of the Society. They run on personal computers under the WINDOWS operating system.

The Head Office of the Society or a local office should be contacted in order to have information on how to obtain one of these programmes.

1.2 MARS

1.2.1 The MARS programme performs the rule scantling check of plating and ordinary stiffeners at any transverse section along the ship hull.

1.2.2 In particular, MARS allows to:

- calculate the transverse section geometric properties
- carry out the hull girder strength checks, including ultimate strength
- carry out all the rule strength checks of:
  - strakes
  - longitudinal and transverse ordinary stiffeners
  - strakes and ordinary stiffeners of transverse bulkheads.

1.3 VERISTAR

1.3.1 Within VERISTAR system, the Society provides an integrated chain of computer programmes to perform rational design analysis of ship hulls.

Transverse section scantlings verification and finite element analysis of hull structure, including automatic generation of part of the finite element model, are integrated in an unique software. Additionally there is automatic load calculation, model load cases generation, and scantling criteria verification, in accordance with the Rules.

1.4 BULK

1.4.1 The BULK programme is designed to assess, according to the IACS Unified Requirements adopted in the rules, the hold mass curves and the structural strength of transverse corrugated bulkheads and double bottoms of new and existing bulk carriers to which these requirements apply.

1.5 RUDDER

1.5.1 The RUDDER programme performs the rule checks of rudders. In particular, it allows to calculate and verify the compliance with the rules of:

- the geometric characteristics of the rudder blade
- the scantlings of rudder stock, rudder blade, pintles and bearings
- the geometric characteristics and the scantlings of rudder horns and sole piece cross-sections.

Part B
Hull and Stability

Chapter 2
GENERAL ARRANGEMENT DESIGN

Symbols used in this Chapter

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}.

SECTION 1 SUBDIVISION ARRANGEMENT

1 General

1.1 Application to ships having additional service feature SPxxx or SPxxx-capable

1.1.1 Ships having additional service feature **SPxxx** or **SPxxx-capable** with xxx equal to or greater than 240 are to comply, in addition to the applicable requirements of this Section, with the requirements of Pt D, Ch 11, Sec 2, considering the special personnel as passengers.

1.1.2 Ships having additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240 are to comply with the requirements of this Section, unless otherwise specified, considering the special personnel as crew.

2 Number and arrangement of transverse watertight bulkheads

2.1 Number of watertight bulkheads

2.1.1 General

All ships, in addition to complying with the requirements of [2.1.2], 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.

2.1.2 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.

Additional bulkheads may be required for ships having to comply with subdivision or damage stability criteria (see Part D or Part E for the different types of ships).

2.2 Water ingress detection

2.2.1 A water ingress detection system is to be fitted according to Pt C, Ch 1, Sec 10, [6.12].

Table 1 : Number of bulkheads

Length (m)	Number of bulkheads for ships with aft machinery **(1)**	Number of bulkheads for other ships
L < 65	3	4
65 ≤ L < 85	4	5
85 ≤ L < 105	4	5
105 ≤ L < 120	5	6
120 ≤ L < 145	6	7
145 ≤ L < 165	7	8
165 ≤ L < 190	8	9
L ≥ 190	to be defined on a case by case basis	

(1) After peak bulkhead and aft machinery bulkhead are the same.

3 Collision bulkhead

3.1

3.1.1 *A collision bulkhead is to be fitted which is to be watertight up to the bulkhead deck of passenger ships and the freeboard deck of cargo ships. 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, except as may be permitted by the Society, not more than 8 per cent of* L_{LL} *or 5 per cent of the* L_{LL} *+ 3 m, whichever is the greater.*

For ships not covered by the SOLAS Convention, the length L_{LL} need not be taken less than 50 m, unless required by the National Authorities.

3.1.2 *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 [3.1.1] 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; whichever gives the smallest measurement.*

3.1.3 *The bulkhead may have steps or recesses provided they are within the limits prescribed in [3.1.1] or [3.1.2].*

No door, manhole, ventilation duct or any other opening is to be fitted in the collision bulkhead below the bulkhead deck of passenger ships and the freeboard deck of cargo ships.

3.1.4 At Owner request and subject to the agreement of the flag Administration, 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 [3.1.1] and [3.1.2], 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 freeboard deck becoming submerged, or in any unacceptable loss of stability.

In such a case, the attention of the Owner and the Shipyard is drawn to the fact that the flag Administration may impose additional requirements and that such an arrangement is, in principle, formalised by the issuance of a certificate of exemption under the SOLAS Convention provisions. Moreover, in case of change of flag, the taking Administration may not accept the exemption.

3.1.5 *Where a long forward superstructure is fitted, the collision bulkhead is to be extended weathertight to the next deck above the bulkhead deck of passenger ships and the freeboard deck of cargo ships. The extension need not be fitted directly above the bulkhead below provided that all parts of the extension, including any part of the ramps attached to it, are located within the limits prescribed in [3.1.1] or [3.1.2] with the exemption permitted by [3.1.6] and the part of the deck which forms the step is made effectively weathertight. The extension is to be so arranged as to preclude the possibility of the bow door or ramp, where fitted, causing damage to it in the case of damage to, or detachment of, a bow door or any part of the ramp.*

3.1.6 *Where bow doors are fitted and a sloping loading ramp forms part of the extension of the collision bulkhead above the bulkhead deck of passenger ships and the freeboard deck of cargo ships, the ramp is to be weathertight over its complete length. In cargo ships, the part of the ramp which is more than 2,3 m above the freeboard deck may extend forward of the limit specified in [3.1.1] or [3.1.2]. Ramps not meeting the above requirements are to be disregarded as an extension of the collision bulkhead.*

3.1.7 *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.*

4 After peak, machinery space bulkheads and stern tubes

4.1

4.1.1 General

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

4.1.2 Sterntubes

In all cases, sterntubes are to be enclosed in watertight spaces of moderate volume. In passenger ships, the stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the sterntube compartment and of such volume that, if flooded by leakage through the stern gland, the bulkhead deck will not be immersed. In cargo ships, other measures to 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.

For ships less than 65 m, where the after peak bulkhead in way of the sterntube stuffing box is not provided, sterntubes are to be enclosed in watertight spaces of moderate volume.

5 Height of transverse watertight bulkheads other than collision bulkhead and after peak bulkhead

5.1

5.1.1 Transverse watertight bulkheads are to extend watertight up to the bulkhead 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 watertight bulkheads and decks for ships having a service notation other than passenger ship or ro-ro passenger ship

6.1 Application

6.1.1 The requirements in [6.2] and [6.3] apply to ships having a service notation other than **passenger ship** or **ro-ro passenger ship**.

Openings in watertight bulkheads below the bulkhead deck for ships with service notation **passenger ship** or **ro-ro passenger ship** are to comply with Part D, Chapter 11 or Part D, Chapter 12, respectively.

6.1.2 The requirements in [6.2] and [6.3] are not applicable to ships having additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240.

Openings in watertight bulkheads below the bulkhead deck for ships with additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240 are to comply with Part D, Chapter 11.

6.2 General

6.2.1 *The number of openings in watertight subdivisions is to be kept to a minimum compatible with the design and proper working of the ship. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity. The 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.*

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

6.2.3 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.

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

6.2.5 The requirements relevant to the operating systems for doors complying with the provisions in [6.3] are specified in:

- Tab 2 for doors of internal watertight bulkheads, and
- Tab 3 for doors of external watertight boundaries below equilibrium or intermediate waterplane.

6.2.6 A diagram showing the location of the door and an indication to show its position is to be provided at the central operating console located at the navigation bridge. A red light is to indicate that the door is in the open position and a green light is to indicate that the door is in the closed position. The red light is to flash when the door is in an intermediate position.

6.2.7 All watertight doors, including sliding doors, operated by hydraulic door actuators, either a central hydraulic unit or independent for each door is to be provided with a low fluid level alarm or low gas pressure alarm, as applicable or some other means of monitoring loss of stored energy in the hydraulic accumulators. This alarm is to be both audible and visible and is to be located on the central operating console at the navigation bridge.

Table 2 : Doors in internal watertight bulkheads of cargo ships

Position relative to freeboard deck	Frequency of use while at sea	Type **(1)**	Remote closure	Remote indication	Audible or visual alarm	Notice
Below	Used	POS	X	X	X (local)	
	Normally closed **(2)**	S, H		X		X
	Permanently closed **(3)**	S, H				X
At or above	Used **(4)** **(5)**	POS	X	X	X (local)	
	Normally closed **(2)**	S, H		X		X
	Permanently closed **(3)**	S, H				X

(1) POS : Power operated, sliding or rolling
S : Sliding or rolling
H : Hinged
(2) If hinged, this door is to be of quick acting or single action type.
(3) Doors are to be fitted with a device which prevents unauthorized opening.
(4) According to Ch 3, App 4, [3], doors separating a main machinery space from a steering gear compartment may be hinged quick acting type provided the lower sill of such doors is above the summer load line and the doors remain closed at sea whilst not in use.
(5) Under MARPOL, hinged watertight doors may be acceptable in watertight bulkhead in the superstructure.

Table 3 : Doors in external watertight boundaries below equilibrium or intermediate waterplane of cargo ships

Position relative to freeboard deck	Frequency of use while at sea	Type **(1)**	Remote closure	Remote indication	Audible or visual alarm	Notice
Below	Permanently closed **(2)**	S, H		X		X
At or above	Normally closed **(3)**	S, H		X		X
	Permanently closed **(2)**	S, H		X		X

(1) POS : Power operated, sliding or rolling
S : Sliding or rolling
H : Hinged
(2) Doors are to be fitted with a device which prevents unauthorized opening.
(3) If hinged, this door is to be of quick acting or single action type.

6.3 Openings in the watertight bulkheads and internal decks

6.3.1 Openings used while at sea

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.

For cargo ships, the angle of list at which operation by hand is to be possible is 30 degrees.

Position indicators are to be provided at all remote operating positions for all ships and locally on both sides of the internal doors for cargo ships. An audible alarm is also 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.

Failure of the normal power supply of the required alarms are to be indicated by an audible and visual alarm.

6.3.2 Openings normally closed at sea

Access doors and access hatch covers normally closed at sea, intended to ensure the watertight integrity of internal openings, are to be provided with position indicators on the bridge for all ships, and locally on both sides of the internal doors for cargo ships, 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.

6.3.3 Doors or ramps in large cargo spaces

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 controlled. 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.

6.3.4 Openings permanently kept closed at sea

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.

SECTION 2 COMPARTMENT ARRANGEMENT

1 General

1.1 Application to ships having additional service feature SPxxx or SPxxx-capable

1.1.1 Ships having additional service feature **SPxxx** or **SPxxx-capable** with xxx equal to or greater than 240 are to comply, in addition of the applicable requirements of this Section with the requirements of Pt D, Ch 11, Sec 2, considering the special personnel as passengers.

1.1.2 Ships having additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240 are to comply with the requirements of this Section, unless otherwise specified, considering the special personnel as crew.

1.2 Definitions

1.2.1 Cofferdam

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.

1.2.2 Machinery spaces of category A

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:

- fuel oil tanks and lubricating oil tanks
- compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and compartments intended for fresh water (drinking water, water for propelling machinery and boilers, water for fire-fighting purposes)
- compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and tanks intended for the carriage of liquid foam for fire extinguishing.

2.1.2 Cofferdams separating:

- fuel oil tanks and lubricating oil tanks
- lubricating oil tanks from compartments intended for fresh water
- lubricating oil tanks from those intended for the carriage of liquid foam for fire extinguishing
- fuel oil tanks from tanks intended for the carriage of liquid foam for fire extinguishing on ships having the service notation **fire-fighting**

need not to be required when agreed 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 7, 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 3, [1.4].

2.1.3 Vented cofferdam may be required to separate heated oil fuel tanks from enclosed spaces located directly above (see Pt C, Ch 1, Sec 10, [11.7.2], item a)).

3 Double bottoms

3.1 Double bottom arrangement for ships other than tankers

3.1.1 *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 *Where a double bottom is required to be fitted, the inner bottom is to be continued out to the ship's sides in such a manner as to protect the bottom to the turn of the bilge. Such protection is to be deemed satisfactory if the inner bottom is not lower at any part than a plane parallel with the keel line and which is located not less than a vertical distance h measured from the keel line, as calculated by the formula:*

$h = B/20$

However, in no case is the value of h to be less than 760 mm, and need not to be taken as more than 2 m.

3.1.3 *Small wells constructed in the double bottom in connection with drainage arrangement are not to extend downward more than necessary. The vertical distance from the bottom of such a well to a plane coinciding with the keel line is not to be less than h/2 or 500 mm, whichever is greater, or compliance with requirement defined in Ch 3, Sec 3, [3.4.3] is to be shown for that part of the ship.*

Other wells (e.g. for lubricating oil under main engines) may be permitted by the Society if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with this regulation.

For a cargo ship of 80 m in length and upwards, proof of equivalent protection is to be shown by demonstrating that the ship is capable of withstanding bottom damages as specified in Ch 3, Sec 3, [3.4.3]. Alternatively, wells for lubricating oil below main engines may protrude into the double bottom below the boundary line defined by the distance h provided that the vertical distance between the well bottom and a plane coinciding with the keel line is not less than h/2 or 500 mm, whichever is the greater.

For a cargo ship of less than 80 m in length, the arrangements are to provide a level of safety to the satisfaction of the Society.

3.1.4 *A double bottom need not be fitted in way of watertight tanks, including dry tanks of moderate size, provided the safety of the ship is not impaired in the event of bottom or side damage as defined in Ch 3, Sec 3, [3.4].*

3.1.5 *Any part of a cargo ship of 80 m in length and upwards that is not fitted with a double bottom in accordance with [3.1.1] or [3.1.4] is to be capable of withstanding bottom damages, as specified in Ch 3, Sec 3, [3.4]. For cargo ships of less than 80 m in length, the alternative arrangements are to provide a level of safety to the satisfaction of the Society.*

3.1.6 *In the case of unusual bottom arrangements in a cargo ship of 80 m in length and upwards, it is to be demonstrated that the ship is capable of withstanding bottom damages as specified in Ch 3, Sec 3, [3.4]. For cargo ships of less than 80 m in length, the alternative arrangements are to provide a level of safety to the satisfaction of the Society.*

3.1.7 Special requirements for passenger ships and tankers are specified in Part D.

4 Compartments forward of the collision bulkhead

4.1 General

4.1.1 The fore peak and other compartments located forward of the collision bulkhead cannot be used for the carriage of fuel oil or other flammable products.

This requirement does not apply to ships of less than 400 tons gross tonnage, except for those where the fore peak is the forward cofferdam of tanks arranged for the carriage of flammable liquid products having a flash point not exceeding 60°C.

5 Minimum bow height

5.1 General

5.1.1 *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:*

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

where:

F_b : *Calculated minimum bow height, in mm*

T_1 : *Draught at 85% of the least moulded depth, in m, as defined in Ch 1, Sec 2, [3.2.4]*

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 [5.1.1] is obtained by sheer, the sheer is to extend for at least 15% of L_{LL} 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 $0,07L_{LL}$ abaft the forward perpendicular and is to be enclosed as defined in Ch 8, 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 $0,15L_{LL}$, but greater than $0,07L_{LL}$, provided that the forecastle height is not less than one half of standard height of superstructure between $0,07L_{LL}$ 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:*

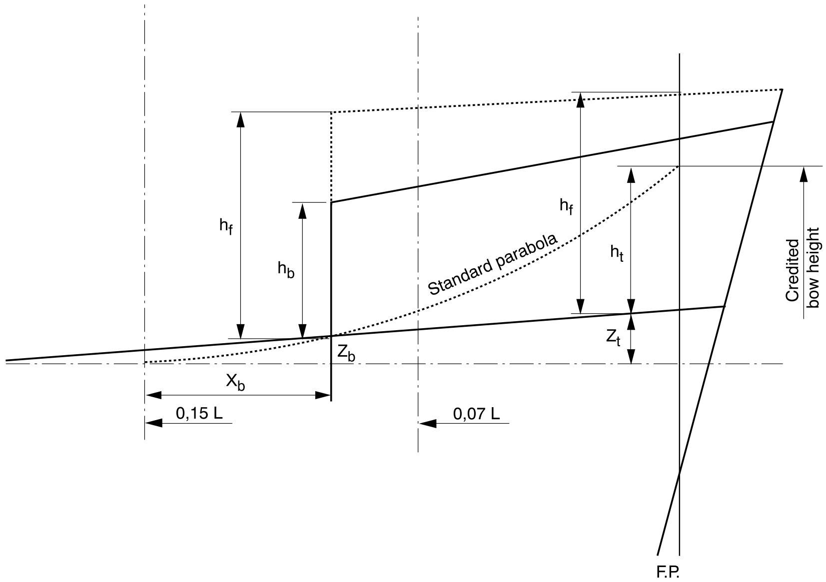
a) *Where the freeboard deck has sheer extending from abaft $0,15L_{LL}$, by a parabolic curve having its origin at $0,15L_{LL}$ abaft the forward perpendicular at a height equal to the midship depth of the ship, extended through the point of intersection of forecastle bulkhead and deck, and up to a point at the forward perpendicular not higher than the level of the forecastle deck (see 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:*

$$h_t = Z_b\left(\frac{0,15L_{LL}}{x_b}\right)^2 - Z_t$$

Z_b, Z_t : *As defined in Fig 1*

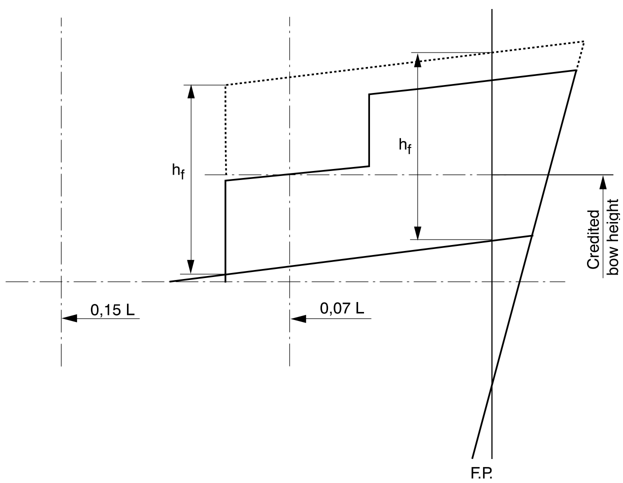
h_f : *Half standard height of superstructure.*

Figure 1 : Credited bow height where the freeboard deck has sheer extending from abaft 0,15 L



b) *Where the freeboard deck has sheer extending for less than $0,15L_{LL}$ or has no sheer, by a line from the forecastle deck at side at $0,07L_{LL}$ extended parallel to the base line to the forward perpendicular (see Fig 2).*

Figure 2 : Credited bow height where the freeboard deck has sheer extending for less than 0,15 L



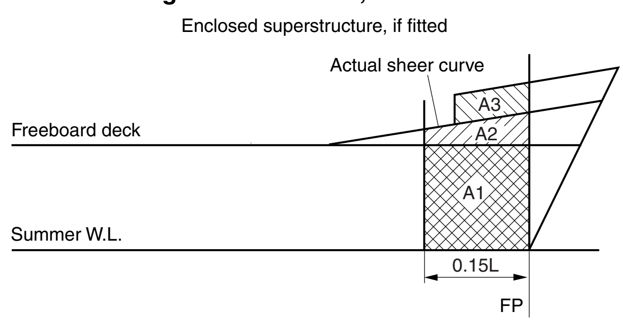
5.1.6 *All ships assigned a type B freeboard, other than oil tankers, chemical tankers and gas carriers, are to have additional reserve buoyancy in the fore end. Within the range of $0,15L_{LL}$ abaft of the forward perpendicular, the sum of the projected area between the summer load waterline and the deck at side (A1 and A2 in Fig 3) and the projected area of an enclosed superstructure, if fitted, is, in m², to be not less than:*

$$A3 = (0,15\ F_{min} + 4\ (L_{LL}/3 + 10))\ L_{LL}/1000$$

where:

- F_{min} : $F_{min} = (F_0 \cdot f_1) + f_2$
- F_0 : *Tabular freeboard, in mm, taken from the International Convention on Load Lines, as amended, Table 28.2, corrected for regulation 27(9) or 27(10), as applicable*
- f_1 : *Correction for block coefficient given in the International Convention on Load Lines, as amended, regulation 30*
- f_2 : *Correction for depth, in mm, given in the International Convention on Load Lines, as amended, regulation 31.*

Figure 3 : Areas A1, A2 and A3



6 Shaft tunnels

6.1 General

6.1.1 Shaft tunnels are to be watertight.

See also Ch 8, Sec 2.

7 Watertight ventilators and trunks

7.1 General

7.1.1 *Watertight ventilators and trunks are to be carried at least up to the bulkhead deck in passenger ships and up to the freeboard deck in ships other than passenger ships.*

8 Fuel oil tanks

8.1 General

8.1.1 *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 *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 *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.

8.2 Fuel oil tank protection

8.2.1 All ships with an aggregate oil fuel capacity of 600 m^3 are to comply with the requirements of the Regulation 12 A of Annex I to Marpol Convention, as amended.

SECTION 3 ACCESS ARRANGEMENT

1 General

1.1

1.1.1 The number and size of small hatchways for trimming and access openings to tanks or other enclosed spaces, are to be kept to the minimum consistent with access and maintenance of the space.

2 Double bottom

2.1 Inner bottom manholes

2.1.1 Inner bottom manholes are to be not less than 400 mm x 400 mm. Their number and location are to be so arranged as to provide convenient access to any part of the double bottom.

2.1.2 Inner bottom manholes are to be closed by watertight plate covers.

Doubling plates are to be fitted on the covers, where secured by bolts.

Where no ceiling is fitted, covers are to be adequately protected from damage by the cargo.

2.2 Floor and girder manholes

2.2.1 Manholes are to be provided in floors and girders so as to provide convenient access to all parts of the double bottom.

2.2.2 The size of manholes and lightening holes in floors and girders is, in general, to be less than 50 per cent of the local height of the double bottom.

Where manholes of greater sizes are needed, edge reinforcement by means of flat bar rings or other suitable stiffeners may be required.

2.2.3 Manholes may not be cut into the continuous centreline girder or floors and girders below pillars, except where allowed by the Society on a case by case basis.

3 Access arrangement to and within spaces in, and forward of, the cargo area

3.1 General

3.1.1 The requirements in [3.2] to [3.4] are not applicable to ships with service notations **bulk carrier**, **bulk carrier CSR ESP**, **bulk carrier CSR BC-A ESP**, **bulk carrier CSR BC-B ESP**, **bulk carrier CSR BC-C ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP**, **combination carrier ESP**, of 20,000 gross tonnage and over, and to ships with service notation **oil tanker ESP** of 500 gross tonnage and over. For such ships, refer to the applicable requirements of Part D.

3.1.2 The requirements in [3.2] to [3.4] are not applicable to spaces in double bottom and double side tanks.

3.2 Access to tanks

3.2.1 Tanks with a length equal to or greater than 35 m

Tanks and subdivisions of tanks having lengths of 35 m and above are to be fitted with at least two access hatchways and ladders, as far apart as practicable longitudinally.

3.2.2 Tanks with a length less than 35 m

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

3.2.3 Dimensions of access hatchways

The dimensions of any access hatchway are to be sufficient to allow a person wearing a self-contained breathing apparatus to ascend or descend the ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the tank. In no case is the clear opening to be less than 600 mm x 600 mm.

3.2.4 Tanks subdivided by wash bulkheads

When a tank is subdivided by one or more wash bulkheads, at least two hatchways are to be fitted, and these hatchways are to be so located that the associated ladders effectively serve all subdivisions of the tank.

3.3 Access within tanks

3.3.1 Wash bulkheads in tanks

Where one or more wash bulkheads are fitted in a tank, they are to be provided with openings not less than 600 x 800 mm and so arranged as to facilitate the access of persons wearing breathing apparatus or carrying a stretcher with a patient.

3.3.2 Passage on the tank bottom

To provide ease of movement on the tank bottom throughout the length and breadth of the tank, a passageway is to be fitted on the upper part of the bottom structure of each tank, or alternatively, manholes having at least the dimensions of 600 mm x 800 mm are to be arranged in the floors at a height of not more than 600 mm from the bottom shell plating.

3.3.3 Passageways in the tanks

a) *Passageways in the tanks are to have a minimum width of 600 mm considering the requirement for the possibility of carrying an unconscious person. Elevated passageways are to be provided with guard rails over their entire length. Where guard rails are provided on one side only, foot rails are to be fitted on the opposite side. Shelves and platforms forming a part of the access to the tanks are to be of non-skid construction where practicable and be fitted with guard rails. Guard rails are to be fitted to bulkhead and side stringers when such structures are being used for recognised access*

b) *Access to elevated passageways from the ship's bottom is to be provided by means of easily accessible passageways, ladders or treads. Treads are to provide lateral support for the foot. Where rungs of ladders are fitted against a vertical surface, the distance from the centre of the rungs to that surface is to be at least 150 mm*

c) *When the height of the bottom structure does not exceed 1,50 m, the passageways required in a) may be replaced by alternative arrangements having regard to the bottom structure and requirement for ease of access of a person wearing a self-contained breathing apparatus or carrying a stretcher with a patient.*

3.3.4 Manholes

Where manholes are fitted, as indicated in [2.2.2], access is to be facilitated by means of steps and hand grips with platform landings on each side.

3.3.5 Guard rails

Guard rails are to be 900 mm in height and consist of a rail and intermediate bar. These guard rails are to be of substantial construction.

3.4 Construction of ladders

3.4.1 General

In general, the ladders are not to be inclined at an angle exceeding 70°. The flights of ladders are not to be more than 9 m in actual length. Resting platforms of adequate dimensions are to be provided.

3.4.2 Construction

Ladders and handrails are to be constructed of steel of adequate strength and stiffness and securely attached to the tank structure by stays. The method of support and length of stay are to be such that vibration is reduced to a practical minimum.

3.4.3 Corrosive effect of the cargo

Provision is to be made for maintaining the structural strength of the ladders and railings taking into account the corrosive effect of the cargo.

3.4.4 Width of ladders

The width of ladders is not to be less than:

- *350 mm for vertical ladders*
- *400 mm for inclined ladders.*

3.4.5 Treads

The treads are to be equally spaced at a distance apart measured vertically not exceeding 300 mm. They are to be formed of two square steel bars of not less than 22 mm by 22 mm in section fitted to form a horizontal step with the edges pointing upward, or of equivalent construction. The treads are to be carried through the side stringers and attached thereto by double continuous welding.

3.4.6 Sloping ladders

All sloping ladders are to be provided with handrails of substantial construction on both sides fitted at a convenient distance above the treads.

4 Shaft tunnels

4.1 General

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

4.1.2 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].

5 Access to steering gear compartment

5.1

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

5.1.2 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.

Part B
Hull and Stability

Chapter 3
STABILITY

SECTION 1 GENERAL

1 General

1.1 Application

1.1.1 General

All ships equal to or greater than 24 m in length may be assigned class only after it has been demonstrated that their intact stability is adequate. Adequate intact stability means compliance with standards laid down by the relevant Administration or with the requirements specified in this Chapter taking into account the ship's size and type. In any case, the level of intact stability is not to be less than that provided by the Rules.

1.1.2 Ships less than 24 m in length

The Rules also apply to ships less than 24 m in length. In this case, the requirements concerned may be partially omitted when deemed appropriate by the Society.

1.1.3 Approval of the Administration

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

1.2 Application to ships having additional service feature SPxxx or SPxxx-capable

1.2.1 Ships having additional service feature **SPxxx** or **SPxxx-capable** with xxx equal to or greater than 240 are to comply, in addition to the applicable requirements of this Chapter, with the requirements of Pt D, Ch 11, Sec 3, considering the special personnel as passengers.

1.2.2 Ships having additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240 are to comply with the requirements of this Chapter, unless otherwise specified, considering the special personnel as crew.

1.3 Application to ships having additional class notation STABLIFT

1.3.1 Ships having additional class notation **STABLIFT** are to comply, in addition to the applicable requirements of this Chapter, with the requirements of Pt E, Ch 8, Sec 3.

2 Examination procedure

2.1 Documents to be submitted

2.1.1 List of documents

For the purpose of the examination of the stability, the documentation listed in Ch 1, Sec 3, [1.1.2] is to be submitted for information.

The stability documentation to be submitted for approval, as indicated in Ch 1, Sec 3, [1.2.1], is as follows:

- Inclining test report for the ship, as required in [2.2] or:
  - where the stability data is based on a sister ship, the inclining test report of that sister ship along with the lightship measurement report for the ship in question; or
  - where lightship particulars are determined by methods other than inclining of the ship or its sister, the lightship measurement report of the ship along with a summary of the method used to determine those particulars as indicated in [2.2.4].
- trim and stability booklet, as required in Ch 3, Sec 2, [1.1.1]
- and, as applicable:
  - grain loading manual, as required in Pt D, Ch 4, Sec 3, [1.2.2]
  - damage stability calculations, as required in Ch 3, Sec 3, [3.1]
  - damage control documentation, as required in Ch 3, Sec 3, [4]
  - loading computer documentation, as required in Ch 3, Sec 2, [1.1.2] and in Ch 3, Sec 3, [3.1.3].

  A copy of the trim and stability booklet and, if applicable, the grain stability booklet, the damage control documentation or the loading computer documentation is to be available on board for the attention of the Master.

2.1.2 Provisional documentation

The Society reserves the right to accept or demand the submission of provisional stability documentation for examination.

Provisional stability documentation includes loading conditions based on estimated lightship values.

2.1.3 Final documentation

Final stability documentation based on the results of the inclining test or the lightweight check is to be submitted for examination.

When provisional stability documentation has already been submitted and the difference between the estimated values of the lightship and those obtained after completion of the test is less than:

- 2% for the displacement, and
- 1% of the length between perpendiculars for the longitudinal position of the centre of gravity

and the determined vertical position of the centre of gravity is not greater than the estimated vertical position of the centre of gravity, the provisional stability documentation may be accepted as the final stability documentation.

2.2 Inclining test/lightweight check

2.2.1 Definitions

a) Lightship

The lightship is a ship complete in all respects, but without consumables, stores, cargo, and crew and effects, and without any liquids on board except for machinery and piping fluids, such as lubricants and hydraulics, at operating levels, and mediums required for the fixed fire-extinguishing systems, such as fresh water, CO_2, dry chemical powder, foam concentrate, etc.

b) Inclining test

The inclining test is a procedure which involves moving a series of known weights, normally in the transverse direction, and then measuring the resulting change in the equilibrium heel angle of the ship. By using this information and applying basic naval architecture principles, the ship's vertical centre of gravity (VCG or KG) is determined.

c) Lightweight check

The lightweight check is a procedure which involves auditing all items which are to be added, deducted or relocated on the ship at the time of the inclining test so that the observed condition of the ship can be adjusted to the lightship condition. The weight and longitudinal, transverse and vertical location of each item are to be accurately determined and recorded. The lightship displacement and longitudinal centre of gravity (LCG) can be obtained using this information, as well as the static waterline of the ship at the time of the inclining test as determined by measuring the freeboard or verified draught marks of the ship, the ship's hydrostatic data and the sea water density.

2.2.2 General

Any ship for which a stability investigation is requested in order to comply with class requirements is to be initially subjected to an inclining test permitting the evaluation of the position of the lightship centre of gravity, or a lightweight check of the lightship displacement, so that the stability data can be determined. Cases for which the inclining test is required and those for which the lightweight check is accepted in its place are listed in [2.2.4] and [2.2.5].

A detailed procedure of the test is to be submitted to the Society prior to the test. This procedure is to include:

a) *identification of the ship by name and shipyard hull number, if applicable*

b) *date, time and location of the test*

c) *inclining weight data:*
   - *type*
   - *amount (number of units and weight of each)*
   - *certification*
   - *method of handling (i.e. sliding rail or crane)*
   - *anticipated maximum angle of heel to each side*

d) *measuring devices:*
   - *pendulums - approximate location and length*
   - *U-tubes - approximate location and length*
   - *inclinometers - Location and details of approvals and calibrations*

e) *approximate trim*

f) *condition of tanks*

g) *estimate weights to deduct, to complete, and to relocate in order to place the ship in its true lightship condition.*

The inclining test or lightweight check is to be attended by a Surveyor of the Society. The Society may accept inclining tests or lightweight checks attended by a member of the flag Administration.

The inclining test is adaptable to ships less than 24 m in length, provided that precautions are taken, on a case by case basis, to ensure the accuracy of the test procedure.

The inclining test or lightweight test report is to be signed by the Surveyor to confirm the information witnessed during the test. In addition, for ships performing regular adjustments of equipment such as for example supply vessels, the report is to include the detailed list of the major equipment on the decks, if they are included in the lightship particulars.

2.2.3 Inclining test

The inclining test is required in the following cases:

- any new ship, after its completion, except for the cases specified in [2.2.4]
- any ship, if deemed necessary by the Society, where any alterations are made so as to materially affect the stability.

Note 1: Due attention is to be paid to SOLAS Ch.II.1 Reg.22 (if applicable) whereby it is stipulated that such allowance is subject to the Flag Authorities agreement (refer to Pt A, Ch 1, Sec 1, [3.1.1]).

2.2.4 Lightweight check

The Society may allow a lightweight check to be carried out in lieu of an inclining test in the case of:

- *stability data are available from the inclining test of a sister ship and it is shown to the satisfaction of the Society that reliable stability information for the exempted ship can be obtained from such basic data. A lightweight survey shall be carried out upon completion and the ship shall be inclined whenever in comparison with the data derived from the sister ship, a deviation from the lightship displacement exceeding 1% for ships of 160 m or more in length and 2% for ships of 50 m or less in length and as determined by linear interpolation for intermediate lengths or a deviation from the lightship longitudinal centre of gravity exceeding 0.5% of* L_S *is found.*
- special types of ship, such as pontoons, provided that the vertical centre of gravity is considered at the level of the deck.
- special types of ship provided that:
  - a detailed list of weights and the positions of their centres of gravity is submitted
  - a lightweight check is carried out, showing accordance between the estimated values and those determined
  - adequate stability is demonstrated in all the loading conditions reported in the trim and stability booklet.

2.2.5 Detailed procedure

A detailed procedure for conducting an inclining test is included in Ch 3, App 1. For the lightweight check, the same procedure applies except as provided for in Ch 3, App 1, [1.1.9].

SECTION 2 INTACT STABILITY

1 General

1.1 Information for the Master

1.1.1 Stability booklet

Each ship is to be provided with a stability booklet, approved by the Society, which contains sufficient information to enable the Master to operate the ship in compliance with the applicable requirements contained in this Section.

Where any alterations are made to a ship so as to materially affect the stability information supplied to the Master, amended stability information is to be provided. If necessary the ship is to be re-inclined.

Stability data and associated plans are to be drawn up in the working language of the ship and any other language the Society may require. reference is also made to the International Safety Management (ISM) Code, adopted by IMO by resolution A.741(18). All translations of the stability booklet are to be approved.

The format of the trim and stability booklet and the information included are specified in Ch 3, App 2.

1.1.2 Loading instrument

As a supplement to the approved stability booklet, a loading instrument, approved by the Society, may be used to facilitate the stability calculations mentioned in Ch 3, App 2.

A simple and straightforward instruction manual is to be provided.

In order to validate the proper functioning of the computer hardware and software, pre-defined loading conditions are to be run in the loading instrument periodically, at least at every periodical class survey, and the print-out is to be maintained on board as check conditions for future reference in addition to the approved test conditions booklet.

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval, are given in Ch 10, Sec 2, [4].

1.1.3 Operating booklets for certain ships

Ships with innovative design are to be provided with additional information in the stability booklet such as design limitations, maximum speed, worst intended weather conditions or other information regarding the handling of the craft that the Master needs to operate the ship.

1.2 Permanent ballast

1.2.1 *If used, permanent ballast is to be located in accordance with a plan approved by the Society and in a manner that prevents shifting of position. Permanent ballast is not to be removed from the ship or relocated within the ship without the approval of the Society. Permanent ballast particulars are to be noted in the ship's stability booklet.*

1.2.2 Permanent solid ballast is to be installed under the supervision of the Society.

2 Design criteria

2.1 General intact stability criteria

2.1.1 General

The intact stability criteria specified in [2.1.2], [2.1.3], [2.1.4],and [2.1.5] are to be complied with for the loading conditions mentioned in Ch 3, App 2, [1.2].

However, the lightship condition not being an operational loading case, the Society may accept that part of the above-mentioned criteria are not fulfilled.

These criteria set minimum values, but no maximum values are recommended. It is advisable to avoid excessive values of metacentric height, since these might lead to acceleration forces which could be prejudicial to the ship, its equipment and to safe carriage of the cargo.

2.1.2 GZ curve area

The area under the righting lever curve (GZ curve) is to be not less than 0,055 m·rad up to θ = 30° angle of heel and not less than 0,09 m·rad up to θ = 40° or the angle of down flooding θ_f if this angle is less than 40°. Additionally, the area under the righting lever curve (GZ curve) between the angles of heel of 30° and 40° or between 30° and θ_f, if this angle is less than 40°, is to be not less than 0,03 m·rad.

Note 1: θ_f is an angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight submerge.

In applying this criterion, openings which cannot be closed weathertight include ventilators that have to remain open to supply air to the engine room or emergency generator room for the effective operation of the ship, but exclude small openings through which progressive flooding cannot take place. This interpretation is not intended to be applied to existing ships.

The means of closing air pipes are to be weathertight and of an automatic type if the openings of the air pipes to which the devices are fitted would be submerged at an angle of less than 40 degrees (or any lesser angle which may be needed to suit stability requirements) when the ship is floating at its summer load line draught. Pressure/vacuum valves (P.V. valves) may be accepted on tankers. Wooden plugs and trailing canvas hoses may not be accepted in positions 1 and 2 as defined in Ch 1, Sec 2, [3.2.3].

2.1.3 Minimum righting lever

The righting lever GZ is to be at least 0,20 m at an angle of heel equal to or greater than 30°.

2.1.4 Angle of maximum righting lever

The maximum righting arm is to occur at an angle of heel preferably exceeding 30° but not less than 25°.

When the righting lever curve has a shape with two maximums, the first is to be located at a heel angle not less than 25°.

In cases of ships with a particular design and subject to the prior agreement of the flag Administration, the Society may accept an angle of heel θ_{max} less than 25° but in no case less than 15°, provided that the area "A" below the righting lever curve up to the angle of θ_{max} is not less than the value obtained, in m.rad, from the following formula:

$$A = 0,055 + 0,001\ (30° - \theta_{max})$$

where θ_{max} is the angle of heel in degrees at which the righting lever curve reaches its maximum.

2.1.5 Initial metacentric height

The initial metacentric height GM_0 is not to be less than 0,15 m.

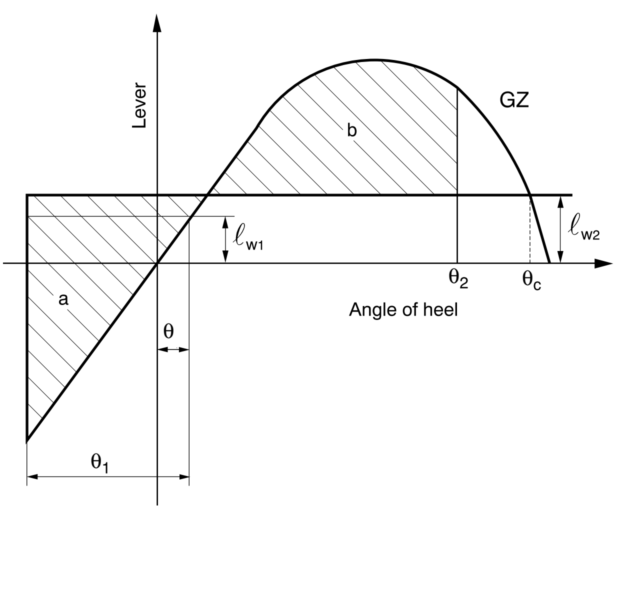
2.1.6 Elements affecting stability

A number of influences such as beam wind on ships with large windage area, icing of topsides, water trapped on deck, rolling characteristics, following seas, etc., which adversely affect stability, are to be taken into account.

2.1.7 Elements reducing stability

Provisions are to be made for a safe margin of stability at all stages of the voyage, regard being given to additions of weight, such as those due to absorption of water and icing (details regarding ice accretion are given in [6]) and to losses of weight such as those due to consumption of fuel and stores.

Figure 1 : Severe wind and rolling



3 Severe wind and rolling criterion (weather criterion)

3.1 Scope

3.1.1 *This criterion supplements the stability criteria given in [2.1] for ships of 24 m in length and over. The more stringent criteria of [2.1] and the weather criterion are to govern the minimum requirements.*

3.2 Weather criterion

3.2.1 Assumptions

The ability of a ship to withstand the combined effects of beam wind and rolling is to be demonstrated for each standard condition of loading, with reference to Fig 1 as follows:

- *the ship is subjected to a steady wind pressure acting perpendicular to the ship's centreline which results in a steady wind heeling lever (ℓ_{w1})*
- *from the resultant angle of equilibrium (θ_0), the ship is assumed to roll owing to wave action to an angle of roll (θ_1) to windward*
- *the ship is then subjected to a gust wind pressure which results in a gust wind heeling lever (ℓ_{w2})*
- *free surface effects, as described in [4], are to be accounted for in the standard conditions of loading as set out in Ch 3, App 2, [1.2].*

3.2.2 Criteria

Under the assumptions of [3.2.1], the following criteria are to be complied with:

- *the area "b" is to be equal to or greater than area "a", where:*
  - *a* : Area above the GZ curve and below ℓ_{w2}, between θ_R and the intersection of ℓ_{w2} with the GZ curve
  - *b* : *Area above the heeling lever ℓ_{w2} and below the GZ curve, between the intersection of ℓ_{w2} with the GZ curve and θ_2*
- *the angle of heel under action of steady wind (θ_0) is to be limited to 16° or 80% of the angle of deck edge immersion, whichever is less.*

3.2.3 Heeling levers

The wind heeling levers ℓ_{w1} and ℓ_{w2}, in m, referred to in [3.2.2], are constant values at all angles of inclination and are to be calculated as follows:

$$\ell_{W1} = \frac{PAZ}{1000 g\Delta}$$

and

$$\ell_{W2} = 1,5\,\ell_{W1}$$

where:

P : *504 N/m² for unrestricted navigation notation. The value of P used for ships with restricted navigation notation may be reduced subject to the approval of the Society*

A : *Projected lateral area in m², of the portion of the ship and deck cargo above the waterline*

Z : *Vertical distance in m, from the centre of A to the centre of the underwater lateral area or approximately to a point at one half the draught*

Δ : *Displacement in t*

g = 9,81 m/s².

3.2.4 Angles of heel

For the purpose of calculating the criteria of [3.2.2], the angles in Fig 1 are defined as follows:

θ_0 : *Angle of heel, in degrees, under action of steady wind*

θ_1 : *Angle of roll, in degrees, to windward due to wave action, calculated as follows:*

$$\theta_1 = 109 k X_1 X_2 \sqrt{rs}$$

θ_2 : *Angle of downflooding (θ_f) in degrees, or 50° or θ_c , whichever is less*

θ_f : *Angle of heel in degrees, at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight immerse. In applying this criterion, openings which cannot be closed weathertight include ventilators that have to remain open to supply air to the engine room or emergency generator room for the effective operation of the ship, but exclude small openings through which progressive flooding cannot take place.*

θ_c : *Angle in degrees, of second intercept between wind heeling lever ℓ_{w2} and GZ curves*

$\theta_R = \theta_0 - \theta_1$

X_1 : *Coefficient defined in Tab 1*

X_2 : *Coefficient defined in Tab 2*

k : *Coefficient equal to:*

k = 1,0 for a round-bilged ship having no bilge or bar keels

k = 0,7 for a ship having sharp bilge

For a ship having bilge keels, a bar keel or both, k is defined in Tab 3.

$r = 0,73 \pm 0,6\ (OG)/T_1$

OG : *Distance in m, between the centre of gravity and the waterline (positive if centre of gravity is above the waterline, negative if it is below)*

T_1 : *Mean moulded draught in m, of the ship*

s : *Factor defined in Tab 4.*

Note 1: The angle of roll θ_1 for ships with anti-rolling devices is to be determined without taking into account the operations of these devices.

Note 2: The angle of roll θ_1 may be obtained, in lieu of the above formula, from model tests or full scale measurements.

The rolling period T_R, in s, is calculated as follows:

$$T_R = \frac{2CB}{\sqrt{GM}}$$

where:

$$C = 0,373 + 0,023\frac{B}{T_1} - 0,043\frac{L_W}{100}$$

The symbols in the tables and formula for the rolling period are defined as follows:

L_W : *Length in m, of the ship at the waterline*

T_1 : *Mean moulded draught in m, of the ship*

A_K : *Total overall area in m² of bilge keels, or area of the lateral projection of the bar keel, or sum of these areas,* or area of the lateral projection of any hull appendages generating added mass during ship roll

GM : *Metacentric height in m, corrected for free surface effect.*

3.2.5 *Tab 1 to Tab 4 and formulae described in [3.2.4] are based on data from ships having:*

- *B/T_1 smaller than 3,5*
- *(KG/T_1-1) between $-0,3$ and 0,5*
- *T_R smaller than 20 s.*

For ships with parameters outside of the above limits the angle of roll (θ_1) may be determined with model experiments of a subject ship with the procedure described in IMO MSC.1/Circ. 1200 as the alternative. In addition, the Society may accept such alternative determinations for any ship, if deemed appropriate.

Table 1 : Values of coefficient X_1

B/T_1	X_1
≤ 2,4	1,00
2,5	0,98
2,6	0,96
2,7	0,95
2,8	0,93
2,9	0,91
3,0	0,90
3,1	0,88
3,2	0,86
3,4	0,82
≥ 3,5	0,80
Note 1: Intermediate values in this table are to be obtained by linear interpolation	

Table 2 : Values of coefficient X_2

C_B	X_2
≤ 0,45	0,75
0,50	0,82
0,55	0,89
0,60	0,95
0,65	0,97
≥ 0,70	1,00
Note 1: Intermediate values in this table are to be obtained by linear interpolation	

Table 3 : Values of coefficient k

$\frac{A_K \times 100}{L \times B}$	k
0,0	1,00
1,0	0,98
1,5	0,95
2,0	0,88
2,5	0,79
3,0	0,74
3,5	0,72
≥ 4,0	0,70
Note 1: Intermediate values in this table are to be obtained by linear interpolation	

Table 4 : Values of factor s

T_R	s
≤ 6	0,100
7	0,098
8	0,093
12	0,065
14	0,053
16	0,044
18	0,038
≥ 20	0,035
Note 1: Intermediate values in this table are to be obtained by linear interpolation	

3.2.6 *Alternative means for determining the wind heeling lever (ℓ_{W1}) may be accepted, to the satisfaction of the Society as an equivalent to the calculation in [3.2.3]. When such alternative tests are carried out, reference shall be made based on the Interim Guidelines for alternative assessment of the weather criterion (IMO MSC.1/Circ.1200). the wind velocity used in the tests shall be 26 m/s in full scale with uniform velocity profile. the value of wind velocity used for ships in restricted services may be reduced to the satisfaction of the Society.*

4 Effects of free surfaces of liquids in tanks

4.1 General

4.1.1 *For all loading conditions, the initial metacentric height and the righting lever curve are to be corrected for the effect of free surfaces of liquids in tanks.*

4.2 Consideration of free surface effects

4.2.1 *Free surface effects are to be considered whenever the filling level in a tank is less than 98% of full condition. Free surface effects need not be considered where a tank is nominally full, i.e. filling level is 98% or above. Free surface effects for small tanks may be ignored under the condition in [4.8.1].*

4.2.2 *Nominally full cargo tanks should be corrected for free surface effects at 98% filling level. In doing so, the correction to initial metacentric height should be based on the inertia moment of liquid surface at 5° of the heeling angle divided by displacement, and the correction to righting lever is suggested to be on the basis of real shifting moment of cargo liquids.*

4.3 Categories of tanks

4.3.1 *Tanks which are taken into consideration when determining the free surface correction may be one of two categories:*

- *tanks with fixed filling level (e.g. liquid cargo, water ballast). The free surface correction is to be defined for the actual filling level to be used in each tank.*
- *tanks with variable filling level (e.g. consumable liquids such as fuel oil, diesel oil, and fresh water, and also liquid cargo and water ballast during liquid transfer operations). Except as permitted in [4.5.1] and [4.6.1], the free surface correction is to be the maximum value attainable among the filling limits envisaged for each tank, consistent with any operating instructions.*

4.4 Consumable liquids

4.4.1 *In calculating the free surfaces effect in tanks containing consumable liquids, it is to be assumed that for each type of liquid at least one transverse pair or a single centreline tank has a free surface and the tank or combination of tanks taken into account are to be those where the effect of free surface is the greatest.*

4.5 Water ballast tanks

4.5.1 *Where water ballast tanks, including anti-rolling tanks and anti-heeling tanks, are to be filled or discharged during the course of a voyage, the free surfaces effect is to be calculated to take account of the most onerous transitory stage relating to such operations.*

4.6 Liquid transfer operations

4.6.1 *For ships engaged in liquid transfer operations, the free surface corrections at any stage of the liquid transfer operations may be determined in accordance with the filling level in each tank at the stage of the transfer operation.*

4.7 GM_0 and GZ curve corrections

4.7.1 *The corrections to the initial metacentric height and to the righting lever curve are to be addressed separately as indicated in [4.7.2] and [4.7.3].*

4.7.2 *In determining the correction to the initial metacentric height, the transverse moments of inertia of the tanks are to be calculated at 0 degrees angle of heel according to the categories indicated in [4.3.1].*

4.7.3 *The righting lever curve may be corrected by any of the following methods:*

- *correction based on the actual moment of fluid transfer for each angle of heel calculated; corrections may be calculated according to the categories indicated in [4.3.1]*
- *correction based on the moment of inertia, calculated at 0 degrees angle of heel, modified at each angle of heel calculated; corrections may be calculated according to the categories indicated in [4.3.1].*

4.7.4 *Whichever method is selected for correcting the righting lever curve, only that method is to be presented in the ship's trim and stability booklet. However, where an alternative method is described for use in manually calculated loading conditions, an explanation of the differences which may be found in the results, as well as an example correction for each alternative, are to be included.*

4.8 Small tanks

4.8.1 *Small tanks which satisfy the following condition using the values of k corresponding to an angle of inclination of 30° need not be included in the correction:*

$M_{fs}/\Delta_{min} < 0,01$ m

where:

Δ_{min} : *Minimum ship displacement, in t, calculated at* d_{min}

d_{min} : *Minimum mean service draught, in m, of ship without cargo, with 10% stores and minimum water ballast, if required.*

4.9 Remainder of liquid

4.9.1 *The usual remainder of liquids in the empty tanks need not be taken into account in calculating the corrections, providing the total of such residual liquids does not constitute a significant free surface effect.*

5 Cargo ships carrying timber deck cargoes

5.1 Application

5.1.1 *The provisions given hereunder apply to ships engaged in the carriage of timber deck cargoes. Ships that are provided with and make use of their timber load line are also to comply with the requirements of regulations 41 to 45 of the International Load Line Convention 1966, as amended.*

5.2 Definitions

5.2.1 Timber

Timber means sawn wood or lumber, cants, logs, poles, pulpwood and all other types of timber in loose or packaged forms. The term does not include wood pulp or similar cargo.

5.2.2 Timber deck cargo

Timber deck cargo means a cargo of timber carried on an uncovered part of a freeboard or superstructure deck. The term does not include wood pulp or similar cargo.

5.2.3 Timber load line

Timber load line means a special load line assigned to ships complying with certain conditions related to their construction set out in the International Convention on Load Lines 1966, as amended, and used when the cargo complies with the stowage and securing conditions of the Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 1991 (Resolution A.715(17)).

5.3 Stability criteria

5.3.1 *For ships loaded with timber deck cargoes and provided that the cargo extends longitudinally between superstructures (where there is no limiting superstructure at the after end, the timber deck cargo is to extend at least to the after end of the aftermost hatchway) and transversely for the full beam of ship after due allowance for a rounded gunwale not exceeding 4% of the breadth of the ship and/or securing the supporting uprights and which remains securely fixed at large angles of heel, the Society may apply the* criteria given in [5.3.2] to [5.3.5], *which substitute those given in [2.1.2], [2.1.3], [2.1.4] and [2.1.5] and in [3.2].*

5.3.2 *The area under the righting lever curve (GZ curve) is to be not less than 0,08 m·rad up to* $\theta = 40°$ *or the angle of flooding if this angle is less than 40°.*

5.3.3 *The maximum value of the righting lever (GZ) is to be at least 0,25 m.*

5.3.4 *At all times during a voyage, the metacentric height* GM_0 *is to be not less than 0,10 m after correction for the free surface effects of liquid in tanks and, where appropriate, the absorption of water by the deck cargo and/or ice accretion on the exposed surfaces. (Details regarding ice accretion are given in [6]).*

5.3.5 *When determining the ability of the ship to withstand the combined effect of beam wind and rolling according to [3.2], the 16° limiting angle of heel under action of steady wind is to be complied with, but the additional criterion of 80% of the angle of deck edge immersion may be ignored.*

5.4 Stability booklet

5.4.1 *The ship is to be supplied with comprehensive stability information which takes into account timber deck cargo. Such information is to enable the Master, rapidly and simply, to obtain accurate guidance as to the stability of the ship under varying conditions of service. Comprehensive rolling period tables or diagrams have proved to be very useful aids in verifying the actual stability conditions.*

5.4.2 *For ships carrying timber deck cargoes, the Society may deem it necessary that the Master be given information setting out the changes in deck cargo from that shown in the loading conditions, when the permeability of the deck cargo is significantly different from 25% (see [5.5.1]).*

5.4.3 *For ships carrying timber deck cargoes, conditions are to be shown indicating the maximum permissible amount of deck cargo having regard to the lightest stowage rate likely to be met in service.*

5.5 Calculation of the stability curve

5.5.1 *In addition to the provisions given in Ch 3, App 2, [1.3], the Society may allow account to be taken of the buoyancy of the deck cargo assuming that such cargo has a permeability of 25% of the volume occupied by the cargo. Additional curves of stability may be required if the Society considers it necessary to investigate the influence of different permeabilities and/or assumed effective height of the deck cargo.*

5.6 Loading conditions to be considered

5.6.1 *The loading conditions which are to be considered for ships carrying timber deck cargoes are specified in Ch 3, App 2, [1.2.2]. For the purpose of these loading conditions, the ship is assumed to be loaded to the summer timber load line with water ballast tanks empty.*

5.7 Assumptions for calculating loading conditions

5.7.1 *The following assumptions are to be made for calculating the loading conditions referred to in Ch 3, App 2, [1.2.2]:*

- *the amount of cargo and ballast is to correspond to the worst service condition in which all the relevant stability criteria reported in [2.1.2], [2.1.3], [2.1.4] and [2.1.5], or the optional criteria given in [5.3], are met*
- *in the arrival condition, it is to be assumed that the weight of the deck cargo has increased by 10% due to water absorption.*

5.7.2 *The stability of the ship at all times, including during the process of loading and unloading timber deck cargo, is to be positive and* in compliance with the stability criteria of [5.3]. *It is to be calculated having regard to:*

- *the increased weight of the timber deck cargo due to:*
  - *absorption of water in dried or seasoned timber, and*
  - *ice accretion, if applicable (as reported in [6])*
- *variations in consumable*
- *the free surface effect of liquid in tanks, and*
- *the weight of water trapped in broken spaces within the timber deck cargo and especially logs.*

5.7.3 *Excessive initial stability is to be avoided as it will result in rapid and violent motion in heavy seas which will impose large sliding and racking forces on the cargo causing high stresses on the lashings.* Unless otherwise stated in the stability booklet, *the metacentric height is* generally *not to exceed 3% of the breadth in order to prevent excessive acceleration in rolling provided that the relevant stability criteria given in [5.3]* are satisfied.

5.8 Stowage of timber deck cargoes

5.8.1 *The stowage of timber deck cargoes is to comply with the provisions of chapter 3 of the Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 1991 (resolution A.715(17)).*

6 Icing

6.1 Application

6.1.1 *For any ship having an ice class notation or operating in areas where ice accretion is likely to occur, adversely affecting a ship's stability, icing allowances are to be included in the analysis of conditions of loading.*

6.2 Ships carrying timber deck cargoes

6.2.1 *The Master is to establish or verify the stability of his ship for the worst service condition, having regard to the increased weight of deck cargo due to water absorption and/or ice accretion and to variations in consumable.*

6.2.2 *When timber deck cargoes are carried and it is anticipated that some formation of ice will take place, an allowance is to be made in the arrival condition for the additional weight.*

6.2.3 Allowance for ice accretion

The ice accretion weight, w, in kg/m², is to be taken as follows:

$$w = 30 \cdot \frac{2{,}3\ (15{,}2\ L - 351{,}8\ )}{l_{FB}} \cdot f_{TL} \cdot \frac{l_{bow}}{0{,}16\ L}$$

where:

f_{TL} : *timber and lashing factor:*

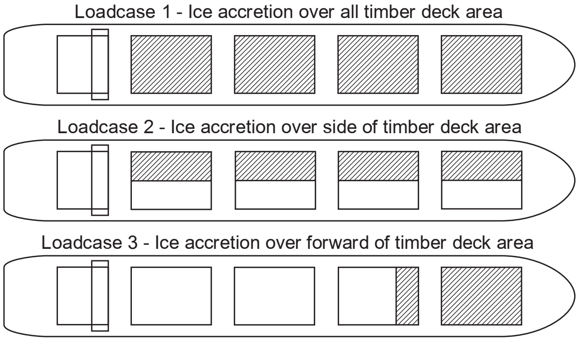
$f_{TL} = 1{,}2$

l_{FB} : *freeboard height, in mm*

l_{bow} : *length of bow flare region, in m, to be taken as the distance from the longitudinal position at which the maximum breadth occurs on a water line located 0,5 m below the freeboard deck at side to the foremost point of the bow at that waterline.*

The ice accretion weight w over the timber deck region is to be applied to each of the load cases as illustrated in Fig 2.

Figure 2 : Ice accretion load case for timber deck cargoes



Load cases are to be applied in stability calculations.

6.3 Calculation assumptions

6.3.1 *For ships operating in areas where ice accretion is likely to occur, the following icing allowance is to be made in the stability calculations:*

- *30 kg per square metre on exposed weather decks and gangways*
- *7,5 kg per square metre for the projected lateral area of each side of the ship above the water plane*
- *the projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging of ships having no sails and the projected lateral area of other small objects are to be computed by increasing the total projected area of continuous surfaces by 5% and the static moments of this area by 10%.*

6.3.2 *Ships intended for operation in areas where ice is known to occur are to be:*

- *designed to minimise the accretion of ice, and*
- *equipped with such means for removing ice as, for example, electrical and pneumatic devices, and/or special tools such as axes or wooden clubs for removing ice from bulwarks, rails and erections.*

6.4 Guidance relating to ice accretion

6.4.1 *The following icing areas are to be considered:*

a) *the area north of latitude 65°30'N, between longitude 28°W and the west coast of Iceland; north of the north coast of Iceland; north of the rhumb line running from latitude 66°N, longitude 15°W to latitude 73°30'N, longitude 15°E, north of latitude 73°30'N between longitude 15°E and 35°E, and east of longitude 35°E, as well as north of latitude 56°N in the Baltic Sea*

b) *the area north of latitude 43°N bounded in the west by the North American coast and the east by the rhumb line running from latitude 43°N, longitude 48°W to latitude 63°N, longitude 28°W and thence along longitude 28°W*

c) *all sea areas north of the North American Continent, west of the areas defined in a) and b)*

d) *the Bering and Okhotsk Seas and the Tartary Strait during the icing season, and*

e) *south of latitude 60°S.*

6.4.2 *For ships operating where ice accretion may be expected:*

- *within the areas defined in a), c), d) and e)* of [6.4.1] *known to having icing conditions significantly different from those described in [6.3], ice accretion requirements of one half to twice the required allowance may be applied*
- *within the area defined in b), where ice accretion in excess of twice the allowance required by [6.3] may be expected, more severe requirements than those given in [6.3] may be applied.*

SECTION 3 DAMAGE STABILITY

1 Application

1.1 Ships for which damage stability is required

1.1.1 Damage stability calculation is required for ships which are assigned with the additional class notation **SDS**.

1.1.2 The damage stability criteria to be applied depend on the ship type as described by its service notation and corresponding rules defined in Pt A, Ch 1, Sec 2.

1.1.3 For tankers assigned with a tropical freeboard and granted with **SDS** additional class notation, the corresponding loading conditions and damage stability calculations are to be submitted into the damage stability booklet.

1.2 Ships having additional class notation SDS and additional service feature SPxxx or SPxxx-capable

1.2.1 Ships having additional class notation **SDS** and additional service feature **SPxxx** or **SPxxx-capable** are to comply, in addition to the applicable requirements of this Section, with the requirements of Pt D, Ch 11, Sec 3, [2.3], considering the special personnel as passengers, where the attained subdivision index A (defined in Pt D, Ch 11, Sec 3, [2.3.3]) is not to be less than:

- R, where the ship is carrying 240 persons or more
- 0,8 R, where the ship is carrying not more than 60 persons
- R value to be calculated by linear interpolation between 0,8 R and R, where the ship is carrying more than 60 (but not more than 240) persons.

1.2.2 However, for ships having additional class notation **SDS** and additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240 persons, Pt D, Ch 11, Sec 3, [2.3.12] is not applicable.

2 General

2.1 Approaches to be followed for damage stability investigation

2.1.1 General

The purpose of damage stability calculations is to assess the equilibrium position and reserve stability of the ship after flooding.

In order to assess the behaviour of the ship after damage, two approaches have been developed: the deterministic and the probabilistic, which are to be applied depending on the ship type.

The metacentric heights (GM), stability levers (GZ) and centre of gravity positions for judging the final conditions are to be calculated by the constant displacement (lost buoyancy) method.

2.1.2 Deterministic approach

The deterministic approach is based on standard dimensions of damage extending anywhere along the ship's length or between transverse bulkheads depending on the relevant requirements.

The consequence of such standard of damage is the creation of a group of damage cases, the number of which, as well as the number of compartments involved in each case, depend on the ship's dimensions and internal subdivision.

For each loading condition, each damage case is to be considered, and the applicable criteria are to be complied with.

Different deterministic methods in damage stability have been developed depending on ship type, on freeboard reduction, and on the kind of cargo carried.

The deterministic methods to be applied in the case of freeboard reduction are specified in Ch 3, App 4.

2.1.3 Probabilistic approach

The probabilistic concept takes the probability of survival after collision as a measure of ship safety in the damaged condition, referred to as the attained subdivision index A.

The damage stability calculations are performed for a limited number of draughts and relevant GM values in order to draw a minimum GM curve where the attained subdivision index A achieves the minimum required level of safety R. For cargo ships, each case of damage is not required to comply with the applicable criteria, but the attained index A, which is the sum of the contribution of all damage cases, is to be equal to or greater than R.

The probabilistic method developed on the basis of the above-mentioned concepts is detailed in Ch 3, App 3.

As a general rule, the probabilistic method applies to cargo ships of a length not less than 80 m, and for which no deterministic methods apply.

3 Documents to be submitted

3.1 Damage stability calculations

3.1.1 Damage stability documentation

For all ships to which damage stability requirements apply, documents including damage stability calculations are to be submitted.

The damage stability calculations are to include:

- list of the characteristics (volume, centre of gravity, permeability) of each compartment which can be damaged

- a table of openings in bulkheads, decks and side shell reporting all the information about:
  - identification of the opening
  - vertical, transverse and horizontal location
  - type of closure: sliding, hinged or rolling for doors
  - type of tightness: watertight, weathertight, semi-watertight or unprotected
  - operating system: remote control, local operation, indicators on the bridge, television surveillance, water leakage detection, audible alarm, as applicable
  - foreseen utilization: open at sea, normally closed at sea, kept closed at sea
- list of all damage cases corresponding to the applicable requirements
- detailed results of damage stability calculations for all the loading conditions foreseen in the applicable requirements
- the limiting GM/KG curve, if foreseen in the applicable requirements
- capacity plan
- cross and down flooding devices and the calculations thereof according to Pt D, Ch 11, App 1 with informations about diameter, valves, pipe lengths and coordinates of inlet/outlet
- watertight and weathertight door plan with pressure calculation
- side contour and wind profile
- pipes and damaged area when the destruction of these pipes results in progressive flooding.

3.1.2 Additional information for the probabilistic approach

In addition to the information listed in [3.1.1], the following is to be provided:

- *subdivision length* L_S
- *initial draughts and the corresponding GM-values*
- *required subdivision index R*
- *attained subdivision index A with a summary table for all contributions for all damaged zones.*
- *draught, trim, GM in damaged condition*
- *damage extension and definition of damage cases with probabilistic values p, v and r*
- *righting lever curve (including GZmax and range) with factor of survivability s*
- *critical weathertight and unprotected openings with their angle of immersion*
- *details of sub-compartments with amount of in-flooded water/lost buoyancy with their centres of gravity.*

3.1.3 Loading instrument

As a supplement to the approved damage stability documentation, a loading instrument, approved by the Society, may be used to facilitate the damage stability calculations mentioned in [3.1.1].

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval, are given in Ch 10, Sec 2, [4.7].

3.2 Permeabilities

3.2.1 Definition

The permeability of a space means the ratio of the volume within that space which is assumed to be occupied by water to the total volume of that space.

3.2.2 General

The permeabilities relevant to the type of spaces which can be flooded depend on the applicable requirements. Such permeabilities are indicated in Part D or Part E for each type of ship.

3.3 Progressive flooding

3.3.1 Definition

Progressive flooding is the additional flooding of spaces which were not previously assumed to be damaged. Such additional flooding may occur through openings or pipes as indicated in [3.3.2] and [3.3.3].

3.3.2 Openings

The openings may be listed in the following categories, depending on their means of closure:

- Unprotected

  Unprotected openings may lead to progressive flooding if they are situated within the range of the positive righting lever curve or if they are located below the waterline after damage (at any stage of flooding). Unprotected openings are openings which are not fitted with at least weathertight means of closure, or ventilators that have to remain open to supply air to the engine room or emergency generator room for the effective operation of the ship.

- Weathertight

  Openings fitted with weathertight means of closure are not able to sustain a constant head of water, but they can be intermittently immersed within the positive range of stability.

  Weathertight openings may lead to progressive flooding if they are located below the waterline after damage (at any stage of flooding).

- Semi-watertight

  Internal openings fitted with semi-watertight means of closure are able to sustain a constant head of water corresponding to the immersion relevant to the highest waterline after damage at the equilibrium of the intermediate stages of flooding.

  Semi-watertight openings may lead to progressive flooding if they are located below the final equilibrium waterline after damage.

- Watertight

  Internal openings fitted with watertight means of closure are able to sustain a constant head of water corresponding to the distance between the lowest edge of this opening and the bulkhead/freeboard deck.

  Air pipe closing devices complying with Pt C, Ch 1, Sec 10, [9.1.6] may not be considered watertight, unless additional arrangements are fitted in order to demonstrate that such closing devices are effectively watertight.

  The pressure/vacuum valves (PV valves) currently installed on tankers do not theoretically provide complete watertightness.

  Manhole covers may be considered watertight provided the cover is fitted with bolts located such that the distance between their axes is less than five times the bolt's diameter.

  Access hatch covers leading to tanks may be considered watertight.

  Watertight openings do not lead to progressive flooding.

3.3.3 Pipes

Progressive flooding through pipes may occur when:

- the pipes and connected valves are located within the assumed damage, and no valves are fitted outside the damage
- the pipes, even if located outside the damage, satisfy all of the following conditions:
  - the pipe connects a damaged space to one or more spaces located outside the damage
  - the highest vertical position of the pipe is below the waterline, and
  - no valves are fitted.

The possibility of progressive flooding through ballast piping passing through the assumed extent of damage, where positive action valves are not fitted to the ballast system at the open ends of the pipes in the tanks served, is to be considered. Where remote control systems are fitted to ballast valves and these controls pass through the assumed extent of damage, then the effect of damage to the system is to be considered to ensure that the valves would remain closed in that event.

If pipes, ducts or tunnels are situated within assumed flooded compartments, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed flooded. However, the Society may permit minor progressive flooding if it is demonstrated that the additional flooding of those compartments cannot lead to the capsizing or the sinking of the ship.

Requirements relative to the prevention of progressive flooding are specified in Pt C, Ch 1, Sec 10, [5.5].

3.4 Bottom damages

3.4.1 General

Ships which are not fitted with a double bottom as required by Ch 2, Sec 2, [3.1.2] or which are fitted with unusual bottom arrangements as defined in Ch 2, Sec 2, [3.1.6], are to comply with [3.4.2] and [3.4.3].

3.4.2 Bottom damage description

The assumed extent of damage is described in Tab 1.

If any damage of a lesser extent than the maximum damage specified in Tab 1 would result in a more severe condition, such damage should be considered.

3.4.3 Stability criteria

Compliance with the requirements of Ch 2, Sec 2, [3.1.5] or Ch 2, Sec 2, [3.1.6] is to be achieved by demonstrating that s_i, when calculated in accordance with Ch 3, App 3, [1.6], is not less than 1 for all service conditions when subject to a bottom damage with an extent specified in [3.4.2] for any position in the affected part of the ship.

Flooding of such spaces shall not render emergency power and lighting, internal communication, signals or other emergency devices inoperable in other parts of the ship.

4 Damage control documentation

4.1 General

4.1.1 Application

The damage control documentation is to include a damage control plan which is intended to provide ship's officers with clear information on the ship's watertight compartmentation and equipment related to maintaining the boundaries and effectiveness of the compartmentation so that, in the event of damage causing flooding, proper precautions can be taken to prevent progressive flooding through openings therein and effective action can be taken quickly to mitigate and, where possible, recover the ship's loss of stability.

The damage control documentation is to be clear and easy to understand. It is not to include information which is not directly relevant to damage control, and is to be provided in the language or languages of the ship's officers. If the languages used in the preparation of the documentation are not English or French, a translation into one of these languages is to be included.

Table 1 : Assumed extent of damage

	For 0,3 L from the forward perpendicular of the ship	Any other part of the ship
Longitudinal extent	1/3 $L^{2/3}$ or 14,5 m, whichever is less	1/3 $L^{2/3}$ or 14,5 m, whichever is less
Transverse extent	B/6 or 10 m, whichever is less	B/6 or 5 m, whichever is less
Vertical extent, measured from the keel line	B/20, to be taken not less than 0,76 m and not more than 2 m	B/20, to be taken not less than 0,76 m and not more than 2 m

The use of a loading instrument performing damage stability calculations may be accepted as a supplement to the damage control documentation. This instrument is to be approved by the Society according to the requirements of Ch 10, Sec 2, [4.8].

The damage control plan is required for the following ships:

- ships carrying passengers
- cargo ships of 500 GT and over.

4.1.2 Application to ships having additional service feature SPxxx or SPxxx-capable

The damage control documentation of ships having additional service feature **SPxxx** or **SPxxx-capable** is to comply with Pt D, Ch 11, Sec 3, [2.3.14].

5 Specific interpretations

5.1 Assumed damage penetration in way of sponsons

5.1.1 *If sponsons are fitted, it is necessary to establish the maximum assumed damage penetration (B/5) to be used when deciding on the various damage cases. For this purpose, the breadth B in the way of such sponsons is to be measured to the outside of the sponsons.*

Clear of any suck sponsons, the breadth B is to be the midship breadth measured to the outside of the original shell. In other words, the assumed penetration of B/5 is the same as that which applied before the fitting of sponsons.

APPENDIX 1 INCLINING TEST AND LIGHTWEIGHT CHECK

1 Inclining test and lightweight check

1.1 General

1.1.1 General conditions of the ship

The following conditions are to be met, as far as practicable:

- the weather conditions are to be favourable
- the ship should be moored in a quiet, sheltered area free from extraneous forces such as propeller wash from passing vessels, or sudden discharges from shore side pumps. The tide conditions and the trim of the ship during the test should be considered. Prior to the test, the depth of water should be measured and recorded in as many locations as are necessary to ensure that the ship will not contact the bottom. The specific gravity of water should be accurately recorded. The ship should be moored in a manner to allow unrestricted heeling. The access ramps should be removed. Power lines, hoses, etc., connected to shore should be at a minimum, and kept slack at all times
- the ship should be as upright as possible; with inclining weights in the initial position, up to one-half degree of list is acceptable. The actual trim and deflection of keel, if practical, should be considered in the hydrostatic data. In order to avoid excessive errors caused by significant changes in the water plane area during heeling, hydrostatic data for the actual trim and the maximum anticipated heeling angles should be checked beforehand
- cranes, derrick, lifeboats and liferafts capable of inducing oscillations are to be secured
- main and auxiliary boilers, pipes and any other system containing liquids are to be filled
- the bilge and the decks are to be thoroughly dried
- the anticipated liquid loading for the test should be included in the planning for the test. Preferably, all tanks should be empty and clean, or completely full. The number of slack tanks should be kept to an absolute minimum. The viscosity of the fluid, the depth of the fluid and the shape of the tank should be such that the free surface effect can be accurately determined
- the weights necessary for the inclination are to be already on board, located in the correct place. Their certificates are to be presented to the Surveyor witnessing the inclining test and are also to be included into the inclining test report.
- all work on board is to be suspended and crew or personnel not directly involved in the incline test are to leave the ship
- the ship is to be as complete as possible at the time of the test. The number of weights to be removed, added or shifted is to be limited to a minimum. Temporary material, tool boxes, staging, sand, debris, etc., on board is to be reduced to an absolute minimum
- decks should be free of water. Water trapped on deck may shift and pocket in a fashion similar to liquids in a tank. Any rain, snow or ice accumulated on the ship should be removed prior to the test.

1.1.2 Inclining weights

The total weight used is preferably to be sufficient to provide a minimum inclination of one degree and a maximum of four degrees of heel to each side. The Society may, however, accept a smaller inclination angle for large ships provided that the requirement on pendulum deflection or U-tube difference in height specified in [1.1.4] is complied with. Test weights are to be compact and of such a configuration that the VCG (vertical centre of gravity) of the weights can be accurately determined. Each weight is to be marked with an identification number and its weight. Re-certification of the test weights is to be carried out prior to the incline. A crane of sufficient capacity and reach, or some other means, is to be available during the inclining test to shift weights on the deck in an expeditious and safe manner. Water ballast transfer may be carried out, when it is impractical to incline using solid weights and subject to requirement of [1.1.3].

Weights, such as porous concrete, that can absorb significant amounts of moisture should only be used if they are weighed just prior to the inclining test or if recent weight certificates are presented. Each weight should be marked with an identification number and its weight. For small ships, drums completely filled with water may be used. Drums should normally be full and capped to allow accurate weight control. In such cases, the weight of the drums should be verified in the presence of a surveyor of the Society using a recently calibrated scale.

Precautions should be taken to ensure that the decks are not overloaded during weight movements. If deck strength is questionable then a structural analysis should be performed to determine if existing framing can support the weight.

Generally, the test weights should be positioned as far outboard as possible on the upper deck. The test weights should be on board and in place prior to the scheduled time of the inclining test.

1.1.3 Water ballast as inclining weight

Where the use of solid weights to produce the inclining moment is deemed to be impracticable, the movement of ballast water may be permitted as an alternative method. This acceptance would be granted for a specific test only, and approval of the test procedure by the Society is required. As a minimal prerequisite for acceptability, the following conditions are to be required:

- inclining tanks are to be wall-sided and free of large stringers or other internal members that create air pockets
- tanks are to be directly opposite to maintain ship's trim
- specific gravity of ballast water is to be measured and recorded
- pipelines to inclining tanks are to be full. If the ship's piping layout is unsuitable for internal transfer, portable pumps and pipes/hoses may be used
- blanks must be inserted in transverse manifolds to prevent the possibility of liquids being "leaked" during transfer. Continuous valve control must be maintained during the test
- all inclining tanks must be manually sounded before and after each shift
- vertical, longitudinal and transverse centres are to be calculated for each movement
- accurate sounding/ullage tables are to be provided. The ship's initial heel angle is to be established prior to the incline in order to produce accurate values for volumes and transverse and vertical centres of gravity for the inclining tanks at every angle of heel. The draught marks amidships (port and starboard) are to be used when establishing the initial heel angle
- verification of the quantity shifted may be achieved by a flowmeter or similar device
- the time to conduct the inclining is to be evaluated. If time requirements for transfer of liquids are considered too long, water may be unacceptable because of the possibility of wind shifts over long periods of time.

1.1.4 Pendulums

The use of three pendulums is recommended but a minimum of two are to be used to allow identification of bad readings at any one pendulum station. However, for ships of a length equal to or less than 30 m, only one pendulum can be accepted. They are each to be located in an area protected from the wind. The pendulums are to be long enough to give a measured deflection, to each side of upright, of at least 15 cm. To ensure recordings from individual instruments are kept separate, it is suggested that the pendulums be physically located as far apart as practical.

The use of an inclinometer or U-tube is to be considered in each separate case. It is recommended that inclinometers or other measuring devices only be used in conjunction with at least one pendulum.

1.1.5 Free surface and slack tanks

The number of slack tanks should normally be limited to one port/starboard pair or one centreline tank of the following:

- fresh water reserve feed tanks
- fuel/diesel oil storage tanks
- fuel/diesel oil day tanks
- lube oil tanks
- sanitary tanks
- potable water tanks.

To avoid pocketing, slack tanks are normally to be of regular (i.e. rectangular, trapezoidal, etc.) cross section and be 20% to 80% full if they are deep tanks and 40% to 60% full if they are double-bottom tanks. These levels ensure that the rate of shifting of liquid remains constant throughout the heel angles of the inclining test. If the trim changes as the ship is inclined, then consideration are also to be given to longitudinal pocketing. Slack tanks containing liquids of sufficient viscosity to prevent free movement of the liquids, as the ship is inclined (such as bunker at low temperature), are to be avoided since the free surface cannot be calculated accurately. A free surface correction for such tanks is not to be used unless the tanks are heated to reduce viscosity. Communication between tanks are never to be allowed. Cross-connections, including those via manifolds, are to be closed. Equal liquid levels in slack tank pairs can be a warning sign of open cross connections. A bilge, ballast, and fuel oil piping plan can be referred to, when checking for cross connection closures.

1.1.6 Means of communications

Efficient two-way communications are to be provided between central control and the weight handlers and between central control and each pendulum station. One person at a central control station is to have complete control over all personnel involved in the test.

1.1.7 Documentation

The person in charge of the inclining test is to have available a copy of the following plans at the time of the test:

- *lines plan*
- *hydrostatic curves or hydrostatic data*
- *general arrangement plan of decks, holds, inner bottoms, etc.*
- *capacity plan showing capacities and vertical and longitudinal centres of gravity of cargo spaces, tanks, etc. When water ballast is used as inclining weights, the transverse and vertical centres of gravity for the applicable tanks, for each angle of inclination, must be available*
- *tank sounding tables*
- *draught mark locations, and*
- *docking drawing with keel profile and draught mark corrections (if available).*

1.1.8 Determination of the displacement

The operations necessary for the accurate evaluation of the displacement of the ship at the time of the inclining test, as listed below, are to be carried out:

- draught mark readings are to be taken at aft, midship and forward, at starboard and port sides
- the mean draught (average of port and starboard reading) is to be calculated for each of the locations where draught readings are taken and plotted on the ship's lines drawing or outboard profile to ensure that all readings are consistent and together define the correct waterline. The resulting plot is to yield either a straight line or a waterline which is either hogged or sagged. If inconsistent readings are obtained, the freeboards/draughts are to be retaken
- the specific gravity of the sea water is to be determined. Samples are to be taken from a sufficient depth of the water to ensure a true representation of the sea water and not merely surface water, which could contain fresh water from run off of rain. A hydrometer is to be placed in a water sample and the specific gravity read and

recorded. For large ships, it is recommended that samples of the sea water be taken forward, midship and aft, and the readings averaged. For small ships, one sample taken from midship is sufficient. The temperature of the water is to be taken and the measured specific gravity corrected for deviation from the standard, if necessary.

A correction to water specific gravity is not necessary if the specific gravity is determined at the inclining experiment site. Correction is necessary if specific gravity is measured when the sample temperature differs from the temperature at the time of the inclining (e.g., if the check of specific gravity is performed at the office). Where the value of the average calculated specific gravity is different from that reported in the hydrostatic curves, adequate corrections are to be made to the displacement curve

- all double bottoms, as well as all tanks and compartments which can contain liquids, are to be checked, paying particular attention to air pockets which may accumulate due to the ship's trim and the position of air pipes, and also taking into account the provisions of [1.1.1]
- it is to be checked that the bilge is dry, and an evaluation of the liquids which cannot be pumped, remaining in the pipes, boilers, condenser, etc., is to be carried out
- the entire ship is to be surveyed in order to identify all items which need to be added, removed or relocated to bring the ship to the lightship condition. Each item is to be clearly identified by weight and location of the centre of gravity
- the possible solid permanent ballast is to be clearly identified and listed in the report.
- normally, the total value of missing weights is not to exceed 2% and surplus weights, excluding liquid ballast, not exceed 4% of the lightship displacement. For smaller vessels, higher percentages may be allowed.

1.1.9 The incline

The standard test generally employs eight distinct weight movements as shown in Fig 1.

Movement No.8, a recheck of the zero point, may be omitted if a straight line plot is achieved after movement No.7. If a straight line plot is achieved after the initial zero and six weight movements, the inclining test is complete and the second check at zero may be omitted. If a straight line plot is not achieved, those weight movements that did not yield acceptable plotted points should be repeated or explained.

The weights are to be transversely shifted, so as not to modify the ship's trim and vertical position of the centre of gravity.

After each weight shifting, the new position of the transverse centre of gravity of the weights is to be accurately determined.

After each weight movement, the distance the weight was moved (centre to centre) is to be measured and the heeling moment calculated by multiplying the distance by the amount of weight moved. The tangent is calculated for each pendulum by dividing the deflection by the length of the pendulum. The resultant tangents are plotted on the graph as shown in Fig 2.

The plot is to be run during the test to ensure that acceptable data are being obtained.

The pendulum deflection is to be read when the ship has reached a final position after each weight shifting.

During the reading, no movements of personnel are allowed.

For ships with a length equal to or less than 30 m, six distinct weight movements may be accepted.

Figure 1 : Weight shift procedure

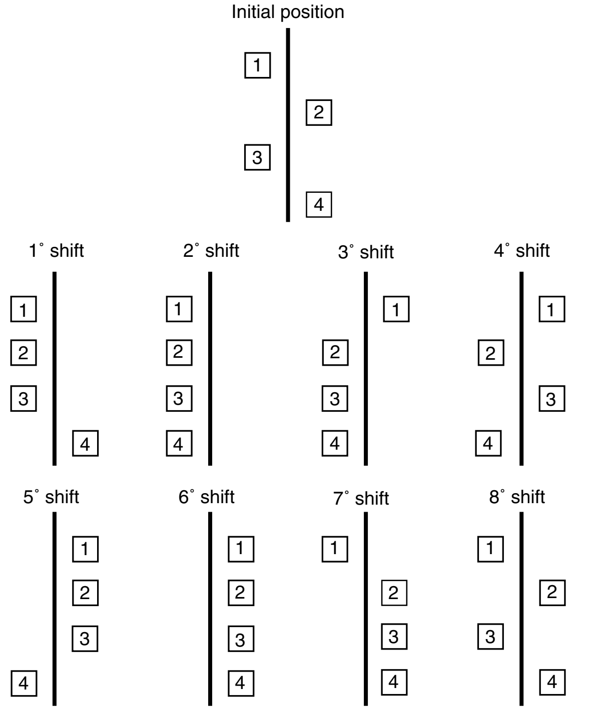
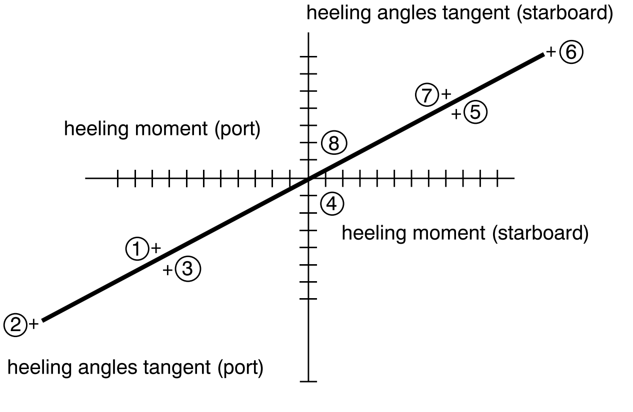


Figure 2 : Graph of resultant tangents



APPENDIX 2 TRIM AND STABILITY BOOKLET

1 Trim and stability booklet

1.1 Information to be included in the trim and stability booklet

1.1.1 General

A trim and stability booklet is a stability manual, to be approved by the Society, which is to contain information to enable the Master to operate the ship in compliance with the applicable requirements contained in the Rules.

The format of the stability booklet and the information included vary depending on the ship type and operation.

Additional information may be required depending on the type of the ship as specified in Part D and Part E.

1.1.2 List of information

The following information is to be included in the trim and stability booklet:

- a general description of the ship, including:
  - the ship's name and the Society classification number
  - the ship type and service notation
  - the class notations
  - the yard, the hull number and the year of delivery
  - the Flag, the port of registry, the international call sign and the IMO number
  - the moulded dimensions
  - the draught corresponding to the assigned summer load line, the draught corresponding to the assigned summer timber load line and the draught corresponding to the tropical load line, if applicable
  - the displacement corresponding to the above-mentioned draughts
- instructions on the use of the booklet
- general arrangement and capacity plans indicating the assigned use of compartments and spaces (cargo, passenger, stores, accommodation, etc.)
- a sketch indicating the position of the draught marks referred to the ship's perpendiculars
- hydrostatic curves or tables corresponding to the design trim, and, if significant trim angles are foreseen during the normal operation of the ship, curves or tables corresponding to such range of trim are to be introduced. A reference relevant to the sea density, in t/m^3, is to be included as well as the draught measure (from keel or underkeel)
- cross curves (or tables) of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves
- tank sounding tables or curves showing capacities, centres of gravity, and free surface data for each tank
- lightship data from the inclining test, as indicated in Ch 3, Sec 1, [2.2], including lightship displacement, centre of gravity co-ordinates, place and date of the inclining test, as well as the Society approval details specified in the inclining test report. It is suggested that a copy of the approved test report be included

  Where the above-mentioned information is derived from a sister ship, the reference to this sister ship is to be indicated, and a copy of the approved inclining test report relevant to this sister ship is to be included
- standard loading conditions as indicated in [1.2] and examples for developing other acceptable loading conditions using the information contained in the booklet
- intact stability results (total displacement and its centre of gravity co-ordinates, draughts at perpendiculars, GM, GM corrected for free surfaces effect, GZ values and curve, criteria as indicated in Ch 3, Sec 2, [2] and Ch 3, Sec 2, [3] as well as possible additional criteria specified in Part D or Part E when applicable, reporting a comparison between the actual and the required values) are to be available for each of the above-mentioned operating conditions. The method and assumptions to be followed in the stability curve calculation are specified in [1.3]
- information on loading restrictions (maximum allowable load on double bottom, maximum specific gravity allowed in liquid cargo tanks, maximum filling level or percentage in liquid cargo tanks, maximum KG or minimum GM curve or table which can be used to determine compliance with the applicable intact and damage stability criteria) when applicable
- information about openings (location, tightness, means of closure), pipes or other progressive flooding sources
- information concerning the use of any special cross-flooding fittings with descriptions of damage conditions which may require cross-flooding, when applicable
- any other guidance deemed appropriate for the operation of the ship
- a table of contents and index for each booklet.

1.2 Loading conditions

1.2.1 General

The standard loading conditions to be included in the trim and stability booklet are:

- lightship condition
- ship in ballast in the departure condition, without cargo but with full stores and fuel
- ship in ballast in the arrival condition, without cargo and with 10% stores and fuel remaining.

Further loading cases may be included when deemed necessary or useful.

The heel at the equilibrium of any sailing condition is not to be greater than 1°.

1.2.2 Ships carrying cargo on deck

In addition to the loading conditions indicated in [1.2.1] to [1.2.14], in the case of cargo carried on deck the following cases are to be considered:

- ship in the fully loaded departure condition having cargo homogeneously distributed in the holds and a cargo specified in extension and weight on deck, with full stores and fuel
- ship in the fully loaded arrival condition having cargo homogeneously distributed in holds and a cargo specified in extension and weight on deck, with 10% stores and fuel.

1.2.3 General cargo ships

In addition to the standard loading conditions reported in [1.2.1], the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, with cargo homogeneously distributed throughout all cargo spaces and with full stores and fuel
- ship in the fully loaded arrival condition with cargo homogeneously distributed throughout all cargo spaces and with 10% stores and fuel remaining.

For ships with service notation **general cargo ship** completed by the additional feature **nonhomload**, the following loading cases are also to be included in the trim and stability booklet:

- ship in the departure condition, with cargo in alternate holds, for at least three stowage factors, one of which is relevant to the summer load waterline and with full stores and consumables

  Where the condition with cargo in alternate holds relevant to the summer load waterline leads to local loads on the double bottom greater than those allowed by the Society, it is to be replaced by the one in which each hold is filled in order to reach the maximum load allowed on the double bottom; in no loading case is such value to be exceeded
- same conditions as above, but with 10% stores and consumables.

1.2.4 Container ships

In addition to the standard loading conditions specified in [1.2.1], for ships with the service notation **container ship** the following loading cases are to be included in the trim and stability booklet:

- ship with a number of containers having a weight corresponding to the maximum permissible weight for each container at the summer load waterline when loaded with full stores and consumables
- same loading condition as above, but with 10% stores and consumables
- lightship condition with full stores and consumables
- lightship condition with 10% stores and consumables.

The vertical location of the centre of gravity for each container is generally to be taken at one half of the container height. Different locations of the vertical centre of gravity may be accepted in specific cases, if documented.

1.2.5 Bulk carriers, ore carriers and combination carriers

Dry cargo is intended to mean grain, as well as any other type of solid bulk cargo.

The term grain covers wheat, maize (corn), oats, rye, barley, rice, pulses, seeds and processed forms thereof, whose behaviour is similar to that of grain in its natural state.

The term solid bulk cargo covers any material, other than liquid or gas, consisting of a combination of particles, granules or any larger pieces of material, generally uniform in composition, which is loaded directly into the cargo spaces of a ship without any intermediate form of containment.

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** and **combination carrier ESP** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure conditions at the summer load waterline, with cargo homogeneously distributed throughout all cargo holds and with full stores and consumables, for at least three specific gravities, one of which is relevant to the complete filling of all cargo holds
- same conditions as above, but with 10% stores and consumables
- ship in the departure condition, with cargo holds not entirely filled, for at least three stowage factors, one of which is relevant to the summer load waterline and with full stores and consumables
- same conditions as above, but with 10% stores and consumables.

For ships with one of the service notations **self-unloading bulk carrier ESP**, **ore carrier ESP** and **combination carrier ESP** and for ships with the service notation **bulk carrier** or **bulk carrier ESP** completed by the additional feature **non-homload**, the following loading cases are also to be included in the trim and stability booklet:

- ship in the departure conditions, with cargo in alternate holds, for at least three stowage factors, one of which is relevant to the summer load waterline, and with full stores and consumables.

  Where the condition with cargo in alternate holds relevant to the summer load waterline leads to local loads on the double bottom greater than those allowed by the Society, it is to be replaced by the one in which each hold is filled in order to reach the maximum load allowed on the double bottom; in no loading case is such value to be exceeded.

- same conditions as above, but with 10% stores and consumables.

1.2.6 Oil tankers and FLS tankers

All the intended cargo loading conditions are to be included in the trim and stability booklet for examination within the scope of Pt D, Ch 7, Sec 3, [2].

Further cases are subject to prior examination by the Society before the loading; alternatively, an approved loading instrument capable of performing damage stability calculations in accordance with the requirements in Pt D, Ch 7, Sec 3, [2] may be used.

In addition to the standard loading conditions specified in [1.2.1], for ships with the service notation **oil tanker ESP** or **FLS tanker** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition at the summer load waterline, with cargo homogeneously distributed throughout all cargo tanks and with full stores and consumables
- same condition as above, but with 10% stores and consumables
- ship in the departure condition loaded with a cargo having a density in order to fill all cargo tanks, with full stores and consumables, but immersed at a draught less than the summer load waterline
- same condition as above, but with 10% stores and consumables
- ship in the fully loaded departure condition at the summer load waterline, with cargo tanks not entirely filled and with full stores and consumables
- same condition as above, but with 10% stores and consumables
- two loading conditions corresponding to different cargo segregations in order to have slack tanks with full stores and consumables

  When it is impossible to have segregations, these conditions are to be replaced by loading conditions with the same specific gravity and with slack cargo tanks

- same loading condition as above, but with 10% stores and consumables
- for oil tankers having segregated ballast tanks as defined in Pt D, Ch 7, Sec 2, [2], the lightship condition with segregated ballast only is also to be included in the trim and stability booklet for examination.

1.2.7 Chemical tankers

All the intended cargo loading conditions are to be included in the trim and stability booklet for examination within the scope of Pt D, Ch 8, Sec 2, [6].

Further cases are subject to prior examination by the Society before the loading; alternatively, an approved loading instrument capable of performing damage stability calculations in accordance with Pt D, Ch 8, Sec 2, [6] may be used.

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **chemical tanker ESP** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, with cargo homogeneously distributed throughout all cargo tanks and with full stores and consumables
- same loading condition as above, but with 10% stores and consumables
- three loading conditions corresponding to different specific gravities with cargo homogeneously distributed throughout all cargo tanks and with full stores and consumables
- same loading conditions as above, but with 10% stores and consumables
- four loading conditions corresponding to different cargo segregations in order to have slack tanks with full stores and consumables. Cargo segregation is intended to mean loading conditions with liquids of different specific gravities

  When it is impossible to have segregations, these conditions are to be replaced by loading conditions corresponding to different specific gravities with slack cargo tanks

- same loading conditions as above, but with 10% stores and consumables.

  When it is impossible to have segregations, these conditions may be replaced by cases corresponding to different specific gravities with slack cargo tanks.

1.2.8 Liquefied gas carriers

All the intended cargo loading conditions are to be included in the trim and stability booklet for examination within the scope of Pt D, Ch 9, Sec 2, [7.1.2].

Further cases are subject to prior examination by the Society before the loading; alternatively, an approved loading instrument capable of performing damage stability calculations in accordance with Pt D, Ch 9, Sec 2, [7.1.2] may be used.

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **liquefied gas carrier** or **LNG bunkering ship** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, with cargo homogeneously distributed throughout all cargo spaces and with full stores and fuel
- ship in the fully loaded arrival condition with cargo homogeneously distributed throughout all cargo spaces and with 10% stores and fuel remaining.

1.2.9 Passenger ships

In addition to the standard loading conditions specified in [1.2.1], for ships with the service notation **passenger ship** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition with full stores and fuel and with the full number of passengers with their luggage
- ship in the fully loaded arrival condition, with the full number of passengers and their luggage but with only 10% stores and fuel remaining
- ship without cargo, but with full stores and fuel and the full number of passengers and their luggage
- ship in the same condition as above, but with only 10% stores and fuel remaining.

1.2.10 Dredgers

For ships with one of the service notations **dredger**, **hopper dredger**, **hopper unit**, **split hopper dredger** and **split hopper unit**, the loading conditions described in a) and b) are to replace the standard loading conditions defined in [1.2.1].

a) State of cargo: liquid

- ship loaded to the dredging draught with cargo considered as a liquid
- hopper(s) fully loaded with a homogeneous cargo having density ρ_m, up to the spill out edge of the hopper coaming:

  $\rho_m = M_1 / V_1$

  M_1 : Mass of cargo, in t, in the hopper when loaded at the dredging draught

  V_1 : Volume, in m^3, of the hopper at the spill out edge of the hopper coaming.

  The conditions of stores and fuel are to be equal to 100% and 10%, and an intermediate condition is to be considered if it is more critical than both 100% and 10%.

- hopper(s) filled or partly filled with a homogeneous cargo having densities equal to 1000, 1200, 1400, 1600, 1800 and 2000 kg/m^3

  When the dredging draught cannot be reached due to the density of the cargo, the hopper is to be considered filled up to the spill out edge of the hopper coaming.

  The conditions of stores and fuel are to be the most conservative obtained from the stability calculations with the density ρ_m.

b) State of the cargo: solid

- ship loaded to the dredging draught with cargo considered as a solid
- hopper(s) fully loaded with a homogeneous cargo having density ρ_m up to the spill out edge of the hopper coaming, as calculated in a)

  The conditions of stores and fuel are to be equal to 100% and 10%, and an intermediate condition is to be considered if it is more conservative than both 100% and 10%.

- hopper(s) filled or partly filled with a homogeneous cargo having densities equal to 1400, 1600, 1800, 2000 and 2200 kg/m^3 if greater than ρ_m.

1.2.11 Tugs and fire-fighting ships

In addition to the standard loading conditions defined in [1.2.1], for ships with one of the service notations **tug** and **fire-fighting**, the following loading cases are to be included in the trim and stability booklet:

- ship in the departure condition at the waterline corresponding to the maximum assigned immersion, with full stores, provisions and consumables
- same conditions as above, but with 10% stores and consumables
- same conditions as above, but with 50% stores and consumables.

1.2.12 Anchor handling vessels

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **anchor handling**, the following loading cases are to be included in the trim and stability booklet:

- service loading condition at the maximum draught at which anchor handling operations may occur with the heeling levers as defined in Pt E, Ch 2, Sec 3, [1.3] for the line tension the ship is capable of with a minimum of 67% stores and fuel, in which all the relevant stability criteria defined in Pt E, Ch 2, Sec 3 are met.
- service loading condition at the minimum draught at which anchor handling operations may occur with the heeling levers as defined in Pt E, Ch 2, Sec 3, [1.3] for the line tension the ship is capable of with 10% stores and fuel, in which all the relevant stability criteria as defined in Pt E, Ch 2, Sec 3 are met.

1.2.13 Supply vessels

In addition to the standard loading conditions specified in [1.2.1], for ships with the service notation **supply** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition having under deck cargo, if any, and cargo specified by position and weight on deck, with full stores and fuel, corresponding to the worst service condition in which all the relevant stability criteria are met
- ship in the fully loaded arrival condition with cargo as specified above, but with 10 per cent stores and fuel
- ship in the worst anticipated operating condition.

1.2.14 Fishing vessels

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **fishing vessel** the following loading cases are to be included in the trim and stability booklet:

- departure conditions for the fishing grounds with full fuel stores, ice, fishing gear, etc.
- departure from the fishing grounds with full catch
- arrival at home port with 10% stores, fuel, etc. remaining and full catch
- arrival at home port with 10% stores, fuel, etc. and a minimum catch, which is normally to be 20% of the full catch but may be up to 40% if documented.

1.2.15 Ships having the additional service feature SPxxx or SPxxx-capable

In addition to the standard loading conditions specified in [1.2.1], for ships with the additional service feature **SPxxx** or **SPxxx-capable** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, having cargo specified by position and weight, with full stores and fuel, and with the total number of persons on board, including crew, special personnel and passengers
- ship in the fully loaded arrival condition, with cargo and total number of persons as specified above, but with 10 per cent stores and fuel
- ship in the worst anticipated operating condition.

1.2.16 Oil recovery ships

For oil recovery ships, additional information to be included in stability booklet are specified in Pt E, Ch 5, Sec 2.

1.2.17 Lifting units

For lifting units, additional information to be included in stability booklet are specified in Pt E, Ch 8, Sec 3.

1.2.18 Semi-submersible cargo ships

For semi-submersible cargo ships, additional information to be included in stability booklet are specified in Pt E, Ch 9, Sec 3.

1.3 Stability curve calculation

1.3.1 General

Hydrostatic and stability curves are normally prepared on a designed trim basis. However, where the operating trim or the form and arrangement of the ship are such that change in trim has an appreciable effect on righting arms, such change in trim is to be taken into account.

The calculations are to take into account the volume to the upper surface of the deck sheathing.

1.3.2 Superstructures, deckhouses, etc. which may be taken into account

Enclosed superstructures complying with Ch 1, Sec 2, [3.13] may be taken into account.

The second tier of similarly enclosed superstructures may also be taken into account.

Deckhouses on the freeboard deck may be taken into account, provided that they comply with the conditions for enclosed superstructures laid down in Ch 1, Sec 2, [3.16].

Where deckhouses comply with the above conditions, except that no additional exit is provided to a deck above, such deckhouses are not to be taken into account; however, any deck openings inside such deckhouses are to be considered as closed even where no means of closure are provided.

Deckhouses, the doors of which do not comply with the requirements of Ch 8, Sec 4, [1.5.4], are not to be taken into account; however, any deck openings inside the deckhouse are regarded as closed where their means of closure comply with the requirements of Ch 8, Sec 7, [9] or Ch 8, Sec 8, as relevant.

Deckhouses on decks above the freeboard deck are not to be taken into account, but openings within them may be regarded as closed.

Superstructures and deckhouses not regarded as enclosed may, however, be taken into account in stability calculations up to the angle at which their openings are flooded (at this angle, the static stability curve is to show one or more steps, and in subsequent computations the flooded space are to be considered non-existent).

Trunks may be taken into account. Hatchways may also be taken into account having regard to the effectiveness of their closures.

1.3.3 Angle of flooding

In cases where the ship would sink due to flooding through any openings, the stability curve is to be cut short at the corresponding angle of flooding and the ship is to be considered to have entirely lost its stability.

Small openings such as those for passing wires or chains, tackle and anchors, and also holes of scuppers, discharge and sanitary pipes are not to be considered as open if they submerge at an angle of inclination more than 30°. If they submerge at an angle of 30° or less, these openings are to be assumed open if the Society considers this to be a source of significant progressive flooding; therefore such openings are to be considered on a case by case basis.

APPENDIX 3 PROBABILISTIC DAMAGE STABILITY METHOD FOR CARGO SHIPS

1 Probabilistic damage stability method for cargo ships

1.1 Application

1.1.1 *The requirements included in this Appendix are to be applied to cargo ships over 80 m in length L_{LL} as defined in* Ch 1, Sec 2, [3.2]*, but are not to be applied to those ships which are shown to comply with subdivision and damage stability regulations* already required in Part D or Part E.

Any reference hereinafter to regulations refers to the set of regulations contained in this Appendix.

The Society may, for a particular ship or group of ships, accept alternative arrangements, if it is satisfied that at least the same degree of safety as represented by these regulations is achieved.

This includes, for example, the following:

- ships constructed in accordance with a standard of damage stability with a set of damage criteria agreed by the Society
- ships of a multi-hull design, where the subdivision arrangements need to be evaluated against the basic principles of the probabilistic method since the regulations have been written specifically for mono-hulls.

1.1.2 The requirements of this Appendix are to be applied in conjunction with the explanatory notes as set out by the IMO resolution MSC 281 (85).

1.2 Definitions

1.2.1 Deepest subdivision draught

The deepest subdivision draught (d_S) is the waterline which corresponds to the summer load line draught of the ship.

1.2.2 Light service draught

Light service draught (d_L) is the service draught corresponding to the lightest anticipated loading and associated tankage, including, however, such ballast as may be necessary for stability and/or immersion.

1.2.3 Partial subdivision draught

The partial subdivision draught (d_P) is the light service draught plus 60% of the difference between the light service draught and the deepest subdivision draught.

1.2.4 Subdivision length L_s

The subdivision length L_s is the greatest projected moulded length of that part of the ship at or below deck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision draught.

1.2.5 Machinery space

Machinery spaces are spaces between the watertight boundaries of a space containing the main and auxiliary propulsion machinery, including boilers, generators and electric motors primarily intended for propulsion. In the case of unusual arrangements, the Society may define the limits of the machinery spaces.

1.2.6 Other definitions

Mid-length is the mid point of the subdivision length of the ship.

Aft terminal is the aft limit of the subdivision length.

Forward terminal is the forward limit of the subdivision length.

Breadth B is the greatest moulded breadth, in m, of the ship at or below the deepest subdivision draught.

Draught d is the vertical distance, in m, from the moulded baseline at mid-length to the waterline in question.

Permeability μ of a space is the proportion of the immersed volume of that space which can be occupied by water.

1.3 Required subdivision index R

1.3.1 *These regulations are intended to provide ships with a minimum standard of subdivision.*

The degree of subdivision to be provided is to be determined by the required subdivision index R, as follows:

- *for ships greater than 100 m in length L_S:*

$$R = 1 - \frac{128}{L_S + 152}$$

- *for ships of 80 m in length L_S and upwards, but not greater than 100 m in length L_S:*

$$R = 1 - \frac{1}{\left(1 + \frac{L_S}{100}\frac{R_0}{(1 - R_0)}\right)}$$

where R_0 is the value of R as calculated in accordance with the formula given for ships greater than 100 m in length L_S.

1.4 Attained subdivision index A

1.4.1 *The attained subdivision index A is obtained by the summation of the partial indices A_S, A_P and A_L (weighed as shown), calculated for the draughts d_S, d_P and d_L defined in [1.2.1], [1.2.2] and [1.2.3], in accordance with the following formula:*

$A = 0,4\ A_S + 0,4\ A_P + 0,2\ A_L$

The attained subdivision index A is not to be less than the required subdivision index R. In addition, the partial indices A_S, A_P and A_L are not to be less than 0,5 R.

1.4.2 *Each partial index is a summation of contributions from all damage cases taken in consideration, using the following formula:*

$A = \Sigma\, p_i\, s_i$

where:

- i : *Represents each compartment or group of compartments under consideration*
- p_i : *Accounts for the probability that only the compartment or group of compartments under consideration may be flooded, disregarding any horizontal subdivision, as defined in [1.5]*
- s_i : *Accounts for the probability of survival after flooding the compartment or group of compartments under consideration, and includes the effects of any horizontal subdivision, as defined in [1.6].*

1.4.3 *As a minimum, the calculation of A is to be carried out at the level trim for the deepest subdivision draught d_s and the partial subdivision draught d_p. The estimated service trim may be used for the light service draught d_l. If, in any anticipated service condition within the draught range from d_s to d_l, the trim variation in comparison with the calculated trim is greater than 0,005 L, one or more additional calculations of A are to be performed for the same draughts but including sufficient trims to ensure that, for all intended service conditions, the difference in trim in comparison with the reference trim used for one calculation will be not more than 0,005L. Each additional calculation of A is to comply with [1.3].*

When determining the positive righting lever (GZ) of the residual stability curve in the intermediate and final equilibrium stages of flooding, the displacement used should be that of the intact loading condition. All calculations should be done with the ship freely trimming.

The summation indicated by the formula in [1.4.2] is to be taken over the ship's subdivision length (L_s) for all cases of flooding in which a single compartment or two or more adjacent compartments are involved. In the case of unsymmetrical arrangements, the calculated A value is to be the mean value obtained from calculations involving both sides. Alternatively, it is to be taken as that corresponding to the side which evidently gives the least favourable result.

1.4.4 *Wherever wing compartments are fitted, contribution to the summation indicated by the formula is to be taken for all cases of flooding in which wing compartments are involved. Additionally, cases of simultaneous flooding of a wing compartment or group of compartments and the adjacent inboard compartment or group of compartments, but excluding damage of transverse extent greater than one half of the ship breadth B, may be added. For the purpose of this regulation, transverse extent is measured inboard from ship's side, at right angle to the centreline at the level of the deepest subdivision draught.*

1.4.5 *In the flooding calculations carried out according to the regulations, only one breach of the hull and only one free surface need to be assumed. The assumed vertical extent of damage is to extend from the baseline upwards to any watertight horizontal subdivision above the waterline or higher. However, if a lesser extent of damage gives a more severe result, such extent is to be assumed.*

1.4.6 *If pipes, ducts or tunnels are situated within the assumed extent of damage, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed flooded. However, the Society may permit minor progressive flooding if it is demonstrated that its effects can be easily controlled and the safety of the ship is not impaired.*

1.5 Calculation of factor p_i

1.5.1 *The factor p_i for a compartment or group of compartments is to be calculated in accordance with [1.5.2] to [1.5.6] using the following notations:*

- j : *The aftmost damage zone number involved in the damage starting with no.1 at the stern*
- n : *The number of adjacent damage zones involved in the damage*
- k : *The number of a particular longitudinal bulkhead as barrier for transverse penetration in a damage zone, counted from shell towards the centreline. The shell has k = 0*
- x_1 : *The distance from the aft terminal of L_s to the aft end of the zone in question*
- x_2 : *The distance from the aft terminal of L_s to the forward end of the zone in question*
- b : *T*he mean transverse distance in metres measured at right angles to the centreline at the deepest subdivision draught between the shell and an assumed vertical plane extended between the longitudinal limits used in calculating the factor p_i and which is a tangent to, or common with, all or part of the outermost portion of the longitudinal bulkhead under consideration. This vertical plane shall be so orientated that the mean transverse distance to the shell is a maximum, but not more than twice the least distance between the plane and the shell. If the upper part of a longitudinal bulkhead is below the deepest subdivision draught, the vertical plane used for the determination of b is assumed to extend upwards to the deepest subdivision waterline. In any case, b is not to be taken greater than B/2.

If the damage involves a single zone only:

$$p_i = p(x_{1(j)}, x_{2(j)}) \cdot [r(x_{1(j)}, x_{2(j)}, b_k) - r(x_{1(j)}, x_{2(j)}, b_{(k-1)})]$$

If the damage involves two adjacent zones:

$$\begin{aligned} p_i = {} & p(x_{1(j)}, x_{2(j+1)}) \cdot [r(x_{1(j)}, x_{2(j+1)}, b_k) - r(x_{1(j)}, x_{2(j+1)}, b_{(k-1)})] \\ & - p(x_{1(j)}, x_{2(j)}) \cdot [r(x_{1(j)}, x_{2(j)}, b_k) - r(x_{1(j)}, x_{2(j)}, b_{(k-1)})] \\ & - p(x_{1(j+1)}, x_{2(j+1)}) \cdot [r(x_{1(j+1)}, x_{2(j+1)}, b_k) - r(x_{1(j+1)}, x_{2(j+1)}, b_{(k-1)})] \end{aligned}$$

If the damage involves three or more adjacent zones:

$$\begin{aligned} p_i = {} & p(x_{1(j)}, x_{2(j+n-1)}) \cdot [r(x_{1(j)}, x_{2(j+n-1)}, b_k) - r(x_{1(j)}, x_{2(j+n-1)}, b_{(k-1)})] \\ & - p(x_{1(j)}, x_{2(j+n-2)}) \cdot [r(x_{1(j)}, x_{2(j+n-2)}, b_k) - r(x_{1(j)}, x_{2(j+n-2)}, b_{(k-1)})] \\ & - p(x_{1(j+1)}, x_{2(j+n-1)}) \cdot [r(x_{1(j+1)}, x_{2(j+n-1)}, b_k) - r(x_{1(j+1)}, x_{2(j+n-1)}, b_{(k-1)})] \\ & + p(x_{1(j+1)}, x_{2(j+n-2)}) \cdot [r(x_{1(j+1)}, x_{2(j+n-2)}, b_k) - r(x_{1(j+1)}, x_{2(j+n-2)}, b_{(k-1)})] \end{aligned}$$

and where $r(x_1, x_2, b_0) = 0$

1.5.2 *The factor $p(x_1, x_2)$ is to be calculated according to the formulae given in [1.5.3] to [1.5.5],*

with:

J_{max} : *Overall normalized max damage length*

$J_{max} = 10 / 33$

J_{kn} : *Knuckle point in the distribution*

$J_{kn} = 5 / 33$

p_k : *Cumulative probability at J_{kn}*

$p_k = 11 / 12$

ℓ_{max} : *Maximum absolute damage length*

$\ell_{max} = 60$ m

L^* : *Length where normalized distribution ends*

$L^* = 260$ m

b_0 : *Probability density at $J = 0$*

$$b_0 = 2\left(\frac{p_k}{J_{kn}} - \frac{1-p_k}{J_{max} - J_{kn}}\right)$$

- *when $L_s \leq L^*$:*

$$J_m = \min\left\{J_{max}, \frac{\ell_{max}}{L_s}\right\}$$

$$J_k = \frac{J_m}{2} + \frac{1 - \sqrt{1 + (1-2p_k)b_0 \cdot J_m + \frac{1}{4}b_0^2 \cdot J_m^2}}{b_0}$$

$$b_{12} = b_0$$

- *when $L_s > L^*$:*

$$J_m^* = \min\left\{J_{max}, \frac{\ell_{max}}{L^*}\right\}$$

$$J_k^* = \frac{J_m^*}{2} + \frac{1 - \sqrt{1 + (1-2p_k)b_0 \cdot J_m^* + \frac{1}{4}b_0^2 \cdot J_m^{*2}}}{b_0}$$

$$J_m = \frac{J_m^* \cdot L^*}{L_s}$$

$$J_k = \frac{J_k^* \cdot L^*}{L_s}$$

$$b_{12} = 2\left(\frac{p_k}{J_k} - \frac{1-p_k}{J_m - J_k}\right)$$

$$b_{11} = 4\frac{1-p_k}{(J_m - J_k)J_k} - 2\frac{p_k}{J_k^2}$$

$$b_{21} = -2\frac{1-p_k}{(J_m - J_k)^2}$$

$$b_{22} = -b_{21} \cdot J_m$$

J : *Non-dimensional damage length:*

$$J = \frac{x_2 - x_1}{L_s}$$

J_n : *Normalized length of a compartment or group of compartments, to be taken as the lesser of J and J_m.*

1.5.3 *Where neither limit of the compartment or group of compartments under consideration coincides with the aft or forward terminals:*

- *$J \leq J_k$:*

$$p(x_1, x_2) = p_1 = \frac{1}{6}J^2(b_{11} \cdot J + 3b_{12})$$

- *$J > J_k$:*

$$p(x_1, x_2) = p_2 = -\frac{b_{11} \cdot J_k^3}{3} + \frac{(b_{11} \cdot J - b_{12})J_k^2}{2} + b_{12} \cdot J \cdot J_k - \frac{b_{21}(J_n^3 - J_k^3)}{3} + \frac{(b_{21} \cdot J - b_{22})(J_n^2 - J_k^2)}{2} + b_{22} \cdot J(J_n - J_k)$$

1.5.4 *Where the aft limit of the compartment or group of compartments under consideration coincides with the aft terminal or the forward limit of the compartment or group of compartments under consideration coincides with the forward terminal:*

- *$J \leq J_k$:*

$$p(x_1, x_2) = \frac{1}{2}(p_1 + J)$$

- *$J > J_k$:*

$$p(x_1, x_2) = \frac{1}{2}(p_2 + J)$$

1.5.5 *Where the compartment or group of compartments considered extends over the entire subdivision length (L_s):*

$$p(x_1, x_2) = 1$$

1.5.6 *The factor $r(x_1, x_2, b)$ is to be determined by the following formula:*

$$r(x_1, x_2, b) = 1 - (1 - C) \cdot \left[1 - \frac{G}{p(x_1, x_2)}\right]$$

where:

$$C = 12J_b(-45J_b + 4)$$

with $J_b = b / (15\ B)$

- *where the compartment or group of compartments considered extends over the entire subdivision length (L_s):*

$$G = G_1 = \frac{1}{2}b_{11} \cdot J_b^2 + b_{12} \cdot J_b$$

- *where neither limit of the compartment or group of compartments under consideration coincides with the aft or forward terminals:*

$$G = G_2 = -\frac{1}{3}b_{11} \cdot J_0^3 + \frac{1}{2}(b_{11} \cdot J - b_{12})J_0^2 + b_{12} \cdot J \cdot J_0$$

with $J_0 = \min(J, J_b)$

- *where the aft limit of the compartment or group of compartments under consideration coincides with the aft terminal or the forward limit of the compartment or group of compartments under consideration coincides with the forward terminal:*

$$G = \frac{1}{2}(G_2 + G_1 \cdot J)$$

1.6 Calculation of factor s_i

1.6.1 *The factor s_i is to be determined for each case of assumed flooding involving a compartment or group of compartments according to the requirement indicated in [1.6.2] to [1.6.12] and the following notations:*

θ_e : *Equilibrium heel angle in any stage of flooding, in degrees*

θ_v : *Angle, in any stage of flooding, where the righting lever becomes negative, or the angle at which an opening incapable of being closed weathertight becomes submerged*

GZ_{max} : *Maximum positive righting lever, in metres, up to the angle θ_v*

Range : *Range of positive righting levers, in degrees, measured from the angle θ_e. The positive range is to be taken up to the angle θ_v*

Flooding stage is any discrete step during the flooding process, including the stage before equalization (if any) until final equilibrium has been reached.

1.6.2 *The factor s_i, for any damage case at any initial loading condition, d_i, shall be obtained from the formula:*

$$s_i = \min[s_{intermediate,i}, s_{final,i}]$$

where:

$s_{intermediate,i}$: *The probability to survive all intermediate flooding stages until the final equilibrium stage, calculated in accordance with [1.6.3]*

$s_{final,i}$: *The probability to survive in the final equilibrium stage of flooding, calculated in accordance with [1.6.4].*

1.6.3 Calculation of $s_{intermediate}$

- For cargo ships fitted with cross-flooding devices, the factor $s_{intermediate,i}$ is to be taken as the least of the s-factors obtained from all flooding stages including the stage before equalization, if any, and is to be calculated as follows:

$$s_{intermediate,i} = \left(\frac{GZ_{max}}{0{,}05} \cdot \frac{Range}{7}\right)^{\frac{1}{4}}$$

  where GZ_{max} is not to be taken as more than 0,05 m and Range as not more than 7°.

  $s_{intermediate} = 0$, if the intermediate heel angle exceeds 30°.

- For cargo ships not fitted with cross-flooding devices the factor $s_{intermediate,i}$ is taken as unity, except if the Society considers that the stability in intermediate stages of flooding may be insufficient. It should require further investigation thereof.

Where cross-flooding fittings are required, the time for equalization is not to exceed 10 min. The time for equalization is to be calculated in accordance with Pt D, Ch 11, App 1.

1.6.4 Calculation of s_{final}

The factor $s_{final,i}$ is to be obtained from the formula:

$$s_{final,i} = K\left(\frac{GZ_{max}}{TGZ_{max}} \cdot \frac{Range}{TRange}\right)^{\frac{1}{4}}$$

where:

GZ_{max} is not to be taken as more than TGZ_{max}

Range is not to be taken as more than TRange.

$TGZ_{max} = 0{,}12$ m

TRange = 16°

K is to be taken equal to:

- $K = 1$ if $\theta_e \leq \theta_{min}$
- $K = 0$ if $\theta_e \geq \theta_{max}$
- $K = \sqrt{\dfrac{\theta_{max} - \theta_e}{\theta_{max} - \theta_{min}}}$ otherwise

θ_{min} is equal to 25°

θ_{max} is equal to 30°.

1.6.5 Cases where s_i is taken as zero

a) *The factor s_i is to be taken as zero in those cases where the final waterline, taking into account sinkage, heel and trim, immerses:*
   - *the lower edge of openings through which progressive flooding may take place and such flooding is not accounted for in the calculation of factor s_i. Such openings are to include air-pipes, ventilators and openings which are closed by means of weathertight doors or hatch covers, but the openings closed by means of watertight manhole covers and flush scuttles, small watertight hatch covers, remotely operated sliding watertight doors, side scuttles of the non-opening type as well as watertight access doors and hatch covers required to be kept closed at sea need not be considered.*
   - *any part of the bulkhead deck considered a horizontal evacuation route.*

b) *The factor s_i is to be taken as zero if, taking into account sinkage, heel and trim, any of the following occur in any intermediate stage or in the final stage of flooding:*
   - *immersion of any vertical escape hatch in the freeboard deck of cargo ships intended for compliance with the applicable requirements of Pt C, Ch 4, Sec 8*
   - *any controls intended for the operation of watertight doors, equalization devices, valves on piping or on ventilation ducts intended to maintain the integrity of watertight bulkheads from above the freeboard deck of cargo ships become inaccessible or inoperable*
   - *immersion of any part of piping or ventilation ducts located within the assumed extent of damage and carried through a watertight boundary if this can lead to the progressive flooding of compartment not assumed as flooded.*

1.6.6 *The ship is to be so designed that s_i calculated in accordance with [1.6.1] will not be less than 1 at the deepest subdivision draught loading condition, level trim or any forward trim loading conditions, if any part of the ship forward of the collision bulkhead is flooded without vertical limits.*

1.6.7 *Unsymmetrical flooding is to be kept to a minimum consistent with the efficient arrangements. Where it is necessary to correct large angles of heel, the means adopted are, where practicable, to be self-acting, but in any case where controls to equalization devices are provided they are to be operable from above the freeboard deck of cargo ships. These fittings, together with their controls, are to be acceptable to the Society. Suitable information concerning the use of equalization devices are to be supplied to the master of the ship.*

1.6.8 *Tanks and compartments taking part in such equalization are to be fitted with air pipes or equivalent means of sufficient cross-section to ensure that the flow of water into the equalization compartments is not delayed.*

1.6.9 *Where horizontal watertight boundaries are fitted above the waterline under consideration, the s-value calculated for the lower compartment or group of compartments is to be obtained by multiplying the value as determined in [1.6.2] by the reduction factor ν_m according to [1.6.10], which represents the probability that the spaces above the horizontal subdivision will not be flooded.*

1.6.10 *The factor ν_m is to be obtained from the following formula:*

$$\nu_m = \nu(H_{j,n,m}, d) - \nu(H_{j,n,m-1}, d)$$

where:

- $H_{j, n, m}$: *Least height above the baseline, in metres, within the longitudinal range of $x_1(j)...x_2(j+n-1)$ of the m^{th} horizontal boundary which is assumed to limit the vertical extent of flooding for the damaged compartments under consideration*
- $H_{j, n, m-1}$: *Least height above the baseline, in metres, within the longitudinal range of $x_1(j)...x_2(j+n-1)$ of the $(m-1)^{th}$ horizontal boundary which is assumed to limit the vertical extent of flooding for the damaged compartments under consideration*
- j : *The aft terminal of the damaged compartments under consideration*
- m : *Each horizontal boundary counted upwards from the waterline under consideration*
- d : *Draught in question, as defined in [1.2]*
- x_1 , x_2 : *Terminals of the compartment or group of compartments considered in [1.5.1].*

1.6.11 *The factors $\nu(H_{j, n, m}, d)$ and $\nu(H_{j, n, m-1}, d)$ are to be obtained from the following formulae:*

- *if $(H_m - d) \le 7{,}8$ m:*

$$\nu(H, d) = 0,8\frac{(H-d)}{7,8}$$

- *in all other cases:*

$$\nu(H, d) = 0,8 + 0,2\left[\frac{(H-d) - 7,8}{4,7}\right]$$

where:

- *$\nu(H_{j, n, m}, d)$ is to be taken as 1, if H_m coincides with the uppermost watertight boundary of the ship within the range $(x_{1(j)} ... x_{2(j+n-1)})$*
- *$\nu(H_{j, n, 0}, d)$ is to be taken as 0.*

In no case is ν_m to be taken as less than zero or more than 1.

1.6.12 *In general, each contribution dA to the index A in the case of horizontal subdivisions is obtained from the following formula:*

$$dA = p_i \cdot [\nu_1 \cdot s_{min1} + (\nu_2 - \nu_1) \cdot s_{min2} + \ldots + (1 - \nu_{m-1}) \cdot s_{min\,m}]$$

where:

- ν_m : *The ν-value calculated in accordance with [1.6.10] and [1.6.11]*
- s_{min} : *The least s-factor for all combinations of damages obtained when the assumed damage extends from the assumed damage height H_m downwards.*

1.7 Permeability

1.7.1 *For the purpose of the subdivision and damage stability calculations* reported in this Appendix*, the permeability of each space or part of a space is to be as per Tab 1.*

Table 1 : Permeability

Spaces	Permeability
Appropriated to stores	0,60
Occupied by accommodations	0,95
Occupied by machinery	0,85
Void spaces	0,95
Intended for liquids	0 or 0,95 **(1)**
(1) whichever results in the more severe requirements	

1.7.2 *For the purpose of the subdivision and damage stability calculations* reported in this Appendix*, the permeability of each cargo compartment is to be as per Tab 2.*
Other figures for permeability may be used if substantiated by calculations.

Table 2 : Permeability of cargo compartments

Spaces	Permeability at draught		
	d_S	d_P	d_L
Dry cargo spaces	0,70	0,80	0,95
Container spaces	0,70	0,80	0,95
Ro-ro spaces	0,90	0,90	0,95
Cargo liquids	0,70	0,80	0,95

1.8 Stability information

1.8.1 *The master is to be supplied with such information satisfactory to the Society as is necessary to enable him by rapid and simple processes to obtain accurate guidance as to the stability of the ship under varying conditions of service. A copy of the stability information is to be furnished to the Society.*

1.8.2 Information to be submitted

The information is to include:

- *curves or tables of minimum operational metacentric height (GM) versus draught which assures compliance with the relevant intact and damage stability requirements, alternatively corresponding curves or tables of the maximum allowable vertical centre of gravity (KG) versus draught, or with the equivalents of either of these curves*
- *instructions concerning the operation of cross-flooding arrangements, and*
- *all other data and aids which might be necessary to maintain the required intact stability and stability after damage.*

1.8.3 *The stability information is to show the influence of various trims in cases where the operational trim range exceeds* $\pm 0,5\%$ *of* L_s.

1.8.4 *For ships which have to fulfil the stability requirements of this Annex, information referred to in [1.8.2] is determined from considerations related to the subdivision index, in the following manner: Minimum required GM (or maximum permissible vertical position of centre of gravity KG) for the three draughts* d_S, d_P *and* d_L *are equal to the GM (or KG values) of corresponding loading cases used for the calculation of survival factor* s_i. *For intermediate draughts, values to be used are to be obtained by linear interpolation applied to the GM value only between the deepest subdivision draught and the partial subdivision draught and between the partial load line and the light service draught respectively. Intact stability criteria are also to be taken into account by retaining for each draught the maximum among minimum required GM values or the minimum of maximum permissible KG values for both criteria. If the subdivision index is calculated for different trims, several required GM curves are to be established in the same way.*

1.8.5 *When curves or tables of minimum operational metacentric height (GM) versus draught are not appropriate, the master is to ensure that the operating condition does not deviate from a studied loading condition, or verify by calculation that the stability criteria are satisfied for this loading condition.*

APPENDIX 4 DAMAGE STABILITY CALCULATION FOR SHIPS ASSIGNED WITH A REDUCED FREEBOARD

1 Application

1.1 General

1.1.1 The requirements of this Appendix apply to:

- Type A ships having a length greater than 150 m, and
- Type B-60 ships and Type B-100 ships having a length greater than 100 m.

Any reference hereafter to regulations refers to the set of regulations contained in this Appendix.

2 Initial loading condition

2.1 Initial condition of loading

2.1.1 *The initial condition of loading before flooding is to be determined* according to [2.1.2] and [2.1.3].

2.1.2 *The ship is loaded to its summer load waterline on an imaginary even keel.*

2.1.3 *When calculating the vertical centre of gravity, the following principles apply:*

a) *Homogeneous cargo is carried.*

b) *All cargo compartments, except those referred to under c), but including compartments intended to be partially filled, are to be considered fully loaded except that in the case of fluid cargoes each compartment is to be treated as 98 per cent full.*

c) *If the ship is intended to operate at its summer load waterline with empty compartments, such compartments are to be considered empty provided the height of the centre of gravity so calculated is not less than as calculated under b).*

d) *Fifty per cent of the individual total capacity of all tanks and spaces fitted to contain consumable liquids and stores is allowed for. It is to be assumed that for each type of liquid, at least one transverse pair or a single centre line tank has maximum free surface, and the tank or combination of tanks to be taken into account are to be those where the effect of free surfaces is the greatest; in each tank the centre of gravity of the contents is to be taken at the centre of volume of the tank. The remaining tanks are to be assumed either completely empty or completely filled, and the distribution of consumable liquids between these tanks is to be effected so as to obtain the greatest possible height above the keel for the centre of gravity.*

e) *At an angle of heel of not more than 5 degrees in each compartment containing liquids, as prescribed in b) except that in the case of compartments containing consumable fluids, as prescribed in d), the maximum free surface effect is to be taken into account.*

   Alternatively, the actual free surface effects may be used, provided the methods of calculation are acceptable to the Society.

f) *Weights are to be calculated on the basis of Tab 1.*

Table 1 : Specific gravities

Weight item	Specific gravity, in t/m^3
Salt water	1,025
Fresh water	1,000
Fuel oil	0,950
Diesel oil	0,900
Lubricating oil	0,900

3 Damage assumptions

3.1 Damage dimension

3.1.1 *The principles* indicated in [3.1.2] to [3.1.5] *regarding the character of the assumed damage apply.*

3.1.2 *The vertical extent of damage in all cases is assumed to be from the base line upwards without limit.*

3.1.3 *The transverse extent of damage is equal to B/5 or 11,5 metres, whichever is the lesser, measured inboard from the side of the ship perpendicularly to the centre line at the level of the summer load waterline.*

3.1.4 *If damage of a lesser extent than specified in* [3.1.2] and [3.1.3] *results in a more severe condition, such lesser extent is to be assumed.*

3.1.5 *Except where otherwise required in [3.4.3], the flooding is to be confined to a single compartment between adjacent transverse bulkheads provided the inner longitudinal boundary of the compartment is not in a position within the transverse extent of assumed damage. Transverse boundary bulkheads of wing tanks, which do not extend over the full breadth of the ship are to be assumed not to be damaged, provided they extend beyond the transverse extent of assumed damage prescribed in [3.1.3].*

3.2 Steps and recesses

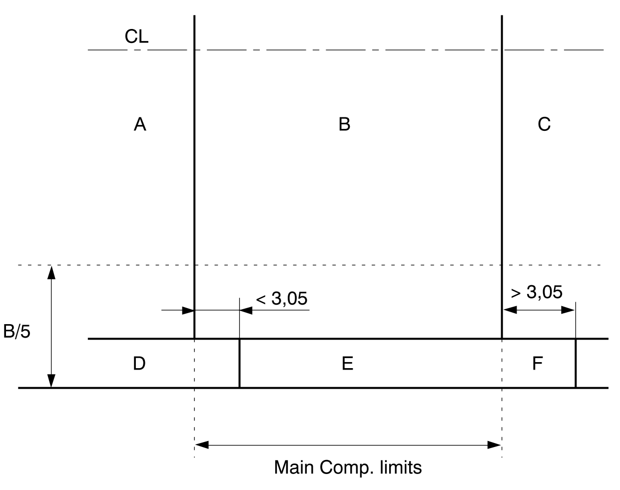
3.2.1 *If in a transverse bulkhead there are steps or recesses of not more than 3,05 metres in length located within the transverse extent of assumed damage as defined in [3.1.3], such transverse bulkhead may be considered intact and the adjacent compartment may be floodable singly. If, however, within the transverse extent of assumed damage there is a step or recess of more than 3,05 metres in length in a transverse bulkhead, the two compartments adjacent to this bulkhead are to be considered as flooded. The step formed by the after peak bulkhead and the after peak tank top is not to be regarded as a step for the purpose of this regulation.*

3.2.2 *Where a main transverse bulkhead is located within the transverse extent of assumed damage and is stepped in way of a double bottom or side tank by more than 3,05 metres, the double bottom or side tanks adjacent to the stepped portion of the main transverse bulkhead are to be considered as flooded simultaneously. If this side tank has openings into one or several holds, such as grain feeding holes, such hold or holds are to be considered as flooded simultaneously. Similarly, in a ship designed for the carriage of fluid cargoes, if a side tank has openings into adjacent compartments, such adjacent compartments are to be considered as empty and flooded simultaneously. This provision is applicable even where such openings are fitted with closing appliances, except in the case of sluice valves fitted in bulkheads between tanks and where the valves are controlled from the deck. Manhole covers with closely spaced bolts are considered equivalent to the unpierced bulkhead except in the case of openings in topside tanks making the topside tanks common to the holds.*

3.2.3 Where a transverse bulkhead forming the forward or aft limit of a wing tank or double bottom tank is not in line with the main transverse bulkhead of the adjacent inboard compartment, it is considered to form a step or recess in the main transverse bulkhead.

Such a step or recess may be assumed not to be damaged provided that, either:

Figure 1 : Step and recesses - Example 1



Compartments to be considered damaged simultaneously: A + D; B + E; C + E + F

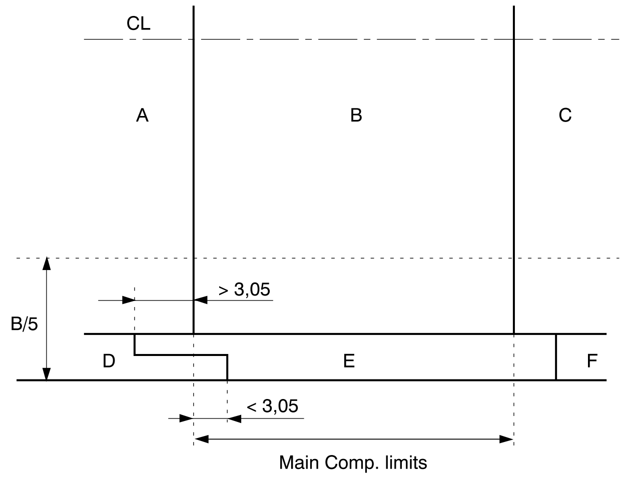
- the longitudinal extent of the step or recess, measured from the plan of the main transverse bulkhead, is not more than 3,05 metres, or
- any longitudinal surface forming the step or recess is located inboard of the assumed damage.

3.2.4 Where, otherwise, the transverse and longitudinal bulkheads bounding a main inboard compartment are entirely inboard of the assumed damage position, damage is assumed to occur between the transverse bulkheads and the adjacent wing compartment. Any step or recess in such wing tank is to be treated as indicated above.

Examples are shown in Fig 1 to Fig 4:

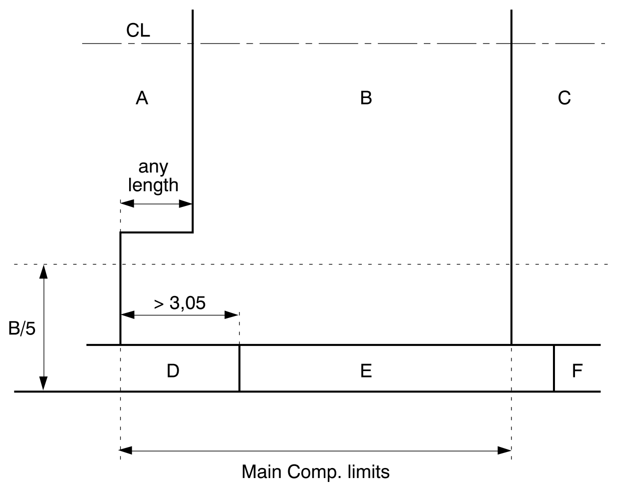
- Fig 1 and Fig 2 refer to [3.2.2]
- Fig 3 and Fig 4 refer to [3.2.1] and [3.2.2].

Figure 2 : Step and recesses - Example 2



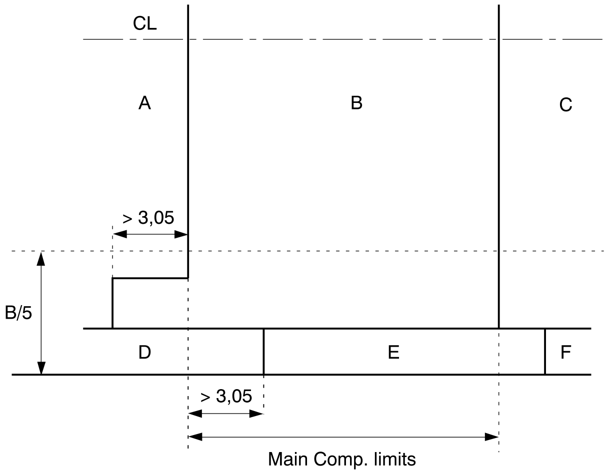
Compartments to be considered damaged simultaneously: A + D + E; B + E

Figure 3 : Step and recesses - Example 3



Compartments to be considered damaged simultaneously: A + D; B + D + E

Figure 4 : Step and recesses - Example 4



3.3 Transverse bulkhead spacing

3.3.1 *Where the flooding of any two adjacent fore and aft compartments is envisaged, main transverse watertight bulkheads are to be spaced at least* $1/3(L)^{2/3}$ *or 14,5 metres, whichever is the lesser, in order to be considered effective. Where transverse bulkheads are spaced at a lesser distance, one or more of these bulkheads are to be assumed as non-existent in order to achieve the minimum spacing between bulkheads.*

3.4 Damage assumption

3.4.1 *A Type A ship, if over 150 metres in length to which a freeboard less than Type B has been assigned, when loaded as considered in [2.1], is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0,95, consequent upon the damage assumptions specified in [3.1], and is to remain afloat in a satisfactory condition of equilibrium as specified in [3.5] and [3.6]. In such a ship, the machinery space is to be treated as a floodable compartment, but with a permeability of 0,85.* See Tab 2.

3.4.2 *A Type B-60 ship, when loaded as considered in [2.1], is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0,95, consequent upon the damage assumptions specified in [3.1], and is to remain afloat in a satisfactory condition of equilibrium as specified in [3.5] and [3.6]. In such a ship, if over 150 metres in length, the machinery space is to be treated as a floodable compartment, but with a permeability of 0,85.* See Tab 2.

3.4.3 *A Type B-100 ship, when loaded as considered in [2.1], is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0,95, consequent upon the damage assumptions specified in [3.1], and is to remain afloat in a satisfactory condition of equilibrium as specified in [3.5] and [3.6]. Furthermore all the requirements stated in [4.1] are to be complied with, provided that throughout the length of the ship any one transverse bulkhead will be assumed to be damaged, such that two adjacent fore and aft compartments are to be flooded simultaneously, except that such damage will not apply to the boundary bulkheads of a machinery space. In such a ship, if over 150 metres in length, the machinery space is to be treated as a floodable compartment, but with a permeability of 0,85.* See Tab 2.

Table 2 : Damage assumption

Type	L, in m	Standard of flooding **(1)**
A	≥ 150	one compartment
B - 60	≥ 100	one compartment
B -100	≥ 100	two adjacent compartments (exemption for machinery space which is to be flooded alone)
(1) except where otherwise required by [4.2].		

3.5 Condition of equilibrium

3.5.1 *The condition of equilibrium after flooding is to be regarded as satisfactory* according to [3.5.2] and [3.5.3].

3.5.2 *The final waterline after flooding, taking into account sinkage, heel and trim, is below the lower edge of any opening through which progressive downflooding may take place. Such openings are to include air pipes, ventilators and openings which are closed by means of weathertight doors or hatch covers,* unless closed by watertight gasketed covers of steel or equivalent material, *and may exclude those openings closed by means of manhole covers and flush scuttles, cargo hatch covers, remotely operated sliding watertight doors, and side scuttles of the non-opening type. However, in the case of doors separating a main machinery space from a steering gear compartment, watertight doors may be of a hinged, quick acting type kept closed at sea, whilst not in use, provided also that the lower sill of such doors is above the summer load waterline.*

3.5.3 *If pipes, ducts or tunnels are situated within the assumed extent of damage penetration as defined in [3.1.3], arrangements are to be made so that progressive flooding cannot thereby extend to compartments other than those assumed to be floodable in the calculation for each case of damage.*

3.6 Damage stability criteria

3.6.1 *The angle of heel due to unsymmetrical flooding does not exceed 15 degrees. If no part of the deck is immersed, an angle of heel of up to 17 degrees may be accepted.*

3.6.2 *The metacentric height in the flooded condition is positive.*

3.6.3 *When any part of the deck outside the compartment assumed flooded in a particular case of damage is immersed, or in any case where the margin of stability in the flooded condition may be considered doubtful, the residual stability is to be investigated. It may be regarded as sufficient if the righting lever curve has a minimum range of 20 degrees beyond the position of equilibrium with a maximum righting lever of at least 0,1 metre within this range. The area under the righting lever curve within this range is to be not less than 0,0175 metre-radians. The Society is to give consideration to the potential hazard presented by protected or unprotected openings which may become temporarily immersed within the range of residual stability.*

3.6.4 *The Society is satisfied that the stability is sufficient during intermediate stages of flooding.* In this regard, the Society will apply the same criteria relevant to the final stage, also during the intermediate stages of flooding.

4 Requirements for Type B-60 and B-100 ships

4.1 Requirements for Type B-60 ships

4.1.1 *Any Type B ships of over 100 metres, having hatchways closed by weathertight covers as specified in [4.3], may be assigned freeboards less than those required for Type B, provided that, in relation to the amount of reduction granted, the* requirements in [4.1.2] to [4.1.4] are considered satisfactory by the Society.

In addition, the requirements stated in [3.4.2] are to be complied with.

4.1.2 *The measures provided for the protection of the crew are to be adequate.*

4.1.3 *The freeing arrangements are* to comply with the provisions of Ch 8, Sec 10.

4.1.4 *The covers in positions 1 and 2 comply with the provisions of [4.3] and have strength complying with Ch 8, Sec 7, special care being given to their sealing and securing arrangements.*

4.2 Requirements for Type B-100 ships

4.2.1 In addition to the requirements specified in [4.1], not taking into account the prescription stated in [3.4.2], the requirements in [4.2.2] to [4.2.4] are to be complied with.

In addition, the provisions of [3.4.3] are to be complied with.

4.2.2 Machinery casings

Machinery casings on Type A ships are to be protected by an enclosed poop or bridge of at least standard height, or by a deckhouse of equal height and equivalent strength, provided that machinery casings may be exposed if there are no openings giving direct access from the freeboard deck to the machinery space. A door complying with the requirements of [4.4] may, however, be permitted in the machinery casing, provided that it leads to a space or passageway which is as strongly constructed as the casing and is separated from the stairway to the engine room by a second weathertight door of steel or other equivalent material.

4.2.3 Gangway and access

An efficiently constructed fore and aft permanent gangway of sufficient strength is to be fitted on Type A ships at the level of the superstructure deck between the poop and the midship bridge or deckhouse where fitted, or equivalent means of access is to be provided to carry out the purpose of the gangway, such as passages below deck. Elsewhere, and on Type A ships without a midship bridge, arrangements to the satisfaction of the Society are to be provided to safeguard the crew in reaching all parts used in the necessary work of the ship.

Safe and satisfactory access from the gangway level is to be available between separate crew accommodation spaces and also between crew accommodation spaces and the machinery space.

4.2.4 Freeing arrangements

Type A ships with bulwarks are to be provided with open rails fitted for at least half the length of the exposed parts of the weather deck or other effective freeing arrangements. The upper edge of the sheer strake is to be kept as low as practicable.

Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

4.3 Hatchways closed by weathertight covers of steel or other equivalent material fitted with gaskets and clamping devices

4.3.1 At positions 1 and 2 the height above the deck of hatchway coamings fitted with weathertight hatch covers of steel or other equivalent material fitted with gaskets and clamping devices is to be:

- 600 millimetres if in position 1
- 450 millimetres if in position 2.

The height of these coamings may be reduced, or the coamings omitted entirely, upon proper justification. Where coamings are provided they are to be of substantial construction.

4.3.2 *Where weathertight covers are of mild steel the strength is to be calculated with assumed loads not less than those specified in Ch 8, Sec 7.*

4.3.3 *The strength and stiffness of covers made of materials other than mild steel are to be equivalent to those of mild steel to the satisfaction of the Society.*

4.3.4 *The means for securing and maintaining weathertightness are to be to the satisfaction of the Society. The arrangements are to ensure that the tightness can be maintained in any sea conditions, and for this purpose tests for tightness are required at the initial survey, and may be required at periodical surveys and at annual inspections or at more frequent intervals.*

4.4 Doors

4.4.1 *All access openings in bulkheads at ends of enclosed superstructures are to be fitted with doors of steel or other equivalent material, 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 means for securing these doors weathertight are to consist of gaskets and clamping devices or other equivalent means and are to be permanently attached to the bulkhead or to the doors themselves, and the doors are to be so arranged that they can be operated from both sides of the bulkhead.*

4.4.2 *Except as otherwise provided, the height of the sills of access openings in bulkheads at ends of enclosed superstructures is to be at least 380 millimetres above the deck.*

Part B
Hull and Stability

Chapter 4
STRUCTURE DESIGN PRINCIPLES

SECTION 1 MATERIALS

1 General

1.1 Characteristics of materials

1.1.1 The characteristics of the materials to be used in the construction of ships are to comply with the applicable requirements of NR216 Materials and Welding.

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 NR216 Materials and Welding.

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 NR216 Materials and Welding. 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 Steels for hull structure

2.1 Application

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

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

2.1.3 When steels with a minimum specified yield stress R_{eH} other than 235 N/mm² are used on a ship, hull scantlings are to be determined by taking into account the material factor k defined in [2.3].

2.1.4 In case of steel used at a temperature θ between 90°C and 300°C, and when no other information is available, the minimum specified yield stress R_{eH} and the Young's modulus E of the steel at the temperature θ may be taken respectively equal to:

$$R_{eH} = R_{eH0}\left(1,04 - \frac{0,75}{1000}\theta\right)$$

$$E = E_0\left(1,03 - \frac{0,5}{1000}\theta\right)$$

where:

R_{eH0} : Value of the minimum specified yield stress at ambient temperature, in N/mm²

E_0 : Value of the Young's modulus at ambient temperature, in N/mm²

θ : Temperature of use of the steel, in °C.

2.1.5 Characteristics of steels with specified through thickness properties are given in NR216 Materials and Welding, Ch 2, Sec 1, [9].

Table 1 : Mechanical properties of hull steels

Steel grades $t \le 100$ mm	Minimum yield stress R_{eH}, in N/mm²	Ultimate minimum tensile strength R_m, in N/mm²
A-B-D-E	235	400 - 520
AH32-DH32 EH32-FH32	315	440 - 570
AH36-DH36 EH36-FH36 EH36CAS-FH36CAS	355	490 - 630
AH40-DH40 EH40- FH40 EH40CAS-FH40CAS	390	510 - 660
EH47 EH47CAS	460	570 - 720
Note 1: Ref.: NR216 Materials and Welding, Ch 2, Sec 1, [2]		

2.2 Information to be kept on board

2.2.1 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.

2.3 Material factor k

2.3.1 Unless otherwise specified, the material factor k has the values defined in Tab 2, as a function of the minimum specified yield stress R_{eH}.

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

2.3.2 Steels with a yield stress lower than 235 N/mm² or greater than 390 N/mm² are considered by the Society on a case by case basis.

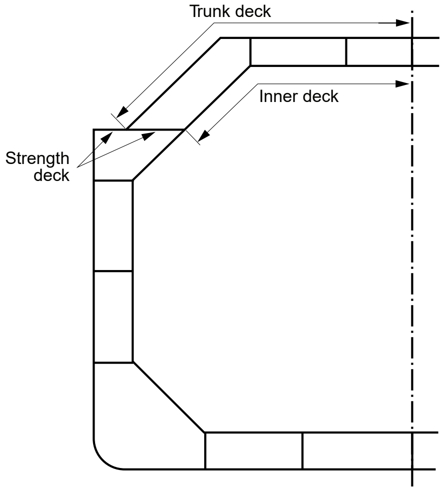
In particular, where higher strength steel having a minimum specified yield stress R_{eH} equal to 460 N/mm² are used according to [2.1.2], the material factor k is to be taken equal to 0,62.

Table 2 : Material factor k

R_{eH} , in N/mm²	k
235	1,00
315	0,78
355	0,72
390	0,68 **(1)**

(1) The material factor k may be taken equal to 0,66 for steels with yield stress equal to 390 N/mm², provided that the hull structure is additionally verified for compliance with finite element analysis and spectral fatigue assessment according to NI 611.

Figure 1 : Typical deck arrangement for membrane-type liquefied natural gas carriers



2.4 Grades of steel

2.4.1 Materials in the various strength members are not to be of lower grade than those corresponding to the material classes and grades specified in Tab 3, Tab 4, Tab 6, Tab 7 and Tab 8, and Tab 9.

General requirements are given in Tab 3. Additional minimum requirements are given in:

- Tab 4 for ships, excluding membrane-type liquefied gas carriers, greater than 150 m in length and having a single strength deck
- Tab 5 for membrane type liquefied gas carriers greater than 150 m in length and having a deck arrangement as shown in Fig 1. Tab 5 may apply to similar ships with a double deck arrangement above the strength deck.
- Tab 6 for ships greater than 250 m in length
- Tab 7 for single-side **bulk carrier**, **bulk carrier ESP** and **combination carrier / OBO ESP**
- Tab 8 for ships with ice strengthening.

2.4.2 Materials are to be of a grade not lower than that indicated in Tab 9 depending on the material class and structural member gross thickness (see [2.4.5]).

2.4.3 For strength members not mentionned in Tab 3, Tab 4, Tab 5, Tab 6, Tab 7 and Tab 8, grade A/AH may generally be used.

2.4.4 Plating materials for sternframes supporting the rudder and propeller boss, rudders, rudder horns and shaft brachets are generally to be of grades not lower than those 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.

2.4.5 The steel grade is to correspond to the as fitted gross thickness when this is greater than the gross thickness obtained from the net thickness required by the Rules, according to Ch 4, Sec 2, [1].

2.4.6 Steel grades of plates or sections of gross thickness greater than the limiting thicknesses in Tab 9 are considered by the Society on a case by case basis.

2.4.7 In specific cases, such as [2.4.8], 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.

2.4.8 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.

2.4.9 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.

2.4.10 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 minimize the risk of lamellar tearing (Z type steel, see NR216 Materials and Welding).

2.4.11 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.

Table 3 : Application of material classes and grades for ships in general

Structural member category		Material class or grade	
		Within 0,4L amidships	Outside 0,4L amidships
SECONDARY	• Longitudinal bulkhead strakes, other than that belonging to the primary category • Deck plating exposed to weather, other than that belonging to the primary or special category • Side plating	I	A / AH
PRIMARY	• Bottom plating, including keel plate • Strength deck plating, excluding that belonging to the special category • Continuous longitudinal plating of strength members above strength deck, excluding hatch coamings, for ships equal to or greater than 90 m in length • Uppermost strake in longitudinal bulkhead • Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	II	A / AH
SPECIAL	• Sheer strake at strength deck **(1)** • Stringer plate in strength deck **(1)** • Deck strake at longitudinal bulkhead excluding deck plating in way of inner-skin bulkhead of double hull ships **(1)**	III	II I outside 0,6L amidships
	• Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch openings configurations	III	II I outside 0,6L amidships Min. class III within cargo region
	• Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch openings configurations • Trunk deck and inner deck plating at corners of openings for liquid and gas domes in membrane type liquefied gas carriers	III	III within 0,6L amidships II within the rest of cargo region
	• Bilge strake in ships with double bottom over the full breadth and length less than 150 m	II	II within 0,6L amidships I outside 0,6L amidships
	• Bilge strake in other ships **(1)**	III	II I outside 0,6L amidships
	• Longitudinal hatch coamings of length greater than 0,15 L, including top plate and flange, for ships equal to or greater than 90 m in length • End brackets and deck house transition of longitudinal cargo hatch coamings	III Not to be less than grade D/DH	II I outside 0,6L amidships Not to be less than grade D/DH

(1) Single strakes required to be of class III within 0.4L amidships are to have breadths not less than (800 + 5 L) mm, need not to be greater than 1800 mm, unless limited by the geometry of the ship's design.

Table 4 : Application of material classes and grades for ships, excluding membrane-type liquefied gas carriers, greater than 150 m in length and having a single strength deck

Structural member category	Material grade
• Longitudinal plating of strength deck where contributing to the longitudinal strength • Continuous longitudinal plating of strength members above strength deck	B/AH within 0,4 L amidships
Single side strakes for ships without inner continuous longitudinal bulkhead(s) between the bottom and the strength deck	B/AH within cargo region

Table 5 : Application of material classes and grades for membrane-type liquefied gas carriers, greater than 150 m in length

Structural member category		Material class or grade
Longitudinal plating of strength deck where contributing to the longitudinal strength		B/AH within 0,4 L amidships
Continuous longitudinal plating of strength members above the strength deck	Trunk deck plating	II within 0,4L amidships
	• Inner deck plating • Longitudinal strength member plating between the trunk deck and inner deck	B/AH within 0,4 L amidships

Table 6 : Application of material classes and grades for ships greater than 250 m in length

Structural member category	Material grade within 0,4 L amidships
Shear strake at strength deck **(1)**	E/EH
Stringer plate in strength deck **(1)**	E/EH
Bilge strake **(1)**	D/DH
(1) Single strakes are required to be of grade E/EH and within 0,4 L amidships are to have breadths not less than (800 + 5 L) mm, but need not be greater than 1800 mm, unless limited by the geometry of the ship's design.	

Table 7 : Application of material classes and grades for single-side bulk carrier, bulk carrier ESP and combination carrier / OBO ESP

Structural member category	Material grade
Lower bracket of ordinary side frame **(1)** **(2)**	D/DH
Side shell strakes included totally or partially between the two points located to 0,125 ℓ above and below the intersection of side shell and bilge hopper sloping plate or inner bottom plate **(2)**	D/DH
(1) the term "lower bracket" means web of lower bracket and web of the lower part of side frames up the point of 0,125 ℓ above the intersection of side shell and bilge hopper sloping plate or inner bottom plate. **(2)** the span of the side frame, ℓ, is defined as the distance between the supporting structures.	

Table 8 : Application of material classes and grades for ships with ice strengthening

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

Table 9 : Material grade requirements for classes I, II and III

Class	I		II		III	
Gross thickness, in mm	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 15	A	AH	A	AH	A	AH
15 < t ≤ 20	A	AH	A	AH	B	AH
20 < t ≤ 25	A	AH	B	AH	D	DH
25 < t ≤ 30	A	AH	D	DH	D	DH
30 < t ≤ 35	B	AH	D	DH	E	EH
35 < t ≤ 40	B	AH	D	DH	E	EH
40 < t ≤ 50	D	DH	E	EH	E	EH
Note 1: "NSS" and "HSS" mean, respectively: "Normal Strength Steel" and "Higher Strength Steel".						

2.5 Grades of steel for structures exposed to low air temperatures

2.5.1 For ships intended to operate in areas with low air temperatures, below −10°C, e.g. regular service during winter seasons to Arctic or Antarctic waters (known as the Polar Regions), the materials in exposed structures are to be selected based on the design temperature t_D, to be taken as defined in [2.5.2].

2.5.2 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

Average : Average during one day and night

Lowest : Lowest during one year.

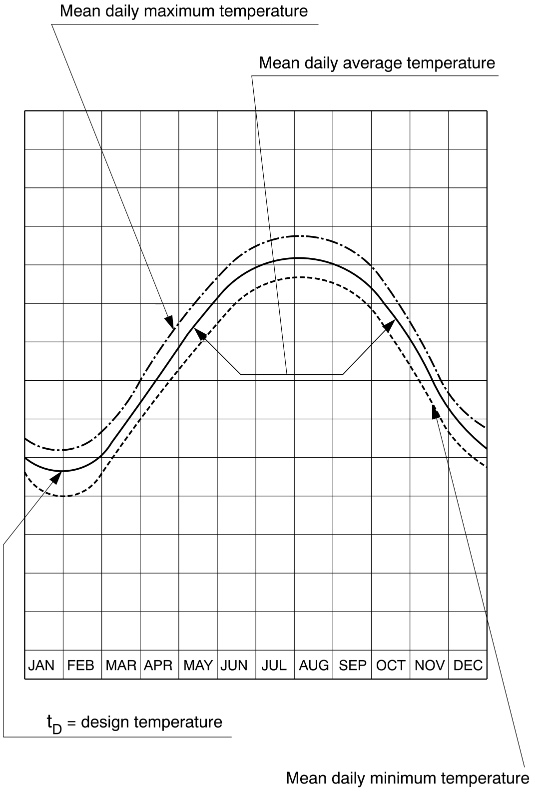
Fig 2 illustrates the temperature definition for Arctic waters.

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

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

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

Figure 2 : Commonly used definitions of temperatures



2.5.3 For the purpose of the selection of steel grades to be used for the structural members above the lowest ballast waterline and exposed to air, the latter are divided into categories (SECONDARY, PRIMARY and SPECIAL), as indicated in Tab 10.

Tab 10 also specifies the classes (I, II and III) of the materials to be used for the various categories of structural members. Class I is to be considered for superstructures and deckhouses structural members exposed to air.

For non-exposed structures (except bulkhead strakes as mentioned in footnote **(6)** of Tab 10) and structures below the lowest ballast waterline, see [2.4].

2.5.4 Materials may not be of a lower grade than that indicated in Tab 11 to Tab 13 depending on the material class, structural member gross thickness and design temperature t_D.

For design temperatures $t_D < -55°C$, materials will be specially considered by the Society on a case by case basis.

2.5.5 Single strakes required to be of class III or of grade E/EH or FH are to have breadths not less than (800+5L) mm, but not necessarily greater than 1800 mm.

Table 10 : Application of material classes and grades - Structures exposed to low air temperatures

Structural member category	Material class	
	Within 0,4L amidships	Outside 0,4L amidships
SECONDARY: Deck plating exposed to weather (in general) Side plating above T_B **(1)** Transverse bulkheads above T_B **(1) (6)**	I	I
PRIMARY: Strength deck plating **(2)** Continuous longitudinal members above strength deck (excluding longitudinal hatch coamings of ships equal to or greater than 90 m in length) Longitudinal bulkhead above T_B **(1) (6)** Topside tank bulkhead above T_B **(1) (6)**	II	I
SPECIAL: Sheer strake at strength deck **(3)** Stringer plate in strength deck **(3)** Deck strake at longitudinal bulkhead **(4)** Continuous longitudinal hatch coamings of ships equal to or greater than 90 m in length **(5)**	III	II

(1) T_B is the draught in light ballast condition, defined in Ch 5, Sec 1, [2.4.3].
(2) Plating at corners of large hatch openings to be considered on a case by case basis.
Class III or grade E/EH to be applied in positions where high local stresses may occur.
(3) To be not less than grade E/EH within 0,4 L amidships in ships with length exceeding 250 m.
(4) In ships with breadth exceeding 70 metres at least three deck strakes to be class III.
(5) To be not less than grade D/DH.
(6) Applicable to plating attached to hull envelope plating exposed to low air temperature. At least one strake is to be considered as exposed plating over a width of not less than 600 mm.

Note 1: Plating materials for sternframes, rudder horns, rudders and shaft brackets are to be of grades not lower than those corresponding to the material classes in [2.4].

Table 11 : Material grade requirements for class I at low temperatures

Gross thickness, in mm	−11°C / −15°C		−16°C / −25°C		−26°C / −35°C		−36°C / −45°C		−46°C / −55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	A	AH	A	AH	B	AH	D	DH	D	DH
10 < t ≤ 15	A	AH	B	AH	D	DH	D	DH	D	DH
15 < t ≤ 20	A	AH	B	AH	D	DH	D	DH	E	EH
20 < t ≤ 25	B	AH	D	DH	D	DH	D	DH	E	EH
25 < t ≤ 30	B	AH	D	DH	D	DH	E	EH	E	EH
30 < t ≤ 35	D	DH	D	DH	D	DH	E	EH	E	EH
35 < t ≤ 45	D	DH	D	DH	E	EH	E	EH	N.A.	FH
45 < t ≤ 50	D	DH	E	EH	E	EH	N.A.	FH	N.A.	FH

Note 1: “NSS” and “HSS” mean, respectively, “Normal Strength Steel” and “Higher Strength Steel”.
Note 2: N.A. = not applicable.

Table 12 : Material grade requirements for class II at low temperatures

Gross thickness, in mm	−11°C / −15°C		−16°C / −25°C		−26°C / −35°C		−36°C / −45°C		−46°C / −55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	A	AH	B	AH	D	DH	D	DH	E	EH
10 < t ≤ 20	B	AH	D	DH	D	DH	E	EH	E	EH
20 < t ≤ 30	D	DH	D	DH	E	EH	E	EH	N.A.	FH
30 < t ≤ 40	D	DH	E	EH	E	EH	N.A.	FH	N.A.	FH
40 < t ≤ 45	E	EH	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
45 < t ≤ 50	E	EH	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.

Note 1: "NSS" and "HSS" mean, respectively, "Normal Strength Steel" and "Higher Strength Steel".
Note 2: N.A. = not applicable.

Table 13 : Material grade requirements for class III at low temperatures

Gross thickness, in mm	−11°C / −15°C		−16°C / −25°C		−26°C / −35°C		−36°C / −45°C		−46°C / −55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	B	AH	D	DH	D	DH	E	EH	E	EH
10 < t ≤ 20	D	DH	D	DH	E	EH	E	EH	N.A.	FH
20 < t ≤ 25	D	DH	E	EH	E	EH	E	FH	N.A.	FH
25 < t ≤ 30	D	DH	E	EH	E	EH	N.A.	FH	N.A.	FH
30 < t ≤ 35	E	EH	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
35 < t ≤ 40	E	EH	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
40 < t ≤ 50	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.	N.A.	N.A.

Note 1: "NSS" and "HSS" mean, respectively, "Normal Strength Steel" and "Higher Strength Steel".
Note 2: N.A. = not applicable.

2.6 Grades of steel within refrigerated spaces

2.6.1 For structural members within or adjacent to refrigerated spaces, when the design temperatures is below 0°C, the materials are to be of grade not lower than those indicated in Tab 14, depending on the design temperature, the structural member gross thickness and its category (as defined in Tab 3).

2.6.2 Unless a temperature gradient calculation is carried out to assess the design temperature and the steel grade in the structural members of the refrigerated spaces, the design temperatures to be considered are specified below:

a) For members within refrigerated spaces:
   - temperature of the space on the uninsulated side, for plating insulated on one side only, either with uninsulated stiffening members (i.e. fitted on the uninsulated side of plating) or with insulated stiffening members (i.e. fitted on the insulated side of plating)
   - mean value of temperatures in the adjacent spaces, for plating insulated on both sides, with insulated stiffening members, when the temperature difference between the adjacent spaces is generally not greater than 10 °C (when the temperature difference between the adjacent spaces is greater than 10°C, the temperature value is established by the Society on a case by case basis)

b) For members adjacent to refrigerated spaces:

   temperature of the non-refrigerated space, conventionally taken equal to 0°C (in such case, the steel grades are to be considered as per [2.4]).

2.6.3 Situations other than those mentioned in [2.6.1] and [2.6.2] or special arrangements will be considered by the Society on a case by case basis.

Table 14 : Material grade requirements for members within or adjacent to refrigerated spaces

Design temperature, in °C	Gross thickness, in mm	Structural member category	
		Secondary	Primary or Special
$-10 \le t_D < 0$	t ≤ 20	B / AH	B / AH
	20 < t ≤ 25	B / AH	D / DH
	t > 25	D / DH	E / EH
$-25 \le t_D < -10$	t ≤ 15	B / AH	D / DH
	15 < t ≤ 25	D / DH	E / EH
	t > 25	E / EH	E / EH
$-40 \le t_D < -25$	t ≤ 25	D / DH	E / EH
	t > 25	E / EH	E / EH

2.6.4 Irrespective of the provisions of [2.6.1], [2.6.2] and Tab 14, steel having grades lower than those required in [2.4], Tab 3 and Tab 9, in relation to the class and gross thickness of the structural member considered, may not be used.

2.7 Through thickness properties

2.7.1 Where normal tensile loads induce out-of-plane stress greater than 0,5 R_y in steel plates:

- for plates with t < 15 mm:

  ultrasonic testing is to be performed
- for plates with t ≥ 15 mm:

  Z-quality steel is to be used or ultrasonic testing is to be performed

in order to prevent laminar tearing.

The above mentioned ultrasonic testing is to be performed, before and after welding, on the area of the plate located within 50 mm or t, whichever is the greater, around the weld, in accordance with NR216 Materials and Welding, Ch 2, Sec 1, [11].

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 NR216 Materials and Welding.

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 NR216 Materials and Welding.

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 NR216 Materials and Welding, the above steels for forging are assigned to class 1 (see NR216 Materials and Welding, Ch 2, Sec 3, [1.2]).

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 requirements of NR216 Materials and Welding, Ch 2, Sec 1, 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 specified minimum tensile strength R_m = 400 N/mm^2 or 440 N/mm^2, in accordance with the applicable requirements of NR216 Materials and Welding, Ch 2, Sec 4.

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 NR216 Materials and Welding, Ch 2, Sec 4, 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 surface and volumetric 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 NR216 Materials and Welding, Ch 3, Sec 2.

Series 5000 aluminium-magnesium alloys or series 6000 aluminium-magnesium-silicon alloys are generally to be used (see NR216 Materials and Welding, Ch 3, Sec 2, [2]).

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 to be agreed by the Society.

4.1.3 Unless otherwise agreed, 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 Mechanical properties of weld joints

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 The as welded properties of aluminium alloys of series 5000 are in general those of condition 0 or H111.

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

4.3.3 The as welded properties of aluminium alloys of series 6000 are to be agreed by the Society.

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 specified yield stress of the parent metal in welded condition $R'_{p0,2}$, in N/mm², but not to be taken greater than 70% of the minimum specified tensile strength of the parent metal in welded condition R'_m , in N/mm²

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

$R'_m = \eta_2 R_m$

$R_{p0,2}$: Minimum specified yield stress, in N/mm², of the parent metal in delivery condition

R_m : Minimum specified tensile stress, in N/mm², of the parent metal in delivery condition.

η_1 and η_2 are given in Tab 15.

Table 15 : 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 16.

Note 1:

$R'_{p0,2}$: Minimum specified yield stress, in N/mm², of material in welded condition (see [4.3])

R'_m : Minimum specified tensile stress, in N/mm², of material in welded condition (see [4.3]).

Table 16 : Aluminium alloys Metallurgical efficiency coefficient β

Aluminium alloy	Temper condition	Gross thickness, in mm	β
6005 A (Open sections)	T5 or T6	t ≤ 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

4.4.2 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.

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.

5 Other materials and products

5.1 General

5.1.1 Other materials and products such as parts made of iron castings, where allowed, products made of copper and copper alloys, rivets, anchors, chain cables, cranes, masts, derrick posts, derricks, accessories and wire ropes are to comply with the applicable requirements of NR216 Materials and Welding.

5.1.2 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 requirements for the acceptance of the materials concerned are to be agreed by the Society.

5.1.3 Materials used in welding processes are to comply with the applicable requirements of NR216 Materials and Welding.

5.2 Iron cast parts

5.2.1 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.

5.2.2 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.

SECTION 2 NET SCANTLING APPROACH

Symbols

t_C : Rule corrosion addition, in mm, see [3]

w_N : Net section modulus, in cm^3, of ordinary stiffeners

w_G : Gross section modulus, in cm^3, of ordinary stiffeners.

1 Application criteria

1.1 General

1.1.1 The scantlings obtained by applying the criteria specified in Part B are net scantlings, i.e. those which provide the strength characteristics required to sustain the loads, excluding any addition for corrosion. Exceptions are the scantlings:

- obtained from the yielding checks of the hull girder in Ch 6, Sec 2
- of bow doors and inner doors in Ch 8, Sec 5
- of side doors and stern doors in Ch 8, Sec 6
- of rudder structures and hull appendages in Part B, Chapter 9
- of massive pieces made of steel forgings, steel castings or iron castings,

which are gross scantlings, i.e. they include additions for corrosion.

1.1.2 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.

1.1.3 The ship is to be built at least with the gross scantlings obtained by adding the corrosion additions, specified in Tab 2, to the net scantlings.

2 Net strength characteristic calculation

2.1 Designer's proposal based on gross scantlings

2.1.1 General criteria

If the Designer provides the gross scantlings of each structural element without providing their corrosion additions, the structural checks are to be carried out on the basis of the net strength characteristics derived as specified in [2.1.2] to [2.1.6].

2.1.2 Plating

The net thickness is to be obtained by deducting t_c from the gross thickness.

2.1.3 Ordinary stiffeners

The net transverse section is to be obtained by deducting t_C from the gross thickness of the elements which constitute the stiffener profile. For bulb profiles, an equivalent angle profile, as specified in Ch 4, Sec 3, [3.1.2], may be considered.

The net strength characteristics are to be calculated for the net transverse section. As an alternative, the net section modulus may be obtained from the following formula:

$$w_N = w_G (1 - \alpha t_C) - \beta t_C$$

where α and β are the coefficients defined in Tab 1.

Table 1 : Coefficients α and β

Type of ordinary stiffeners	α	β
Flat bars	0,035	2,8
Flanged profiles	0,060	14,0
Bulb profiles: $w_G \leq 200$ cm^3 $w_G > 200$ cm^3	 0,070 0,035	 0,4 7,4

2.1.4 Primary supporting members analysed through an isolated beam structural model

The net transverse section is to be obtained by deducting t_C from the gross thickness of the elements which constitute the primary supporting members.

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

2.1.5 Primary supporting members analysed through a three dimensional model or a complete ship model

The net thickness of plating which constitutes primary supporting members is to be obtained by deducting $0,5t_c$ from the gross thickness.

2.1.6 Hull girder net strength characteristics to be used for the check of plating, ordinary stiffeners and primary supporting members

For the hull girder, the net hull transverse sections are to be considered as being constituted by plating and stiffeners having net scantlings calculated on the basis of the corrosion additions t_C, according to [2.1.2] to [2.1.4].

It is to be checked whether:

$$Z_{NA} \geq 0,9\ Z_{GD}$$

where:

Z_{NA} : Net midship section modulus, in m^3, calculated on the basis of the net scantlings obtained considering the corrosion additions t_C according to [2.1.2] to [2.1.4]

Z_{GD} : Gross midship section modulus, in m^3, calculated on the basis of the gross scantlings proposed by the Designer.

Where the above condition is not satisfied, the hull girder normal and shear stresses, to be used for the checks of plating, ordinary stiffeners and primary supporting members analysed through an isolated beam structural model, are to be obtained by dividing by 0,9 those obtained by considering the hull girder transverse sections with their gross scantlings.

2.1.7 Hull girder net strength characteristics to be used for the check of hull girder ultimate strength

For the hull girder, the net hull transverse sections are to be considered as being constituted by plating and stiffeners having net scantlings calculated on the basis of the corrosion additions t_C , according to [2.1.2] to [2.1.4].

It is to be checked whether:

$Z_{NA} \geq 0,9\ Z_{GD}$

where:

Z_{NA} : Net midship section modulus, in m^3, calculated on the basis of the net scantlings obtained considering the corrosion additions t_C according to [2.1.2] to [2.1.4]

Z_{GD} : Gross midship section modulus, in m^3, calculated on the basis of the gross scantlings proposed by the Designer.

Where the above condition is not satisfied, the net scantling of plating and ordinary stiffeners constituting the transverse section are to be calculated on the basis of the corrosion additions ηt_c, where:

η : Coefficient to be calculated so that:

$Z_{NA} = 0,9\ Z_{GD}$

2.2 Designer’s proposal based on net scantlings

2.2.1 Net strength characteristics and corrosion additions

If the Designer provides the net scantlings of each structural element, the structural checks are to be carried out on the basis of the proposed net strength characteristics.

The Designer is also to provide the corrosion additions or the gross scantlings of each structural element. The proposed corrosion additions are to be not less than the values specified in [3].

2.2.2 Hull girder net strength characteristics to be used for the check of plating, ordinary stiffeners and primary supporting members

For the hull girder, the net hull transverse sections are to be considered as being constituted by plating and stiffeners having the net scantlings proposed by the Designer.

It is to be checked whether:

$Z_{NAD} \geq 0,9\ Z_{GD}$

where:

Z_{NAD} : Net midship section modulus, in m^3, calculated on the basis of the net scantlings proposed by the Designer

Z_{GD} : Gross midship section modulus, in m^3, calculated on the basis of the gross scantlings proposed by the Designer.

Where the above condition is not satisfied, the hull girder normal and shear stresses, to be used for the checks of plating, ordinary stiffeners and primary supporting members analysed through an isolated beam structural model, are to be obtained by dividing by 0,9 those obtained by considering the hull girder transverse sections with their gross scantlings.

2.2.3 Hull girder net strength characteristics to be used for the check of hull girder ultimate strength

The hull girder strength characteristic calculation is to be carried out according to [2.1.7] by using the corrosion additions proposed by the Designer in lieu of t_c.

3 Corrosion additions

3.1 Values of corrosion additions

3.1.1 General

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

The Designer may define values of corrosion additions greater than those specified in [3.1.2].

3.1.2 Corrosion additions for steel other than stainless steel

In general, the corrosion addition to be considered for plating forming the boundary between two compartments of different types is equal to:

- for plating with a gross thickness greater than 10 mm, the sum of the values specified in Tab 2 for one side exposure to each compartment
- for plating with a gross thickness less than or equal to 10 mm, the smallest of the following values:
  - 20 % of the gross thickness of the plating
  - sum of the values specified in Tab 2 for one side exposure to each compartment.

For an internal member within a given compartment, or for plating forming the boundary between two compartments of the same type, the corrosion addition to be considered is twice the value specified in Tab 2 for one side exposure to that compartment.

When, according to Tab 2, a structural element is affected by more than one value of corrosion additions (e.g. a side frame in a dry bulk cargo hold extending above the lower zone), the scantling criteria are generally to be applied considering the value of corrosion addition applicable at the lowest point of the element.

3.1.3 Corrosion additions for stainless steel

For structural members made of stainless steel, the corrosion addition t_c is to be taken equal to 0.

3.1.4 Corrosion additions for non-alloyed steel clad with stainless steel

For plates made of non-alloyed steel clad with stainless steel, the corrosion addition t_c is to be taken equal to 0 only for the plate side clad with stainless steel.

3.1.5 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 2 : Corrosion additions t_c , in mm, for each exposed side

Compartment type		General **(1)**	Special cases
Ballast tank **(2)**		1,00	1,25 in upper zone **(7)**
Cargo oil tank and fuel oil tank **(3)**	Plating of horizontal surfaces	0,75	1,00 in upper zone **(7)**
	Plating of non-horizontal surfaces	0,50	1,00 in upper zone **(7)**
	Ordinary stiffeners and primary supporting members	0,75	1,00 in upper zone **(7)**
Independent tank of ships with service notation **liquefied gas carrier** or **LNG bunkering ship** **(4)** Independent gas fuel tanks of ships with the additional service feature **gasfuel** or **dualfuel** **(5)**		0,00	
Cofferdam in cargo area of ships with the service notation **liquefied gas carrier** or **LNG bunkering ship** Cofferdam adjacent to the gas fuel tank on ships with the additional service feature **dualfuel** or **gasfuel**		1,00	
Dry bulk cargo hold **(6)**	General	1,00	
	Inner bottom plating Side plating for single hull ship Inner side plating for double hull ship Sloping stool plate of hopper tanks and lower stool Transverse bulkhead plating	1,75	
	Frames, ordinary stiffeners and primary supporting members	1,00	1,50 in lower zone **(8)**
Tanks for fresh water		0.5	
Tanks dedicated to water-based or oil-based process muds		1.25	
Tanks for drilling brines		1.25	
Moonpool		1.75	
Compartment located between independent tank and inner side of ships with the service notation **asphalt carrier**		1,00	
Hopper well of dredging ships		2,00	
Accommodation space **(9)**		0,00	
Compartments other than those mentioned above **(9)** Outside sea and air		0,50	

(1) General: corrosion additions t_c are applicable to all members of the considered item with possible exceptions given for upper and lower zones.
(2) Ballast tank: does not include cargo oil tanks which may carry ballast according to Regulation 18 of MARPOL 73/78 as amended.
(3) For ships with the service notation **chemical tanker ESP**, the corrosion addition t_C may be taken equal to 0 for cargo tanks covered with a protective lining or coating (see IBC, 6).
(4) The corrosion addition t_C specified for cargo tanks is to be applied when required in Pt D, Ch 9, Sec 4, [2.1.5].
(5) The corrosion addition t_C specified for gas fuel tanks is to be applied when required in NR529, 6.4.1.
(6) Dry bulk cargo hold: includes holds, intended for the carriage of dry bulk cargoes, which may carry oil or water ballast.
(7) Upper zone: area within 1,5 m below the top of the tank. This is to be applied only to tanks with weather deck as the tank top.
(8) Lower zone: area within 3 m above the bottom of the tank or the hold.
(9) When not covered by any sheeting, AC Room, galleys, technical areas and crew staircases are to be considered as "other compartments"

SECTION 3 STRENGTH PRINCIPLES

Symbols

E : Young's modulus, in N/mm², to be taken equal to:
- for steels in general:
  $E = 2{,}06 \cdot 10^5$ N/mm²
- for stainless steels:
  $E = 1{,}95 \cdot 10^5$ N/mm²
- for aluminium alloys:
  $E = 7{,}0 \cdot 10^4$ N/mm²

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

ℓ : Span, in m, of an ordinary stiffener or a primary supporting member, as the case may be, measured between the supporting members (see Fig 2 to Fig 5)

ℓ_b : Length, in m, of brackets (see Fig 4 and Fig 5)

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

w : Net section modulus, in cm³, of an ordinary stiffener or a primary supporting member, as the case may be, with attached plating of width b_p

I : Net moment of inertia, in cm⁴, of an ordinary stiffener or a primary supporting member, as the case may be, with attached plating, around its neutral axis parallel to the plating (see Fig 4 and Fig 5)

1 General principles

1.1 Structural continuity

1.1.1 The variation in scantlings between the midship region and the fore and aft parts is to be gradual.

1.1.2 The structural continuity is to be ensured:

- in way of changes in the framing system
- at the connections of primary or ordinary stiffeners
- in way of the ends of the fore and aft parts (see Ch 8, Sec 1 and Ch 8, Sec 2) and machinery space (see Ch 8, Sec 3)
- in way of ends of superstructures (see Ch 8, Sec 4).

1.1.3 Longitudinal members contributing to the hull girder longitudinal strength, according to Ch 6, Sec 1, [2], are to extend continuously for a sufficient distance towards the ends of the ship and in way of areas with changes in framing system.

Ordinary stiffeners contributing to the hull girder longitudinal strength are generally to be continuous when crossing primary supporting members. Otherwise, the detail of connections is considered by the Society on a case by case basis.

Longitudinals of the bottom, bilge, sheerstrake, deck, upper and lower longitudinal bulkhead and inner side strakes, as well as the latter strakes themselves, the lower strake of the centreline bottom girder and the upper strake of the centreline deck girder, where fitted, are to be continuous through the transverse bulkheads of the cargo area and cofferdams. Alternative solutions may be examined by the Society on a case by case basis, provided they are equally effective.

1.1.4 Where stress concentrations may occur in way of structural discontinuities, adequate compensation and reinforcements are to be provided.

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

Where necessary, the shape of openings is to be specially designed to reduce the stress concentration factors.

Openings are to be generally well rounded with smooth edges.

Generally, the radius of openings corners is to be not less than 50 mm. In way of highly stressed areas, the radius is to be taken as the greater of 50 mm and 8% of the opening width.

1.1.6 Primary supporting members are to be arranged in such a way that they ensure adequate continuity of strength. Abrupt changes in height or in cross-section are to be avoided.

1.2 Connections with higher strength steel

1.2.1 The vertical extent of higher strength steel is to comply with the requirements of Ch 6, Sec 2, [4.5].

1.2.2 When a higher strength steel is adopted at deck, members not contributing to the longitudinal strength and welded on the strength deck (e.g. hatch coamings, strengthening of deck openings) are also generally to be made of the same higher strength steel.

1.3 Connections between steel and aluminium

1.3.1 Any direct contact between steel and aluminium alloy is to be avoided (e.g. by means of zinc or cadmium plating of the steel parts and application of a suitable coating on the corresponding light alloy parts).

1.3.2 Any heterogeneous jointing system is considered by the Society on a case by case basis.

1.3.3 The use of transition joints made of aluminium/steel-clad plates or profiles is considered by the Society on a case by case basis (see NR216 Materials, Ch 3, Sec 2, [4]).

2 Plating

2.1 Insert plates and doublers

2.1.1 A local increase in plating thickness is generally to be achieved through insert plates. Local doublers, which are normally only allowed for temporary repair, may however be accepted by the Society on a case by case basis.

In any case, doublers and insert plates are to be made of materials of a quality at least equal to that of the plates on which they are welded.

2.1.2 Doublers having width, in mm, greater than:

- 20 times their thickness, for thicknesses equal to or less than 15 mm
- 25 times their thickness, for thicknesses greater than 15 mm

are to be fitted with slot welds, to be effected according to Ch 11, Sec 1, [2.6].

2.1.3 When doublers fitted on the outer shell and strength deck within 0,6L amidships are accepted by the Society, their width and thickness are to be such that slot welds are not necessary according to the requirements in [2.1.2]. Outside this area, the possibility of fitting doublers requiring slot welds will be considered by the Society on a case by case basis.

3 Ordinary stiffeners

3.1 General

3.1.1 Stiffener not perpendicular to the attached plating

Where the stiffener is not perpendicular to the attached plating, the actual net section modulus w, in cm^3, and net shear area A_{sh}, in cm^2, and net moment of inertia I, in cm^4, may be obtained, from the following formulae:

$$w = w_0 \sin \varphi_w$$

$$A_{sh} = A_0 \sin \varphi_w$$

$$I = I_0 \sin^2 \varphi_w$$

where:

- w_0 : Actual net section modulus, in cm^3, of the stiffener assumed to be perpendicular to the plating
- A_0 : Actual net shear area, in cm^2, of the stiffener assumed to be perpendicular to the plating
- I_0 : Net moment of inertia, in cm^4, of the stiffener assumed to be perpendicular to the attached plating
- φ_w : Angle, in degree, between the attached plating and the web of the stiffener, measured at mid-span of the stiffener (see Fig 8).

3.1.2 Bulb section: equivalent angle profile

A bulb section may be taken as equivalent to an angle profile.

The dimensions of the equivalent angle profile are to be obtained, in mm, from the following formulae:

$$h_w = h'_w - \frac{h'_w}{9,2} + 2$$

$$t_w = t'_w$$

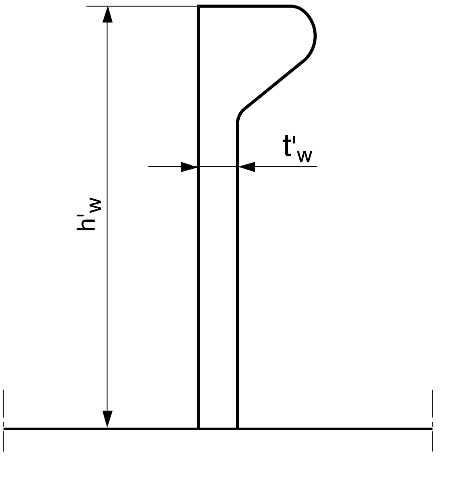
$$b_f = \varphi\left[t'_w + \frac{h'_w}{6,7} - 2\right]$$

$$t_f = \frac{h'_w}{9,2} - 2$$

where:

- h'_w, t'_w : Height and net thickness of the bulb section, in mm, as shown in Fig 1

Figure 1 : Dimensions of a bulb section



φ : Coefficient equal to:

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

$$1 \quad \text{for } h'_w > 120$$

3.2 Span of ordinary stiffeners

3.2.1 General

The span ℓ of ordinary stiffeners is to be measured as shown in Fig 2 to Fig 5.

3.2.2 Ordinary stiffeners connected by struts

The span of ordinary stiffeners connected by one or two struts, dividing the span in equal lengths, may be taken equal to $0,7\ell$.

Figure 2 : Ordinary stiffener without brackets

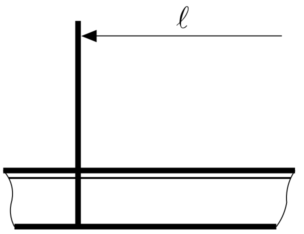


Figure 3 : Ordinary stiffener with a stiffener at one end

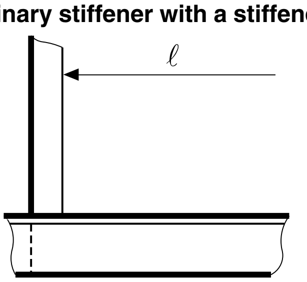


Figure 4 : Ordinary stiffener with end bracket

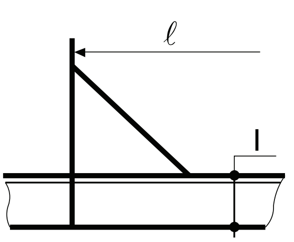
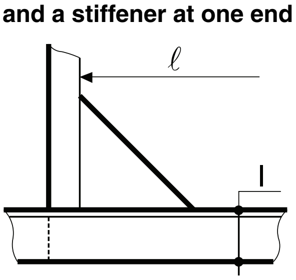


Figure 5 : Ordinary stiffener with a bracket and a stiffener at one end



3.3 Width of attached plating

3.3.1 Yielding check

The width of the attached plating to be considered 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:

  $b_P = s$

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

  $b_P = 0,5s$.

3.3.2 Buckling check and ultimate strength check

The attached plating to be considered for the buckling and ultimate strength check of ordinary stiffeners is defined in Ch 7, Sec 2, [4.1] and Ch 7, Sec 2, [5.2], respectively.

3.4 Geometric properties

3.4.1 Built section

The geometric properties of built sections as shown in Fig 6 may be calculated as indicated in the following formulae.

These formulae are applicable provided that:

$A_a \ge t_f b_f$

$\frac{h_w}{t_p} \ge 10$

$\frac{h_w}{t_f} \ge 10$

where:

A_a : Net sectional area, in mm², of the attached plating.

The net section modulus of a built section with attached plating is to be obtained, in cm³, from the following formula:

$$w = \frac{h_w t_f b_f}{1000} + \frac{t_W h_W^2}{6000}\left(1 + \frac{A_a - t_f b_f}{A_a + \frac{t_W h_W}{2}}\right)$$

The distance from face plate to neutral axis is to be obtained, in cm, from the following formula:

$$v = \frac{h_W(A_a + 0,5 t_W h_W)}{10(A_a + t_f b_f + t_W h_W)}$$

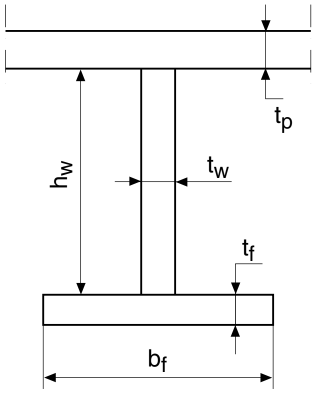
The net moment of inertia of a built section with attached plating is to be obtained, in cm⁴, from the following formula:

$I = w \cdot v$

The net shear sectional area of a built section with attached plating is to be obtained, in cm², from the following formula:

$$A_{Sh} = \frac{h_w t_w}{100}$$

Figure 6 : Dimensions of a built section



3.4.2 Corrugations

The net section modulus of a corrugation is to be obtained, in cm³, from the following formula:

$$w = \frac{td}{6}(3b + c)10^{-3}$$

where:

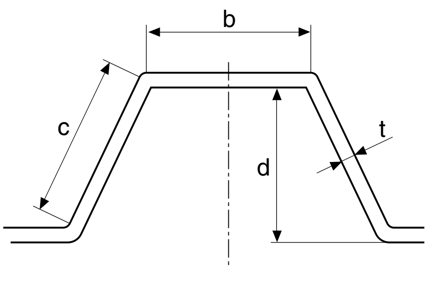
t : Net thickness of the plating of the corrugation, in mm

d, b, c : Dimensions of the corrugation, in mm, shown in Fig 7.

Where the web continuity is not ensured at ends of the bulkhead, the net section modulus of a corrugation is to be obtained, in cm³, from the following formula:

$w = 0,5\ b\ t\ d\ 10^{-3}$

Figure 7 : Dimensions of a corrugation



3.4.3 Plastic section modulus

The actual net effective plastic section modulus Z_{pl} of a transverse or longitudinal ordinary stiffener, in cm³, is given by the formula in item a) or item b), depending on:

- the cross-sectional area of the attached plate A_p
- the net cross-sectional area of the ordinary stiffener: $A_w' + A_f$

where:

A_p : Net cross-sectional area of the attached plate, in cm², taken equal to:

$A_p = 10\ t_p\ s$

A_f : Net cross-sectional area of the stiffener flange, in cm², taken equal to:

$$A_f = \frac{b_f\ t_f}{100}$$

A_w' : Net cross-sectional area of the stiffener web, in cm², taken equal to:

$$A_w' = \frac{h_w\ t_w}{100}$$

a) When $A_p \geq A_w' + A_f$, the plastic neutral axis PNA is assumed to be tangent to the uppermost edge of the attached plate.

$$Z_{pl} = \frac{A_p'\ x_p + A_w'\ x_w + A_f\ x_f}{10}$$

where:

A_p' : Net cross-sectional area of the stiffener, in cm², taken equal to:

$A_p' = A_w' + A_f$

x_p : Distance, in mm, between the centre of gravity of area A_p and PNA, taken equal to:

$$x_p = \text{Min}\left(\frac{A_w' + A_f}{20\ s}\ ;\ \frac{t_p}{2}\right)$$

x_w : Distance, in mm, between the centre of gravity of area A_w' and PNA, taken equal to:

$$x_w = \frac{h_w \sin\varphi_w}{2}$$

x_f : Distance, in mm, between the centre of gravity of area A_f and PNA, taken equal to:

$x_f = h_{fc} \sin\varphi_w - b_w \cos\varphi_w$

h_{fc} : Height, in mm, of the stiffener, measured up to the centre of the flange area, see Fig 8

b_w : Distance, in mm, from the mid-thickness plane of the stiffener web to the centre of the flange area, see Fig 8

φ_w : As defined in [3.1.1].

b) When $A_p < A_w' + A_f$ the plastic neutral axis PNA is located at a distance z_a above the attached plate, in mm, given by:

$$z_a = \frac{(100\,A_f + h_w t_w - 1000\,t_p s)\ \sin\varphi_w}{2\ t_w}$$

$$Z_{pl} = \frac{(A_p x_p + A_{wa} x_{wa} + A_{wb} x_{wb} + A_f x_f)}{10}$$

where:

x_p : Distance, in mm, between the centre of gravity of area A_p and PNA, taken equal to:

$$x_p = z_a + \frac{t_p}{2}$$

A_{wa} : Net cross-sectional area, in cm², of the part of the stiffener located above PNA, taken equal to:

$$A_{wa} = \left(h_w - \frac{z_a}{\sin\varphi_w}\right)\frac{t_w}{100}$$

x_{wa} : Distance, in mm, between the centre of gravity of area A_{wa} and PNA, taken equal to:

$$x_{wa} = \left(h_w - \frac{z_a}{\sin\varphi_w}\right)\frac{\sin\varphi_w}{2}$$

A_{wb} : Net cross-sectional area, in cm², of the part of ordinary stiffener located below the PNA, taken equal to:

$$A_{wb} = \frac{t_w\ z_a}{100\ \sin\varphi_w}$$

x_{wb} : Distance, in mm, between the centre of gravity of area A_{wb} and PNA, taken equal to:

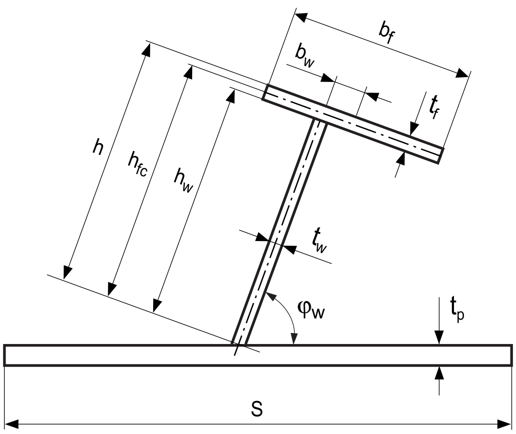
$$x_{wb} = \frac{z_a}{2}$$

x_f : Distance, in mm, between the centre of gravity of area A_f and PNA, taken equal to:

$$x_f = h_{fc} \sin \varphi_w - b_w \cos \varphi_w - z_a$$

φ_w : As defined in [3.1.1].

Figure 8 : Dimensions of a built section



3.5 End connections

3.5.1 Where ordinary stiffeners are continuous through primary supporting members, they are to be connected to the web plating so as to ensure proper transmission of loads, e.g. by means of one of the connection details shown in Fig 9 to Fig 12.

Connection details other than those shown in Fig 9 to Fig 12 may be considered by the Society on a case by case basis. In some cases, the Society may require the details to be supported by direct calculations submitted for review.

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

The net thickness of brackets is to be not less than that of ordinary stiffeners. Brackets with net thickness, in mm, less than $15L_b$, where L_b is the length, in m, of the free edge of the end bracket, are to be flanged or stiffened by a welded face plate. The net sectional area, in cm², of the flanged edge or face plate is to be at least equal to $10\ L_b$.

3.5.3 Where necessary, the Society may require backing brackets to be fitted, as shown in Fig 13, in order to improve the fatigue strength of the connection (see also [4.7.4]).

Figure 9 : End connection of ordinary stiffener Without collar plate

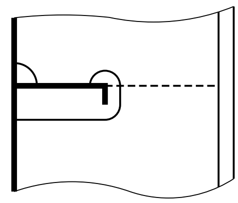


Figure 10 : End connection of ordinary stiffener Collar plate

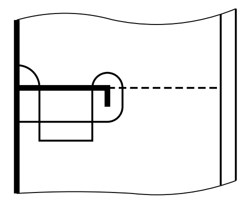


Figure 11 : End connection of ordinary stiffener One large collar plate

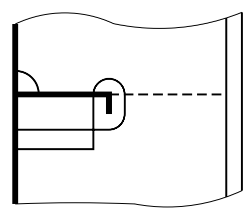


Figure 12 : End connection of ordinary stiffener Two large collar plates

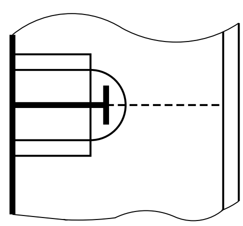
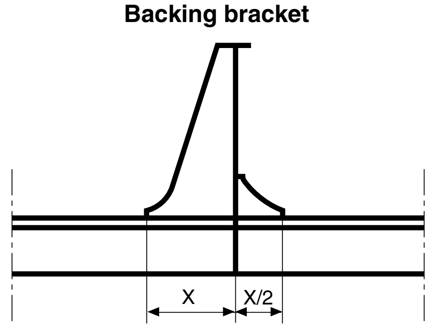


Figure 13 : End connection of ordinary stiffener Backing bracket



4 Primary supporting members

4.1 Span of primary supporting members

4.1.1 The span of primary supporting members is to be determined in accordance with [3.2].

4.2 Width of attached plating

4.2.1 General

The width of the attached plating to be considered for the yielding check of primary supporting members analysed through beam structural models is to be obtained, in m, from the following formulae:

- where the plating extends on both sides of the primary supporting member:

  $b_P = \min(s; 0{,}2\ell)$

- where the plating extends on one side of the primary supporting member (i.e. primary supporting members bounding openings):

  $b_P = 0{,}5 \min(s; 0{,}2\ell)$

4.2.2 Corrugated bulkheads

The width of attached plating of corrugated bulkhead primary supporting members is to be determined as follows:

- when primary supporting members are parallel to the corrugations and are welded to the corrugation flanges, the width of the attached plating is to be calculated in accordance with [4.2.1] and is to be taken not greater than the corrugation flange width
- when primary supporting members are perpendicular to the corrugations, the width of the attached plating is to be taken equal to the width of the primary supporting member face plate.

4.3 Geometric properties

4.3.1 Standard roll sections

The geometric properties of primary supporting members made of standard roll sections may be determined in accordance with [3.4.1], reducing the web height h_w by the depth of the cut-out for the passage of ordinary stiffeners, if any (see [4.6.1]).

4.3.2 Built sections

The geometric properties of primary supporting members made of built sections (including primary supporting members of double skin structures, such as double bottom floors and girders) are generally determined in accordance with [3.4.1], reducing the web height h_w by the depth of the cut-out for the passage of ordinary stiffeners, if any (see [4.6.1]).

Additional requirements relevant to the net shear sectional area are provided in [4.3.3].

4.3.3 Net shear sectional area in the case of web large openings

Where large openings are fitted in the web of primary supporting members (e.g. where a pipe tunnel is fitted in the double bottom, see Fig 14), their influence is to be taken into account by assigning an equivalent net shear sectional area to the primary supporting member.

This equivalent net shear sectional area is to be obtained, in cm², from the following formula:

$$A_{Sh} = \frac{A_{Sh1}}{1 + \dfrac{0{,}0032\,\ell^2 A_{Sh1}}{I_1}} + \frac{A_{Sh2}}{1 + \dfrac{0{,}0032\,\ell^2 A_{Sh2}}{I_2}}$$

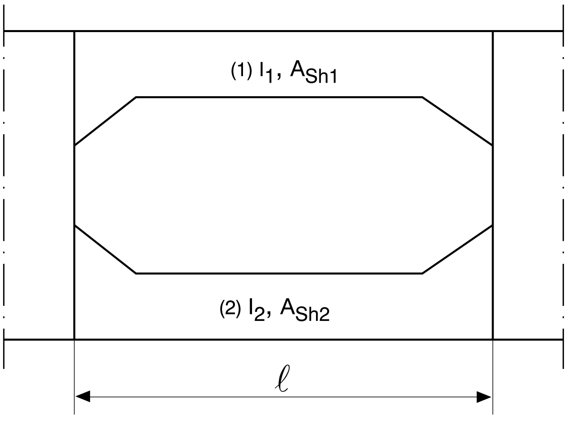
where (see Fig 14):

I_1, I_2 : Net moments of inertia, in cm⁴, 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 cm², 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



4.4 Bracketed end connections

4.4.1 General

Brackets or equivalent structure are to be provided at ends of primary supporting members.

End brackets are generally to be soft-toed.

Bracketless connections may be applied according to [4.5] provided that there is adequate support of adjoining face plates.

4.4.2 Scantling of end brackets

In general, with the exception of primary supporting members of transversely framed single sides (see Ch 4, Sec 5, [3.2]), the arm length of brackets connecting PSMs, as shown in Fig 15, is not to be less than the web depth of the member, and need not be taken greater than 1,5 times the web depth.

In general, the bracket thickness is not to be less than the thickness of the adjoining primary supporting member web plate.

The scantling of the end brackets is to be such that the section modulus of the primary supporting member with end bracket, excluding face plate where it is sniped, is not less than the section modulus of the primary supporting member at mid-span.

The net cross-sectional area A_f, in cm², of bracket face plates is to be such that:

$A_f \geq \ell_b \, t_b$

where:

ℓ_b : Length of the bracket edge, in m (see Fig 15). For curved brackets, the length of the bracket edge may be taken as the length of the tangent at the midpoint of the edge

t_b : Minimum net bracket web thickness, in mm:

$$t_b \geq (2 + 0,2\sqrt{w})\sqrt{\frac{R_{eH,S}}{R_{eH,B}}}$$

with:

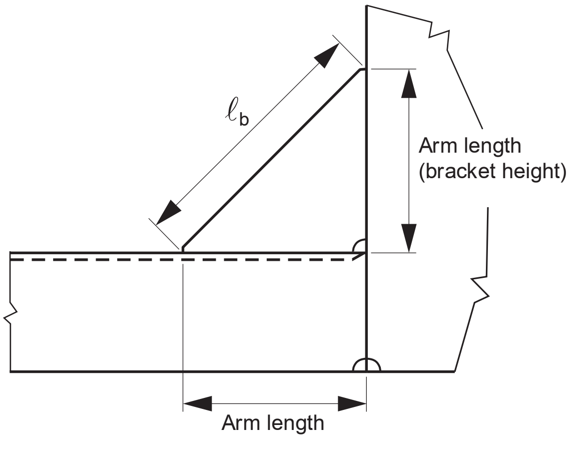
w : Net required section modulus of the primary supporting member, in cm³.

$R_{eH,S}$: Minimum yield stress, in N/mm², of the stiffener material.

$R_{eH,B}$: Minimum yield stress, in N/mm², of the bracket material.

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

Figure 15 : Bracket dimensions



4.4.3 Arrangement of end brackets

Where length ℓ_b of the bracket free edge is greater than 1,5 m, the web of the bracket is to be stiffened as follows:

- the net sectional area, in cm², of stiffener webs is not to be less than 16,5 ℓ, where ℓ is the span, in m, of the stiffener
- tripping flat bars are to be fitted. Where the width of the symmetrical face plate is greater than 400 mm, additional backing brackets are to be provided.

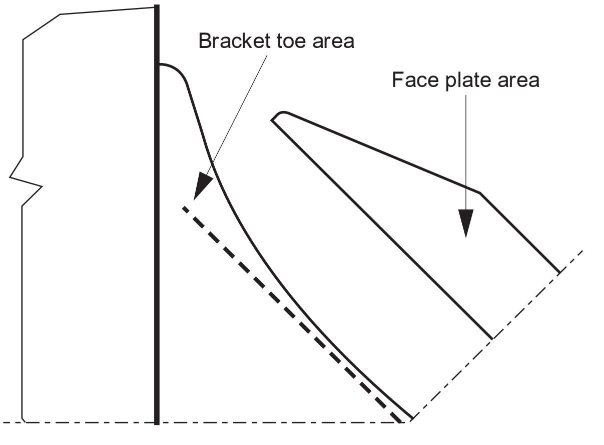
For a ring system, where the end bracket is integral with the web of the members and the face plate is welded continuously onto the edge of the members and the bracket, the full area of the larger face plate is to be maintained close to the mid-point of the bracket and gradually tapered to the smaller face plate. Butts in face plates are to be kept well clear of the bracket toes.

Where a wide face plate abuts a narrower one, the taper is not to be greater than 1 to 4.

The bracket toes are not to land on unstiffened plating. The toe height is not to be greater than the thickness of the bracket toe, but need not be less than 15 mm. In general, the end brackets of primary supporting members are to be soft-toed. Where primary supporting members are constructed of steel having a strength higher than the strength of the bracket steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations.

Where a face plate is welded onto, or adjacent to, the edge of the end bracket (see Fig 16), the face plate is to be sniped and tapered at an angle not greater than 30°.

Figure 16 : Bracket face plate adjacent to the edge



Note: The details shown in this Figure are only used to illustrate items described in the text and are not intended to represent a design guidance or recommendations.

4.4.4 Requirements for symmetrical face plates

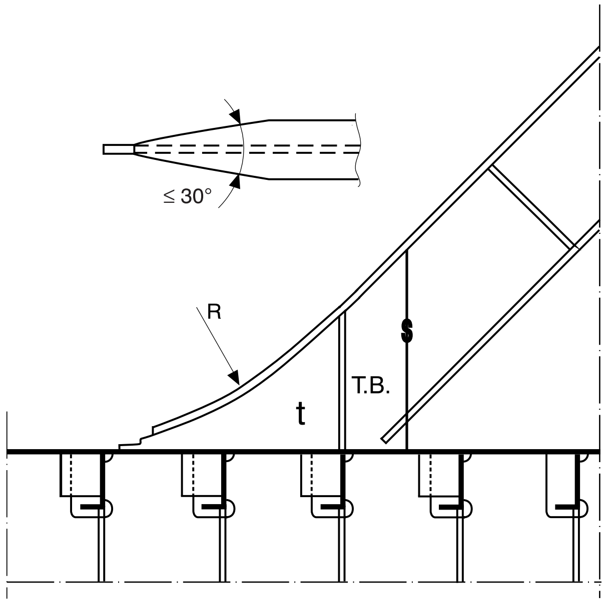
Where face plates of end connecting brackets are symmetrical, the following requirements are in general to be complied with:

- face plates are to be tapered at ends with a total angle not greater than 30°
- the breath of face plates at ends is not to be greater than 25 mm
- face plates of 20 mm thick and above are to be tapered in thickness at their ends down to their mid-thickness
- bracket toes are to be of increased thickness
- an additional tripping bracket is to be fitted
- the radius R of the face plate is to be as large as possible
- collar plates welded to the plating are to be fitted in way of the bracket toes
- throat thickness of fillet welds is not to be less than t/2, with t being the thickness of the bracket toe.

An example of bracket with symmetrical face plate is indicated in Fig 17.

4.4.5 In addition, the net scantling of end brackets is to comply with the applicable requirements given from Ch 4, Sec 4 to Ch 4, Sec 7.

Figure 17 : Bracket with symmetrical face plate



4.5 Bracketless end connections

4.5.1 In the case of bracketless crossing between two primary supporting members (see Fig 18), the net thickness of the common part of the webs, in mm, is to be not less than the greatest value obtained from the following formula:

$$t_b = \frac{\gamma_R \gamma_m Sf_1 \sigma_1}{0,5 h_2 R_y}$$

$$t_b = \frac{\gamma_R \gamma_m Sf_2 \sigma_2}{0,5 h_1 R_y}$$

t_b = max (t_1 , t_2)

where:

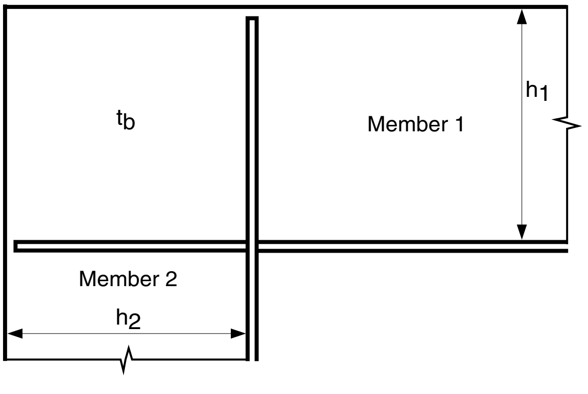
γ_R, γ_m : Partial safety factors as defined in Ch 7, Sec 3, [1.4]

Sf_1, Sf_2 : Net flange section, in mm^2,of member 1 and member 2 respectively

σ_1, σ_2 : Normal stresses, in N/mm^2 , in member 1 and member 2 respectively

t_1, t_2 : Net web thicknesses, in mm, of member 1 and member 2 respectively

Figure 18 : Bracketless end connections between two primary supporting members



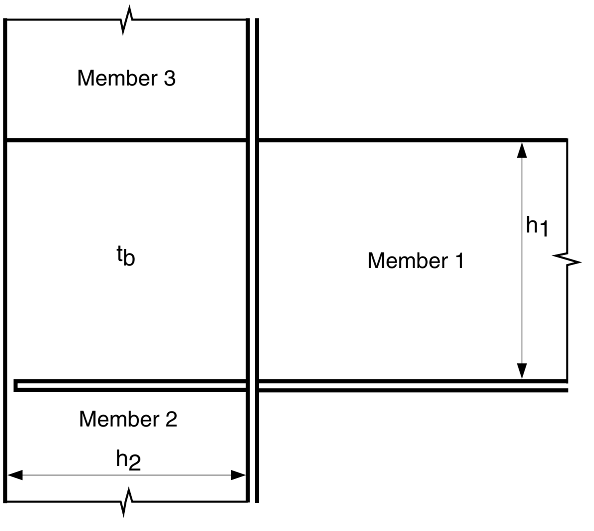
4.5.2 In the case of bracketless crossing between three primary supporting members (see Fig 19), when the flange of member 2 and member 3 is continuous, the net thickness, in mm, of the common part of the webs is not to be less than the greater of:

$$t_b = \frac{\gamma_R \gamma_m Sf_1 \sigma_1}{0,5 h_2 R_y}$$

t_b = max (t_1 , t_2)

When the flanges of member 2 and member 3 are not continuous, the net thickness of the common part of the webs is to be defined as [4.5.1].

Figure 19 : Bracketless end connections between three primary supporting members



4.5.3 The common part of the webs is to be generally stiffened where the minimum height of the member 1 and member 2 is greater than $100t_b$.

4.5.4 When lamellar tearing of flanges may occur, the flange in way of the connection may be requested to be of Z quality or a 100% ultrasonic testing of the flange in way of the weld may be required prior to and after welding.

4.6 Cut-outs and holes

4.6.1 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.

4.6.2 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.

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

4.6.4 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.

4.6.5 In the case of large openings as shown in Fig 20, the secondary stresses in primary supporting members are to be considered for the reinforcement of the openings.

The secondary stresses may be calculated in accordance with the following procedure.

Members (1) and (2) are subjected to the following forces, moments and stresses:

$$F = \frac{M_A + M_B}{2d}$$

$$m_1 = \left|\frac{M_A - M_B}{2}\right| K_1$$

$$m_2 = \left|\frac{M_A - M_B}{2}\right| K_2$$

$$\sigma_{F1} = 10\frac{F}{S_1}$$

$$\sigma_{F2} = 10\frac{F}{S_2}$$

$$\sigma_{m1} = \frac{m_1}{w_1}10^3$$

$$\sigma_{m2} = \frac{m_2}{w_2}10^3$$

$$\tau_1 = 10\frac{K_1 Q_T}{S_{w1}}$$

$$\tau_2 = 10\frac{K_2 Q_T}{S_{w2}}$$

where:

- M_A, M_B : Bending moments, in kN.m, in sections A and B of the primary supporting member
- m_1, m_2 : Bending moments, in kN.m, in (1) and (2)
- d : Distance, in m, between the neutral axes of (1) and (2)
- σ_{F1}, σ_{F2} : Axial stresses, in N/mm², in (1) and (2)
- σ_{m1}, σ_{m2} : Bending stresses, in N/mm², in (1) and (2)
- Q_T : Shear force, in kN, equal to Q_A or Q_B, whichever is greater
- τ_1, τ_2 : Shear stresses, in N/mm², in (1) and (2)
- w_1, w_2 : Net section moduli, in cm³, of (1) and (2)
- S_1, S_2 : Net sectional areas, in cm², of (1) and (2)
- S_{w1}, S_{w2} : Net sectional areas, in cm², of webs in (1) and (2)
- I_1, I_2 : Net moments of inertia, in cm⁴, of (1) and (2) with attached plating

$$K_1 = \frac{I_1}{I_1 + I_2}$$

$$K_2 = \frac{I_2}{I_1 + I_2}$$

The combined stress σ_C calculated at the ends of members (1) and (2) is to be obtained from the following formula:

$$\sigma_c = \sqrt{(\sigma_F + \sigma_m)^2 + 3\tau^2}$$

The combined stress σ_C is to comply with the checking criteria in Ch 7, Sec 3, [3.6] or Ch 7, Sec 3, [4.4], as applicable. Where these checking criteria are not complied with, the cut-out is to be reinforced according to one of the solutions shown in Fig 21 to Fig 23:

- continuous face plate (solution 1): see Fig 21
- straight face plate (solution 2): see Fig 22
- compensation of the opening (solution 3): see Fig 23
- combination of the above solutions.

Other arrangements may be accepted provided they are supported by direct calculations submitted to the Society for review.

Figure 20 : Large openings in primary supporting members - Secondary stresses

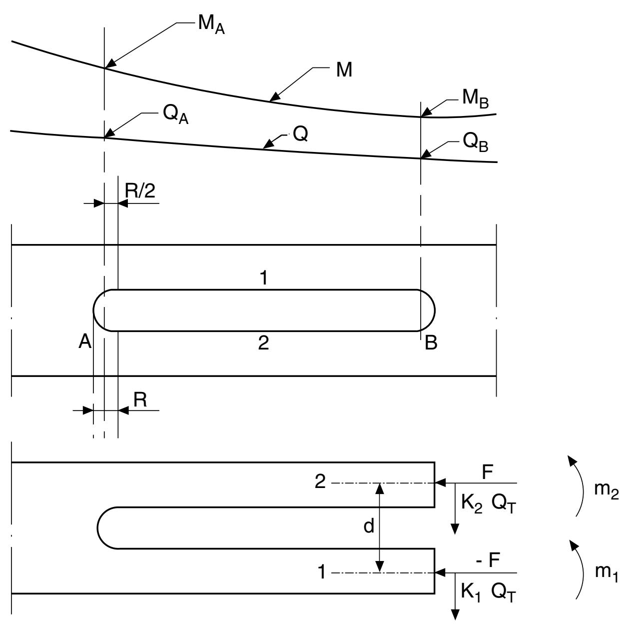


Figure 21 : Stiffening of large openings in primary supporting members - Solution 1

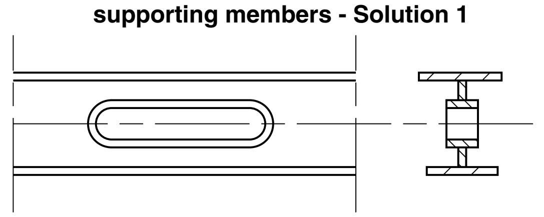


Figure 22 : Stiffening of large openings in primary supporting members - Solution 2

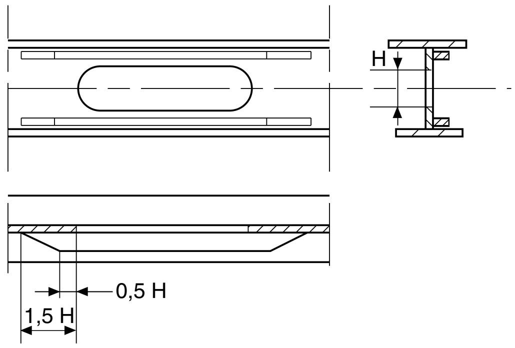
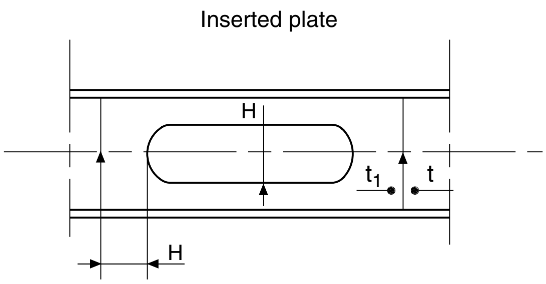


Figure 23 : Stiffening of large openings in primary supporting members - Solution 3



4.7 Stiffening arrangement

4.7.1 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.

4.7.2 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:

$$A = 0{,}1 k_1 (\gamma_{S2} p_S + \gamma_{W2} p_W) s \ell$$

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 Fig 9)
- k_1 = 0,225 for connections with a collar plate (see Fig 10)
- k_1 = 0,20 for connections with one or two large collar plates (see Fig 11 and Fig 12)

p_S, p_W : Still water and wave pressure, respectively, in kN/m², acting on the ordinary stiffener, defined in Ch 7, Sec 2, [3.3.2]

γ_{S2}, γ_{W2} : Partial safety factors, defined in Ch 7, Sec 2, Tab 1 for yielding check (general)

ℓ : Span of ordinary stiffeners, in m

s : Spacing of ordinary stiffeners, in m.

4.7.3 The net moment of inertia, I, of the web stiffeners of primary supporting members is not to be less than the value obtained, in cm⁴, from the following formula:

- for web stiffeners parallel to the flange of the primary supporting members (see Fig 24):

$$I = C \ell^2 A \frac{R_{eH}}{235}$$

- for web stiffeners normal to the flange of the primary supporting members (see Fig 25):

$$I = 11{,}4\, s t_w (2{,}5\, \ell^2 - 2 s^2) \frac{R_{eH}}{235}$$

where:

C : Slenderness coefficient to be taken as:

- C = 1,43 for longitudinal web stiffeners including sniped stiffeners
- C = 0,72 for other web stiffeners

ℓ : Length, in m, of the web stiffener

s : Spacing, in m, of web stiffeners

t_w : Web net thickness, in mm, of the primary supporting member

A : Net section area, in cm², of the web stiffener, including attached plate assuming effective breadth of 80% of stiffener spacing s

R_{eH} : Minimum specified yield stress of the material of the web plate of primary supporting member.

Figure 24 : Web stiffeners parallel to the flange

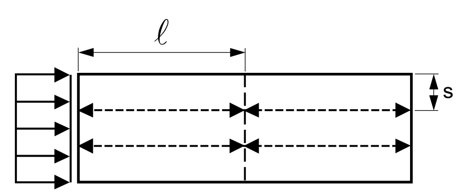
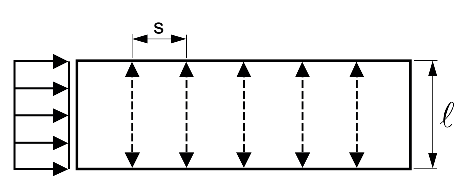


Figure 25 : Web stiffeners normal to the flange



4.7.4 Tripping brackets (see Fig 26) welded to the face plate are generally to be fitted:

- 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.

4.7.5 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 [4.7.4].

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

$$d = 0,38b$$

$$d = 0,85b\sqrt{\frac{s_t}{t}}$$

where:

- b : Height, in m, of tripping brackets, shown in Fig 26
- s_t : Spacing, in m, of tripping brackets
- t : Net thickness, in mm, of tripping brackets.

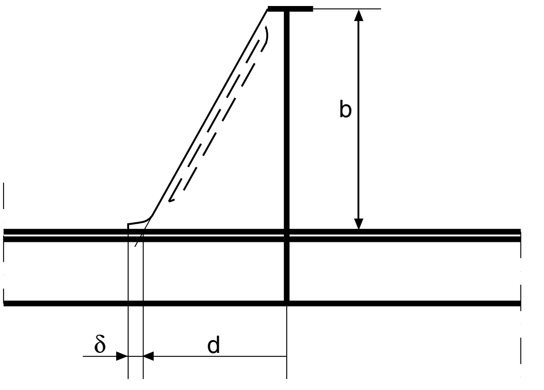
It is recommended that the bracket toe should be designed as shown in Fig 26.

4.7.7 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.

Figure 26 : Tripping bracket



SECTION 4 BOTTOM STRUCTURE

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinally or transversely framed single and double bottom structures.

1.2 General arrangement

1.2.1 In ships greater than 120 m in length, the bottom is, in general, to be longitudinally framed.

1.2.2 The bottom structure is to be checked by the Designer to make sure that it withstands the loads resulting from the dry-docking of the ship.

1.2.3 The bottom is to be locally stiffened where concentrated loads are envisaged.

1.2.4 Girders or floors are to be fitted under each line of pillars, when deemed necessary by the Society on the basis of the loads carried by the pillars.

1.2.5 Adequate tapering is to be provided between double bottom and adjacent single bottom structures. Similarly, adequate continuity is to be provided in the case of height variation in the double bottom. 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.

1.2.6 Provision is to be made for the free passage of water from all parts of the bottom to the suctions, taking into account the pumping rate required.

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

1.3 Keel

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

$$b = 0,8 + 0,5\frac{L}{100}$$

1.4 Drainage and openings for air passage

1.4.1 Holes are to be cut into floors and girders to ensure the free passage of air and liquids from all parts of the double bottom.

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

2 Longitudinally framed single bottom

2.1 General

2.1.1 Single bottom ships are to be fitted with a centre girder formed by a vertical continuous or intercostal web plate and a horizontal face plate continuous over the floors.

Intercostal web plates are to be aligned and welded to floors.

2.1.2 In general, girders are to be fitted spaced not more than 2,5 m apart and formed by a vertical intercostal web plate and a horizontal face plate continuous over the floors.

Intercostal web plates are to be aligned and welded to floors.

2.1.3 Centre and side girders are to be extended as far aft and forward as practicable.

2.1.4 Where side girders are fitted in lieu of the centre girder, the scarfing is to be adequately extended and additional stiffening of the centre bottom may be required.

2.1.5 Longitudinal girders are to be fitted in way of each line of pillars.

2.1.6 Floors are to be made with a welded face plate between the collision bulkhead and 0,25L from the fore end.

2.2 Floors

2.2.1 In general, the floor spacing is to be not greater than 5 frame spacings.

2.3 Longitudinal ordinary stiffeners

2.3.1 Longitudinal ordinary stiffeners are generally to be continuous when crossing primary members.

3 Transversely framed single bottom

3.1 General

3.1.1 The requirements in [2.1] apply also to transversely framed single bottoms.

3.2 Floors

3.2.1 Floors are to be fitted at every frame.

3.2.2 The height, in m, of floors at the centreline is to be not less than $\ell/16$. In the case of ships with considerable rise of floor, this height may be required to be increased so as to assure a satisfactory connection to the frames.

4 Longitudinally framed double bottom

4.1 General

4.1.1 The centre girder is to be continuous and extended over the full length of ship and the spacing of adjacent longitudinal girders is generally to be not greater than 6,5 m.

4.2 Double bottom height

4.2.1 The double bottom height is given in Ch 2, Sec 2, [3].

4.3 Floors

4.3.1 The spacing of plate floors, in m, is generally to be not greater than 0,05L or 3,8 m, whichever is the lesser.

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

4.3.2 Plate floors are generally to be provided with stiffeners in way of longitudinal ordinary stiffeners.

4.3.3 Where the double bottom height exceeds 0,9 m, watertight floors are to be fitted with stiffeners having a net section modulus not less than that required for tank bulkhead vertical stiffeners.

4.4 Bottom and inner bottom longitudinal ordinary stiffeners

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

4.5 Brackets to centreline girder and margin plate

4.5.1 In general, intermediate brackets are to be fitted connecting either the margin plate or the centre girder to the nearest bottom and inner bottom ordinary stiffeners.

4.5.2 Such brackets are to be stiffened at the edge with a flange having a width not less than 1/10 of the local double bottom height.

If necessary, the Society may require a welded flat bar to be arranged in lieu of the flange.

4.5.3 Where the side shell is transversely stiffened, margin plate brackets are to be fitted at every frame.

4.6 Duct keel

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

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

4.7 Bilge wells

4.7.1 Bilge wells arranged in the double bottom are to be limited in depth and formed by steel plates having a net thickness not less than the greater of that required for watertight floors and that required for the inner bottom.

4.7.2 In ships for which damage stability requirements are to comply with, such bilge wells are to be fitted so that the distance of their bottom from the shell plating is not less than 460 mm.

4.7.3 Where there is no margin plate, well arrangement is considered by the Society on a case by case basis.

5 Transversely framed double bottom

5.1 General

5.1.1 The requirements in [4.1], [4.2], [4.5], [4.6] and [4.7] apply also to transversely framed double bottoms.

5.2 Floors

5.2.1 Plate floors are to be fitted at every frame forward of 0,75L from the aft end.

Plate floors are also to be fitted:

- in way of transverse watertight bulkheads
- in way of double bottom steps.

Elsewhere, plate floors may be arranged at a distance not exceeding 3 m.

5.2.2 In general, plate floors are to be continuous between the centre girder and the margin plate.

5.2.3 Open floors are to be fitted in way of intermediate frames.

5.2.4 Where the double bottom height exceeds 0,9 m, plate floors are to be fitted with vertical stiffeners spaced not more than 1,5 m apart.

These stiffeners may consist of flat bars with a width equal to one tenth of the floor depth and a net thickness, in mm, not less than $0,8\ L^{0,5}$.

5.3 Girders

5.3.1 Side girders are to be arranged in such a way that their distance to adjacent girders or margin plate does not generally exceed 4,5 m.

5.3.2 Where the double bottom height exceeds 0,9 m, longitudinal girders are to be fitted with vertical stiffeners spaced not more than 1,5 m apart.

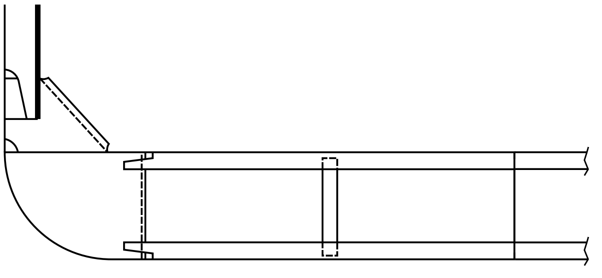
These stiffeners may consist of flat bars with a width equal to one tenth of the girder height and a net thickness, in mm, not less than $0,8L^{0,5}$.

5.3.3 In way of open floors, side girders are to be provided with stiffeners having a web height which is generally to be not less than 150 mm.

5.4 Open floors

5.4.1 At each frame between plate floors, open floors are to be arranged consisting of a frame connected to the bottom plating and a reverse frame connected to the inner bottom plating (See Fig 1).

Figure 1 : Open floor



5.4.2 Open floors are to be attached to the centreline girder and to the margin plate by means of flanged brackets having a width of flange not less than 1/10 of the local double bottom height.

5.4.3 Where frames and reverse frames are interrupted in way of girders, double brackets are to be fitted.

6 Bilge keel

6.1 Arrangement, scantlings and connections

6.1.1 Arrangement

Bilge keels may not be welded directly on the shell plating. An intermediate flat, or doubler, is required on the shell plating.

The ends of the bilge keel are to be sniped at an angle of 15° or rounded with large radius. They are to be located in way of a transverse bilge stiffener. The ends of the intermediate flat are to be sniped at an angle of 15°.

In general, scallops and cut-outs are not to be used. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of the hole is to be greater than the width W of the butt weld and is to be a minimum of 25 mm (see Fig 2). Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

The arrangement shown in Fig 2 is recommended.

The arrangement shown in Fig 3 may also be accepted.

6.1.2 Materials

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.

6.1.3 Scantlings

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.

6.1.4 Welding

Welding of bilge keel and intermediate plate connections is to be in accordance with Ch 11, Sec 1, [3.2].

Figure 2 : Bilge keel arrangement

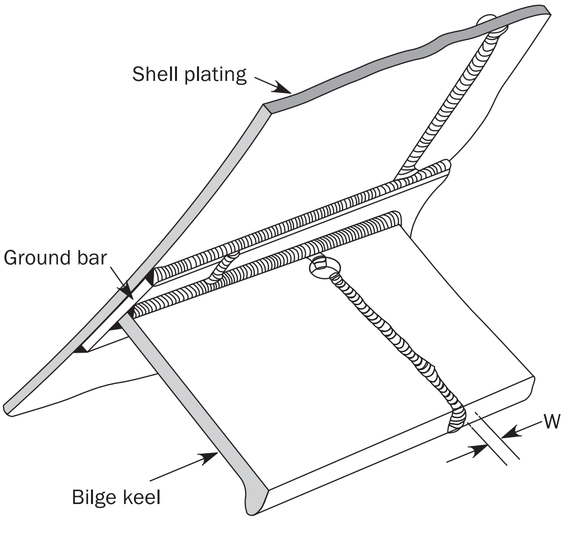
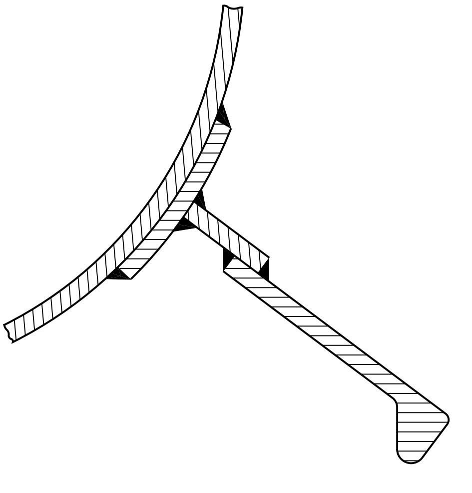


Figure 3 : Bilge keel alternative arrangement



SECTION 5 SIDE STRUCTURE

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinally or transversely framed single and double side structures.

1.1.2 The transversely framed side structures are built with transverse frames possibly supported by side girders (see [5.3.1]).

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

1.2 General arrangement

1.2.1 Unless otherwise specified, side girders are to be fitted aft of the collision bulkhead up to 0,2L aft of the fore end, in line with fore peak girders.

1.2.2 Side vertical primary supporting members are to be fitted in way of hatch end beams.

1.3 Sheerstrake

1.3.1 The width of the sheerstrake, in m, is to be not less than 0,8 + L / 200, measured vertically, but need not be greater than 1,8 m.

1.3.2 The sheerstrake may be either welded to the stringer plate or rounded. If the sheerstrake is rounded, its radius, in mm, is to be not less than 17 ts , where ts is its net thickness, in mm.

1.3.3 The upper edge of the welded sheerstrake is to be rounded, smooth, and free of notches. Fixtures, such as bulwarks and eye plates, are not to be directly welded on the upper edge of the sheerstrake, except in fore and aft parts. Drainage openings with a smooth transition in the longitudinal direction may be permitted.

1.3.4 The transition from a rounded sheerstrake to an angled sheerstrake associated with the arrangement of the superstructures is to be designed to avoid any discontinuities.

Drawings showing the details of this transition are to be submitted for approval to the Society.

1.3.5 The longitudinal seam welds of a rounded sheerstrake are to be located outside the bent area, at a distance not less than 5 times the maximum net thickness of the sheerstrake.

1.3.6 The welding of deck fittings onto rounded sheerstrakes is to be avoided within 0,6 L amidships.

2 Longitudinally framed single side

2.1 Longitudinal ordinary stiffeners

2.1.1 Longitudinal ordinary stiffeners are generally to be continuous when crossing primary members.

2.2 Primary supporting members

2.2.1 In general, the side vertical primary supporting member spacing may not exceed 5 frame spacings.

2.2.2 In general, the side vertical primary supporting members are to be bracketed to the double bottom transverse floors.

3 Transversely framed single side

3.1 Frames

3.1.1 Transverse frames are to be fitted at every frame.

3.1.2 Frames are generally to be continuous when crossing primary members.

Otherwise, the detail of the connection is to be examined by the Society on a case by case basis.

3.1.3 In general, the net section modulus of ‘tween deck frames is to be not less than that required for frames located immediately above.

3.2 Primary supporting members

3.2.1 In 'tweendecks of more than 4 m in height, side girders or side vertical primary supporting members or both may be required by the Society.

3.2.2 Side girders are to be flanged or stiffened by a welded face plate.

The width of the flanged edge or face plate is to be not less than 22t, where t is the web net thickness, in mm, of the girder.

3.2.3 The height of end brackets is to be not less than half the height of the primary supporting member.

4 Longitudinally framed double side

4.1 General

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

In particular, scarfing of the inner side is to be ensured beyond the cargo hold region.

4.1.2 Knuckles of the inner side are to be adequately stiffened.

4.2 Primary supporting members

4.2.1 The height of side vertical primary supporting members may be gradually tapered from bottom to deck. The maximum acceptable taper, however, is 8 cm per metre.

4.2.2 Side vertical primary supporting members supported by a strut and two diagonals converging on the former are to be considered by the Society on a case by case basis.

5 Transversely framed double side

5.1 General

5.1.1 The requirements in [4.1] also apply to transversely framed double side.

5.1.2 Transverse frames may be connected to the vertical ordinary stiffeners of the inner side by means of struts.

Struts are generally to be connected to transverse frames and vertical ordinary stiffeners of the inner side by means of vertical brackets.

5.2 Frames

5.2.1 Transverse frames are to be fitted at every frame.

5.3 Primary supporting members

5.3.1 Unless otherwise specified, transverse frames are to be supported by side girders if $D \geq 6$ m.

These girders are to be supported by side vertical primary supporting members spaced no more than 3,8 m apart.

5.3.2 In the case of ships having $4,5 < D < 6$ m, side vertical primary supporting members are to be fitted, in general not more than 5 frame spacings apart.

6 Frame connections

6.1 General

6.1.1 End connections of frames are to be bracketed.

6.1.2 'Tweendeck frames are to be bracketed at the top and welded or bracketed at the bottom to the deck.

In the case of bulb profiles, a bracket may be required to be fitted at bottom.

6.1.3 Brackets are normally connected to frames by lap welds. The length of overlap is to be not less than the depth of frames.

6.2 Upper brackets of frames

6.2.1 The arm length of upper brackets connecting frames to deck beams is to be not less than the value obtained, in mm, from the following formula:

$$d = \varphi \sqrt{\frac{w + 30}{t}}$$

where:

φ : Coefficient equal to:
- for unflanged brackets:
  $\varphi = 48$
- for flanged brackets:
  $\varphi = 43,5$

w : Required net section modulus of the stiffener, in cm^3, given in [6.2.2] and [6.2.3] and depending on the type of connection

t : Bracket net thickness, in mm.

6.2.2 For connections of perpendicular stiffeners located in the same plane (see Fig 1) or connections of stiffeners located in perpendicular planes (see Fig 2), the required net section modulus is to be taken equal to:

$w = w_2$ if $w_2 \leq w_1$

$w = w_1$ if $w_2 > w_1$

where w_1 and w_2 are the required net section moduli of stiffeners, as shown in Fig 1 and Fig 2.

Figure 1 : Connections of perpendicular stiffeners in the same plane

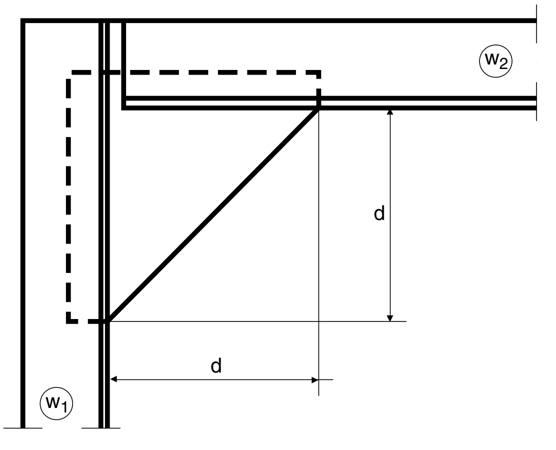
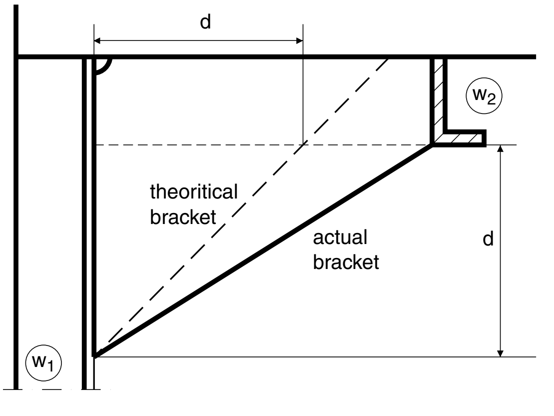


Figure 2 : Connections of stiffeners located in perpendicular planes



6.2.3 For connections of frames to deck beams (see Fig 3), the required net section modulus is to be taken equal to:

- for bracket "A":

  $w_A = w_1$ if $w_2 \le w_1$

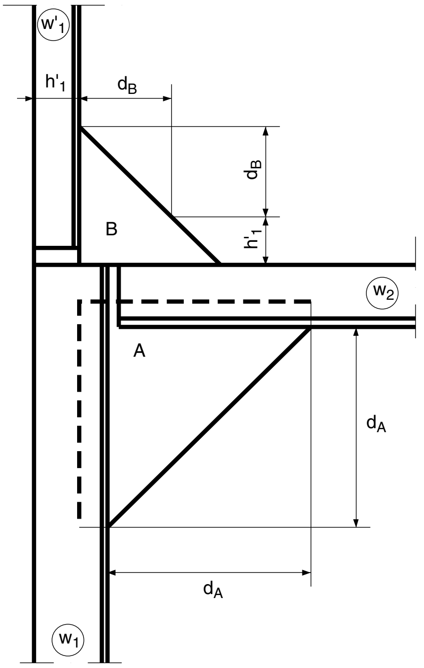
  $w_A = w_2$ if $w_2 > w_1$

- for bracket "B":

  $w_B = w'_1$ need not be greater than w_1 ,

where w_1 , w'_1 and w_2 are the required net section moduli of stiffeners, as shown in Fig 3.

Figure 3 : Connections of frames to deck beams



6.3 Lower brackets of frames

6.3.1 In general, frames are to be bracketed to the inner bottom or to the face plate of floors as shown in Fig 4.

6.3.2 The arm lengths d_1 and d_2 of lower brackets of frames are to be not less than the value obtained, in mm, from the following formula:

$$d = \varphi\sqrt{\frac{w + 30}{t}}$$

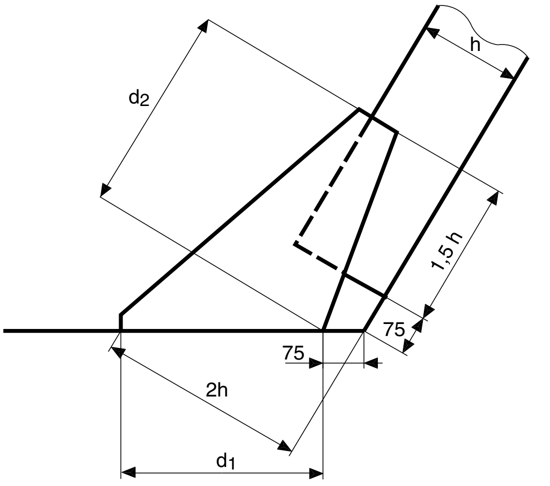
where:

- φ : Coefficient equal to:
  - for unflanged brackets: $\varphi = 50$
  - for flanged brackets: $\varphi = 45$
- w : Required net section modulus of the frame, in cm^3
- t : Bracket net thickness, in mm.

6.3.3 Where the bracket net thickness, in mm, is less than $15\ L_b$, where L_b is the length, in m, of the bracket free edge, the free edge of the bracket is to be flanged or stiffened by a welded face plate.

The net sectional area, in cm^2, of the flange or the face plate is to be not less than $10\ L_b$.

Figure 4 : Lower brackets of main frames



7 Openings in the shell plating

7.1 Position of openings

7.1.1 Openings in the shell plating are to be located at a vertical distance from the decks at side not less than:

- two times the opening diameter, in case of circular opening
- the opening minor axis, in case of elliptical openings.

See also Ch 4, Sec 6, Fig 1.

7.2 Local strengthening

7.2.1 Openings in the ship sides, e.g. for cargo ports, are to be well rounded at the corners and located well clear of superstructure ends or any openings in the deck areas at sides of hatchways.

7.2.2 Openings for sea intakes are to be well rounded at the corners and, within 0,6 L amidships, located outside the bilge strakes. Where arrangements are such that sea intakes are unavoidably located in the curved zone of the bilge strakes, such openings are to be elliptical with the major axis in the longitudinal direction. Openings for stabiliser fins are considered by the Society on a case by case basis. The thickness of sea chests is generally to be that of the local shell plating, but in no case less than 12 mm.

7.2.3 Openings in [7.2.1] and [7.2.2] and, when deemed necessary by the Society, other openings of considerable size are to be adequately compensated by means of insert plates of increased thickness or doublers sufficiently extended in length. Such compensation is to be partial or total depending on the stresses occurring in the area of the openings.

Circular openings on the sheerstrake need not be compensated where their diameter does not exceed 20% of the sheerstrake minimum width, defined in [1.3], or 380 mm, whichever is the lesser, and where they are located away from openings on deck at the side of hatchways or superstructure ends.

SECTION 6 DECK STRUCTURE

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinally or transversely framed deck structures.

1.2 General arrangement

1.2.1 The deck supporting structure consists of ordinary stiffeners (beams or longitudinals), longitudinally or transversely arranged, supported by primary supporting members which may be sustained by pillars.

1.2.2 Where beams are fitted in a hatched deck, these are to be effectively supported by at least two longitudinal girders located in way of hatch side girders to which they are to be connected by brackets and/or clips.

1.2.3 In ships greater than 120 m in length, the zones outside the line of openings of the strength deck and other decks contributing to longitudinal strength are, in general, to be longitudinally framed.

Where a transverse framing type is adopted for such ships, it is considered by the Society on a case by case basis.

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

- stepped or knuckled strength decks
- changes in the framing system.

Details of structural arrangements are to be submitted for review to the Society.

1.2.5 Where applicable, deck transverses of reinforced scantlings are to be aligned with floors.

1.2.6 Inside the line of openings, a transverse structure is generally to be adopted for cross-deck structures, beams are to be adequately supported by girders and, in ships greater than 120 m in length, extend up to the second longitudinal from the hatch side girders toward the bulwark.

Where this is impracticable, intercostal stiffeners are to be fitted between the hatch side girder and the second longitudinal.

Other structural arrangements may be accepted, subject to their strength verification. In particular, their buckling strength against the transverse compression loads is to be checked. Where needed, deck transverses may be required to be fitted.

1.2.7 Deck supporting structures under deck machinery, cranes and king posts are to be adequately stiffened.

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

1.2.9 Special arrangements, such as girders supported by cantilevers, are considered by the Society on a case by case basis.

1.2.10 Where devices for vehicle lashing arrangements and/or corner fittings for containers are directly attached to deck plating, provision is to be made for the fitting of suitable additional reinforcements of the sizes required by the load carried.

1.2.11 Stiffeners are also to be fitted in way of the ends and corners of deck houses and partial superstructures.

1.3 Construction of watertight decks

1.3.1 *Watertight decks 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.*

1.4 Stringer plate

1.4.1 The width of the stringer plate, in m, is to be not less than 0,8 + L / 200, measured parallel to the deck, but need not be greater than 1,8 m.

However, the stringer plate is also to comply with the requirements of Ch 4, Sec 1, [2.4.5] and Ch 4, Sec 1, [2.5.5].

Rounded stringer plates, where adopted, are to comply with the requirements of Ch 4, Sec 5, [1.3] for rounded sheerstrakes.

1.4.2 Stringer plates of lower decks not extending over the full ship's length are to be gradually tapered or overlapped by adequately sized brackets.

2 Longitudinally framed deck

2.1 General

2.1.1 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.

2.1.2 In general, the spacing of deck transverses is not to exceed 5 frame spacings.

2.1.3 In case of deck transverses located above the deck, longitudinal girders are to be fitted above the deck, in addition of tripping brackets.

2.2 Longitudinal ordinary stiffeners

2.2.1 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.

2.2.2 Frame brackets, in ships with transversely framed sides, are generally to have their horizontal arm extended to the adjacent longitudinal ordinary stiffener.

3 Transversely framed deck

3.1 General

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

4 Pillars

4.1 General

4.1.1 Pillars are to be fitted, as far as practicable, in the same vertical line.

4.1.2 In general, pillars are to be fitted below winches, cranes, windlasses and steering gear, in the engine room and at the corners of deckhouses.

4.1.3 In tanks, solid or open section pillars are generally to be fitted. Pillars located in spaces intended for products which may produce explosive gases are to be of open section type.

4.1.4 Tight or non-tight bulkheads may be considered as pillars, provided that their arrangement complies with Ch 4, Sec 7, [1.2.8].

4.2 Connections

4.2.1 Heads and heels of pillars are to be attached to the surrounding structure by means of brackets or insert plates so that the loads are well distributed.

Insert plates may be replaced by doubling plates, except in the case of pillars which may also work under tension such as those in tanks. In such case, the doubling plates are to comply with the requirements in Ch 4, Sec 1, [2.7] in order to prevent laminar tearing.

In general, the net thickness of doubling plates is to be not less than 1,5 times the net thickness of the pillar.

4.2.2 Pillars are to be attached at their heads and heels by continuous welding.

4.2.3 Pillars are to be connected to the inner bottom at the intersection of girders and floors.

4.2.4 Where pillars connected to the inner bottom are not located in way of intersections of floors and girders, partial floors or girders or equivalent structures suitable to support the pillars are to be arranged.

4.2.5 Manholes may not be cut in the girders and floors below the heels of pillars.

4.2.6 Where pillars are fitted in tanks, head and heel brackets may be required if tensile stresses are expected.

4.2.7 Where side pillars are not fitted in way of hatch ends, vertical stiffeners of bulkheads supporting hatch side girders or hatch end beams are to be bracketed at their ends.

5 Hatch supporting structures

5.1 General

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

In general, hatched end beams and deck transverses are to be in line with bottom and side transverse structures, so as to form a reinforced ring.

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

5.1.3 The details of connection of deck transverses to longitudinal girders and web frames are to be submitted to the Society for approval.

6 Openings in the strength deck

6.1 Position of openings and local strengthening

6.1.1 Openings in the strength deck are to be kept to a minimum and spaced as far apart from one another and from breaks of effective superstructures as practicable. Openings are generally to be cut outside the hatched areas; in particular, they are to be cut as far as practicable from hatchway corners.

The dashed areas in Fig 1 are those where openings are generally to be avoided. The meaning of the symbols in Fig 1 is as follows:

c, e : Longitudinal and transverse dimensions of hatched area:

$c = 0,07\ \ell + 0,10\ b$ without being less than 0,25 b

$e = 0,25\ (B - b)$

a : Transverse dimension of openings

g : Transverse dimension of the area where openings are generally to be avoided in way of the connection between deck and side (as shown in Fig 1), deck and longitudinal bulkheads, deck and large deck girders:

- in the case of circular openings:

  $g = 2\ a$

- in the case of elliptical openings:

  $g = a$

Figure 1 : Position of openings in the strength deck

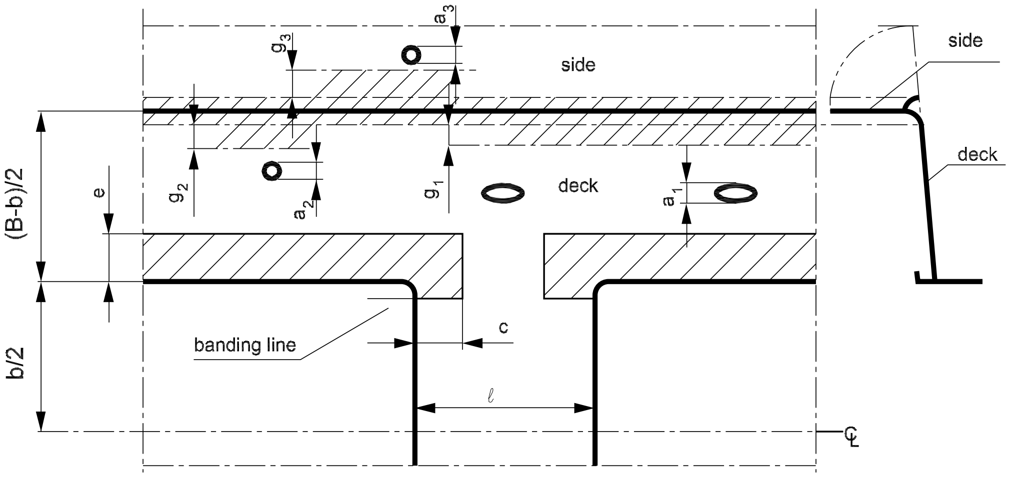
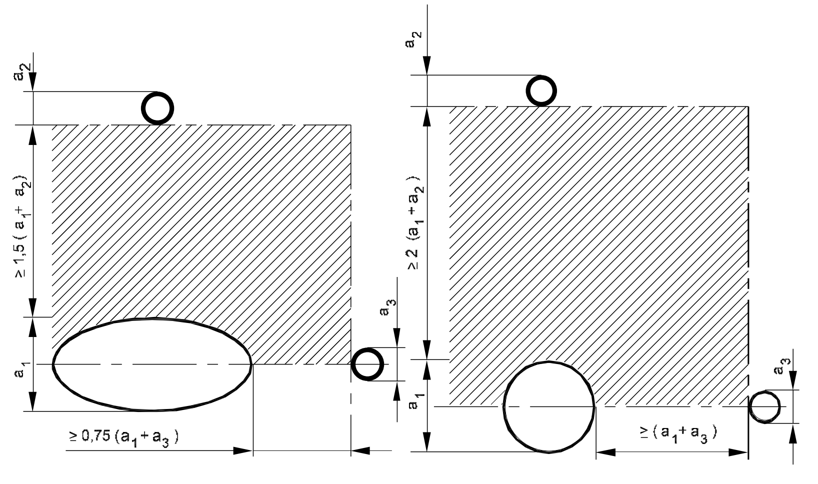


Figure 2 : Circular openings in the strength deck



6.1.2 No compensation is required where the openings are:

- circular of less than 350 mm in diameter and at a distance from any other opening in compliance with Fig 2
- elliptical with the major axis in the longitudinal direction and the ratio of the major to minor axis not less than 2.

6.1.3 If the openings arrangements do not comply with the requirements of the present Sub-Article, the hull girder longitudinal strength assessment is to be carried out by subtracting such opening areas.

6.2 Corners of hatchways

6.2.1 For hatchways located within the cargo area, insert plates, whose thickness is to be determined according to [6.2.3], 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
- 8% of the hatch width, where no continuous longitudinal deck girder is fitted below the hatch coaming.

Corner radiusing, in the case of the arrangement of two or more hatchways athwartship, is considered by the Society on a case by case basis.

6.2.2 For hatchways located in the positions specified in [6.2.1], 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.

6.2.3 Where insert plates are required, their thickness is obtained, in mm, from the following formula:

$$t_{INS} = \left(0,8 + 0,4\frac{\ell}{b}\right)t$$

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 1)

b : Width, in m, of the hatchway considered, measured in the transverse direction (see Fig 1)

t : Actual thickness, in mm, of the deck at the side of the hatchways.

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.

6.2.4 Where insert plates are required, the arrangement shown in Ch 11, App 2, Tab 66 is to be complied with.

6.2.5 For hatchways located in positions other than those in [6.2.1], 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.

7 Openings in decks other than the strength deck

7.1 General

7.1.1 The requirements for such openings are similar to those in [6.1] for the strength deck. However, circular openings need not to be compensated.

7.1.2 Corners of hatchway openings are to be rounded, as specified in [6.2] for the strength deck; insert plates may be omitted, however, when deemed acceptable by the Society.

SECTION 7 BULKHEAD STRUCTURE

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinal or transverse bulkhead structures which may be plane or corrugated.

1.1.2 Bulkheads may be horizontally or vertically stiffened.

Horizontally framed bulkheads consist of horizontal ordinary stiffeners supported by vertical primary supporting members.

Vertically framed bulkheads consist of vertical ordinary stiffeners which may be supported by horizontal girders.

1.2 General arrangement

1.2.1 The number and location of watertight bulkheads are to be in accordance with the relevant requirements given in Ch 2, Sec 1.

1.2.2 For ships greater than 170 m in length, longitudinal corrugated bulkheads are to have horizontal corrugations and the upper and lower strakes of longitudinal corrugated bulkheads are to be plane up to a distance of at least 0,1D from deck and bottom.

Transverse corrugated bulkheads having horizontal corrugations are to be fitted with vertical primary supporting members of number and size sufficient to ensure the required vertical stiffness of the bulkhead.

1.2.3 Where an inner bottom terminates on a bulkhead, the lowest strake of the bulkhead forming the watertight floor of the double bottom is to extend at least 300 mm above the inner bottom.

1.2.4 Longitudinal bulkheads are to terminate at transverse bulkheads and are to be effectively tapered to the adjoining structure at the ends and adequately extended in the machinery space, where applicable.

1.2.5 Where the longitudinal watertight bulkheads contribute to longitudinal strength, the plating thickness is to be uniform for a distance of at least 0,1D from the deck and bottom.

1.2.6 The structural continuity of the bulkhead vertical and horizontal primary supporting members with the surrounding supporting structures is to be carefully ensured.

1.2.7 The height of vertical primary supporting members of longitudinal bulkheads may be gradually tapered from bottom to deck. The maximum acceptable taper, however, is 8 cm per metre.

1.2.8 Bulkheads acting as pillars

Each vertical stiffener is to comply with the applicable buckling requirement in Ch 7, Sec 2, [4]

- a width of associated plating equal to 35 times the plating net thickness
- a supported load determined according to the requirements for pillars in Ch 7, Sec 3, [7.2.1]
- a resistance partial safety factor, γ_R, equal to 1,15 for column buckling and 1,05 for torsional and local buckling.

1.3 Watertight bulkheads of trunks, tunnels, etc.

1.3.1 *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.*

1.4 Openings in watertight bulkheads

1.4.1 Openings may not be cut in the collision bulkhead below the freeboard deck.

The number of openings in the collision bulkhead above the freeboard deck is to be kept to the minimum compatible with the design and proper working of the ship.

All such openings are to be fitted with means of closing to weathertight standards.

1.4.2 Certain openings below the freeboard deck are permitted in the other bulkheads, but these are to be kept to a minimum compatible with the design and proper working of the ship and to be provided with watertight doors having strength such as to withstand the head of water to which they may be subjected.

1.5 Watertight doors

1.5.1 Where vertical stiffeners are cut in way of watertight doors, reinforced stiffeners are to be fitted on each side of the door and suitably overlapped; cross-bars are to be provided to support the interrupted stiffeners.

2 Plane bulkheads

2.1 General

2.1.1 Where a bulkhead does not extend up to the uppermost continuous deck (such as the after peak bulkhead), suitable strengthening is to be provided in the extension of the bulkhead.

2.1.2 Bulkheads are to be stiffened in way of deck girders.

2.1.3 The webs of vertical stiffeners on hopper and topside tank watertight transverse bulkheads are generally to be aligned with the webs of longitudinal stiffeners on sloping plates of inner hull.

2.1.4 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.

2.1.5 Plate floors are to be fitted in the double bottom in way of plane transverse bulkheads.

2.1.6 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 sterntube, unless the net thickness of the bulkhead plating is increased by at least 60%.

2.2 End connections of ordinary stiffeners

2.2.1 The crossing of ordinary stiffeners through a watertight bulkhead is to be watertight.

2.2.2 In general, end connections of ordinary stiffeners are to be bracketed (see [2.3]). However, stiffeners of watertight bulkheads in upper 'tweendecks may be sniped, provided the scantlings of such stiffeners are modified accordingly.

2.2.3 Where hull lines do not enable compliance with the requirements of [2.2.2], sniped ends may be accepted, provided the scantlings of stiffeners are modified accordingly.

2.2.4 Where sniped ordinary stiffeners are fitted, the snipe angle is to be not greater than 30° and their ends are to be extended, as far as practicable, to the boundary of the bulkhead.

2.3 Bracketed ordinary stiffeners

2.3.1 Where bracketed ordinary stiffeners are fitted, the arm lengths of end brackets of ordinary stiffeners, as shown in Fig 1 and Fig 2, 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:

$$b = 80\sqrt{\frac{w+20}{t}}$$

$$b = \alpha\frac{ps\ell}{t}$$

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 midspan

α : Coefficient equal to:

$\alpha = 4,9$ for tank bulkheads

$\alpha = 3,6$ for watertight bulkheads.

2.3.2 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 1 : Bracket at upper end of ordinary stiffener on plane bulkhead

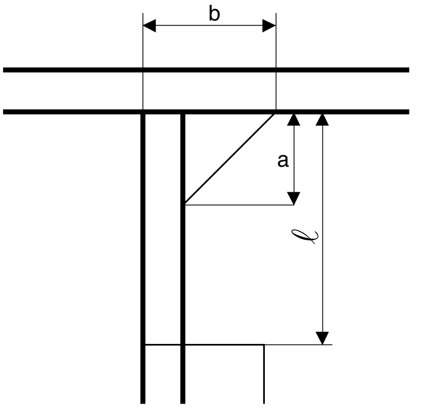
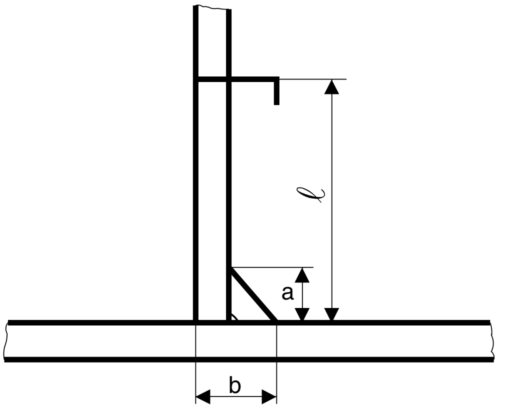


Figure 2 : Bracket at lower end of ordinary stiffener on plane bulkhead



3 Corrugated bulkheads

3.1 General

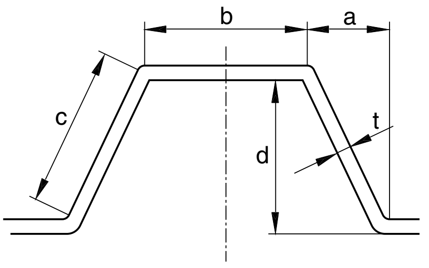
3.1.1 The main dimensions a, b, c and d of corrugated bulkheads are defined in Fig 3.

3.1.2 Unless otherwise specified, the following requirement is to be complied with:

$a \leq 1,2\,d$

Moreover, in some cases, the Society may prescribe an upper limit for the ratio b/t.

Figure 3 : Corrugated bulkhead



3.1.3 In general, the bending internal radius is to be not less than the following values, in mm:

- for normal strength steel: $R_i = 2,5\ t$
- for high tensile steel: $R_i = 3,0\ t$

where t is the net thickness, in mm, of the corrugated plate.

3.1.4 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, as a function of the importance of the structural element.

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.

3.1.5 In general, where girders or vertical primary supporting members are fitted on corrugated bulkheads, they are to be arranged symmetrically.

3.2 Structural arrangement

3.2.1 The strength continuity of corrugated bulkheads is to be ensured at ends of corrugations.

3.2.2 Where corrugated bulkheads are cut in way of primary members, attention is to be paid to ensure correct alignment of corrugations on each side of the primary member.

3.2.3 The connection of the corrugated bulkhead with the deck and the bottom is to be carefully designed and specially considered by the Society.

3.2.4 In general, where vertically corrugated transverse bulkheads are welded on the inner bottom, plate floors are to be fitted in way of the flanges of corrugations.

However, other arrangements ensuring adequate structural continuity may be accepted by the Society.

3.2.5 In general, where vertically corrugated longitudinal bulkheads are welded on the inner bottom, girders are to be fitted in way of the flanges of corrugations.

However, other arrangements ensuring adequate structural continuity may be accepted by the Society.

3.2.6 In general, the upper and lower parts of horizontally corrugated bulkheads are to be flat over a depth equal to 0,1D.

3.2.7 Where stools are fitted at the lower part of transverse bulkheads, the net thickness of adjacent plate floors is to be not less than that of the stool plating.

3.3 Bulkhead stool

3.3.1 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.

3.3.2 Brackets or deep webs are to be fitted to connect the upper stool to the deck transverses or hatch end beams, as the case may be.

3.3.3 The continuity of the corrugated bulkhead with the stool plating is to be adequately ensured. In particular, the 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.

4 Wash bulkheads

4.1 General

4.1.1 The requirements in [4.2] apply to transverse and longitudinal wash bulkheads whose main purpose is to reduce the liquid motions in partly filled tanks.

4.2 Openings

4.2.1 The total area of openings in a transverse wash bulkhead is generally to be between 10% and 30% of the total bulkhead area.

In the upper, central and lower portions of the bulkhead (the depth of each portion being 1/3 of the bulkhead height), the areas of openings, expressed as percentages of the corresponding areas of these portions, are to be within the limits given in Tab 1.

4.2.2 In general, openings may not be cut within 0,15D from bottom and from deck.

Table 1 : Areas of openings in transverse wash bulkheads

Bulkhead portion	Lower limit	Upper limit
Upper	10 %	15 %
Central	10 %	50 %
Lower	2 %	10 %

Part B
Hull and Stability

Chapter 5
DESIGN LOADS

Symbols used in this Chapter

n, n_1 : Navigation coefficients, defined in Pt B, Ch 5, Sec 1, [2.6]

F : Froude's number:

$F = 0,164\ V / L^{0,5}$

V : Maximum ahead service speed, in knots

T_1 : Draught, in m, defined in Pt B, Ch 5, Sec 1, [2.4.3] or Pt B, Ch 5, Sec 1, [2.5.3], as the case may be

g : Gravity acceleration, in m/s^2:

$g = 9,81\ m/s^2$

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [4].

SECTION 1 GENERAL

1 Definitions

1.1 Still water loads

1.1.1 Still water loads are those acting on the ship at rest in calm water.

1.2 Wave loads

1.2.1 Wave loads are those due to wave pressures and ship motions, which can be assumed to have the same wave encounter period.

1.3 Dynamic loads

1.3.1 Dynamic loads are those that have a duration much shorter than the period of the wave loads.

1.4 Local loads

1.4.1 Local loads are pressures and forces which are directly applied to the individual structural members: plating panels, ordinary stiffeners and primary supporting members.

- still water local loads are constituted by the hydrostatic external sea pressures and the static pressures and forces induced by the weights carried in the ship spaces.
- wave local loads are constituted by the external sea pressures due to waves and the inertial pressures and forces induced by the ship accelerations applied to the weights carried in the ship spaces.
- dynamic local loads are constituted by the impact and sloshing pressures.

1.4.2 For structural watertight elements located below the deepest equilibrium waterline (excluding side shell structural elements) which constitute boundaries intended to stop vertical and horizontal flooding, the still water and wave pressures in flooding conditions are also to be considered.

1.5 Hull girder loads

1.5.1 Hull girder loads are (still water, wave and dynamic) forces and moments which result as effects of local loads acting on the ship as a whole and considered as a beam.

1.6 Loading condition

1.6.1 A loading condition is a distribution of weights carried in the ship spaces arranged for their storage.

1.7 Load case

1.7.1 A load case is a state of the ship structures subjected to a combination of hull girder and local loads.

2 Application criteria

2.1 Fields of application

2.1.1 General

The wave induced and dynamic loads defined in this Chapter corresponds to an operating life of the ship equal to 20 years.

2.1.2 Requirements applicable to all types of ships

The requirements of the present Section are applicable for all ships covered in the scope of Part B, as stated in Ch 1, Sec 1, [1.1.1].

2.1.3 Requirements applicable to specific ship types

The design loads applicable to specific ship types are to be defined in accordance with the requirements in Part D or Part E.

2.1.4 Load direct calculation

As an alternative to the formulae in Ch 5, Sec 2 and Ch 5, Sec 3, the Society may accept the values of wave induced loads and dynamic loads derived from direct calculations, when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

2.2 Hull girder loads

2.2.1 The still water, wave and dynamic hull girder loads to be used for the determination of:

- the hull girder strength, according to the requirements of Part B, Chapter 6, and
- the structural scantling of plating, ordinary stiffeners and primary supporting members contributing to the hull girder strength, in combination with the local loads given in Ch 5, Sec 5 and Ch 5, Sec 6, according to the requirements in Part B, Chapter 7,

are specified in Ch 5, Sec 2.

2.3 Local loads

2.3.1 Load cases

The local loads defined in [1.4] are to be calculated in each of the mutually exclusive load cases described in Ch 5, Sec 4.

Dynamic loads are to be taken into account and calculated according to the criteria specified in Ch 5, Sec 5 and Ch 5, Sec 6.

2.3.2 Ship motions and accelerations

The wave local loads are to be calculated on the basis of the reference values of ship motions and accelerations specified in Ch 5, Sec 3.

2.3.3 Calculation and application of local loads

The criteria for calculating:

- still water local loads
- wave local loads on the basis of the reference values of ship motions and accelerations

are specified in Ch 5, Sec 5 for sea pressures and in Ch 5, Sec 6 for internal pressures and forces.

2.3.4 Flooding conditions

The still water and wave pressures in flooding conditions are specified in Ch 5, Sec 6, [9]. The pressures in flooding conditions applicable to specific ship types are to be defined in accordance with the requirements in Part D or Part E.

2.4 Load definition criteria to be adopted in structural analyses based on plate or isolated beam structural models

2.4.1 Application

The requirements of this sub-article apply for the definition of local loads to be used in the scantling checks of:

- plating, according to Ch 7, Sec 1
- ordinary stiffeners, according to Ch 7, Sec 2
- primary supporting members for which a three dimensional structural model is not required, according to Ch 7, Sec 3, [3].

2.4.2 Cargo and ballast distributions

When calculating the local loads for the structural scantling of an element which separates two adjacent compartments, the latter may not be considered simultaneously loaded. The local loads to be used are those obtained considering the two compartments individually loaded.

For elements of the outer shell, the local loads are to be calculated considering separately:

- the still water and wave external sea pressures, considered as acting alone without any counteraction from the ship interior
- the still water and wave differential pressures (internal pressure minus external sea pressure) considering the compartment adjacent to the outer shell as being loaded.

2.4.3 Draught associated with each cargo and ballast distribution

Local loads are to be calculated on the basis of the ship's draught T_1 corresponding to the cargo or ballast distribution considered according to the criteria in [2.4.2]. The ship draught is to be taken as the distance measured vertically on the hull transverse section at the middle of the length L, from the moulded base line to the waterline in:

- full load condition, when:
  - one or more cargo compartments (e.g. oil tank, dry cargo hold, vehicle space, passenger space) are considered as being loaded and the ballast tanks are considered as being empty
  - the still water and wave external pressures are considered as acting alone without any counteraction from the ship's interior
- light ballast condition, when one or more ballast tanks are considered as being loaded and the cargo compartments are considered as being empty. In the absence of more precise information, the ship's draught in light ballast condition may be obtained, in m, from the following formulae:
  - $T_B = 0{,}03\ L \leq 7{,}5$ m in general
  - $T_B = 2 + 0{,}02\ L$ for ships with one of the service notations **bulk carrier, bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP**, **combination carrier ESP** or **oil tanker ESP**.

2.5 Load definition criteria to be adopted in structural analyses based on three dimensional structural models

2.5.1 Application

The requirements of this sub-article apply for the definition of local loads to be used in the scantling checks of primary supporting members for which a three dimensional structural model is required, according to Ch 7, Sec 3, [4].

2.5.2 Loading conditions

For all ship types for which analyses based on three dimensional models are required according to Ch 7, Sec 3, [4], the most severe loading conditions for the structural elements under investigation are to be considered. These loading conditions are to be selected among those envisaged in the ship loading manual.

For ships with the service notation **general cargo ship, bulk carrier**, **bulk carrier ESP** or **self-unloading bulk carrier ESP** completed by the additional service feature **nonhomload**, the loading conditions to be considered are to include the cases where the selected holds are empty at draught T, according to the indications specified in the ship notation.

Further criteria applicable to specific ship types are specified in Part D or Part E.

2.5.3 Draught associated with each loading condition

Local loads are to be calculated on the basis of the ship's draught T_1 corresponding to the loading condition considered according to the criteria in [2.5.2].

2.6 Navigation coefficients

2.6.1 The navigation coefficients, which appear in the formulae of this Chapter for the definition of wave hull girder and local loads, are defined in Tab 1 depending on the assigned navigation notation.

Table 1 : Navigation coefficients

Navigation notation	Navigation coefficient n	Navigation coefficient n_1
Unrestricted navigation	1,00	1,00
Summer zone	0,90	0,95
Tropical zone	0,80	0,90
Coastal area	0,80	0,90
Sheltered area	0,65	0,80

SECTION 2 HULL GIRDER LOADS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

C : Wave parameter:

$$C = (118 - 0{,}36L)\frac{L}{1000} \quad \text{for } 65\,m \leq L < 90\,m$$

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

$$C = 10{,}75 \quad \text{for } 300\,m \leq L \leq 350\,m$$

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

H : Wave parameter:

$$H = 8{,}13 - \left(\frac{250 - 0{,}7L}{125}\right)^3$$

without being taken greater than 8,13.

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships having the following characteristics:

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

Ships not having one or more of these characteristics, ships intended for the carriage of heated cargoes and ships of unusual type or design will be considered by the Society on a case by case basis.

1.2 Sign conventions of vertical bending moments and shear forces

1.2.1 The sign conventions of bending moments and shear forces at any ship transverse section are as shown in Fig 1, namely:

- the vertical bending moment M is positive when it induces tensile stresses in the strength deck (hogging bending moment); it is negative in the opposite case (sagging bending moment)
- 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.

2 Still water loads

2.1 General

2.1.1 Still water load calculation

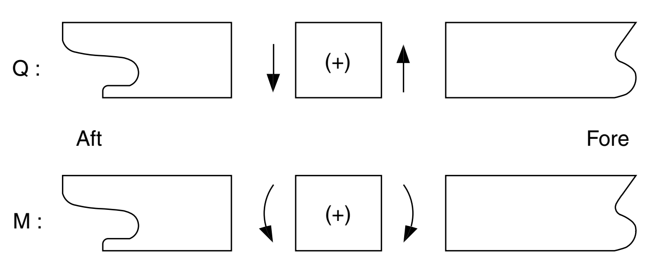
For all ships, the longitudinal distributions of still water bending moment and shear force are to be calculated, for each of the loading conditions in [2.1.2], on the basis of realistic data related to the amount of cargo, ballast, fuel, lubricating oil and fresh water.

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.

The actual hull lines and lightweight distribution are to be taken into account in the calculations. The lightweight distribution may be replaced, if the actual values are not available, by a statistical distribution of weights accepted by the Society.

The designer is to supply the data necessary to verify the calculations of still water loads.

Figure 1 : Sign conventions for shear forces Q and bending moments M



2.1.2 Loading conditions

Still water loads are to be calculated for all the design loading conditions (cargo and ballast) subdivided into departure and arrival conditions, on which the approval of hull structural scantlings is based.

For all ships, the following loading conditions are to be considered:

- homogeneous loading conditions at maximum draught
- ballast 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:

  - the allowable stress limits defined in Ch 6, Sec 2, [3] are satisfied for all filling levels between empty and full and
  - for ships with the service notation **bulk carrier**, the requirements in Pt D, Ch 4, Sec 3, [3.1], as applicable, are complied with all filling levels between empty and full.

  To demonstrate compliance with all filling levels between empty and full, it is acceptable if, in each condition at departure, arrival and where required in [2.1.1] any intermediate condition, the tanks intended to be partially filled are assumed to be:

  - empty
  - full
  - partially filled at intended level.

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

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

  - trim by stern of 3,0% of the ship's length, or
  - trim by bow of 1,5% of the ship's length, or
  - any trim that cannot maintain propeller immersion (l/D) not less than 25%, where:

    l : Distance, in m, from propeller centerline to the waterline

    D : Propeller diameter, in m.

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

- cargo loading conditions

  For cargo loading conditions involving partially filled peak and/or other ballast tanks, the requirements specified in bullet item before apply to the peak tanks only

- sequential ballast water exchange for ships granted with **BWE** notation

  The requirements concerning the partially filled ballast tanks in ballast loading conditions and the partially filled ballast tanks in cargo loading conditions (refer to the two previous bullet items) are not applicable to ballast water exchange using the sequential method.

  However, bending moment and shear force calculations for each deballasting or ballasting stage in the ballast water exchange sequence are to be included in the loading manual or ballast water management plan of any ship that intends to employ the sequential ballast water exchange method.

- special loadings (e.g. light load conditions at less than the maximum draught, deck cargo conditions, etc., where applicable)
- short voyage or harbour conditions, where applicable
- loading and unloading transitory conditions, where applicable
- docking condition afloat
- ballast exchange at sea, if applicable.

For ships with the service notation **general cargo ship** completed by the additional service feature **nonhomload**, the loading conditions to be considered are to include the cases where the selected holds are empty at draught T, according to the indications specified in the ship notation.

Part D and Part E specify other loading conditions which are to be considered depending on the ship type.

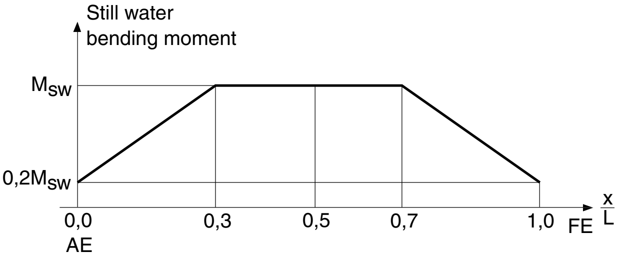
2.2 Still water bending moments

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 specified in [2.1.2].

Where no sagging bending moments act in the hull section considered, the value of $M_{SW,S}$ is to be taken as specified in Part B, Chapter 6 and Part B, Chapter 7.

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.

Figure 2 : Preliminary still water bending moment distribution



In Fig 2, M_{SW} is the design still water bending moment amidships, in hogging or sagging conditions, whose absolute values are to be taken not less than those obtained, in kN.m, from the following formulae:

- hogging conditions:

$$M_{SWM,H} = 175 n_1 C L^2 B (C_B + 0,7) 10^{-3} - M_{WV,H}$$

- sagging conditions:

$$M_{SWM,S} = 175 n_1 C L^2 B (C_B + 0,7) 10^{-3} + M_{WV,S}$$

where $M_{WV,H}$, $M_{WV,S}$ are the vertical wave bending moments, in kN.m, defined in [3.1].

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 specified in [2.1.2].

3 Wave loads

3.1 Vertical wave bending moments

3.1.1 The vertical wave bending moments at any hull transverse section are obtained, in kN.m, from the following formulae:

- hogging conditions:

$$M_{WV,H} = 190 \ F_M \ n \ C \ L^2 \ B \ C_B \ 10^{-3}$$

- sagging conditions:

$$M_{WV,S} = -110 \ F_M \ n \ C \ L^2 \ B \ (C_B + 0,7) \ 10^{-3}$$

where:

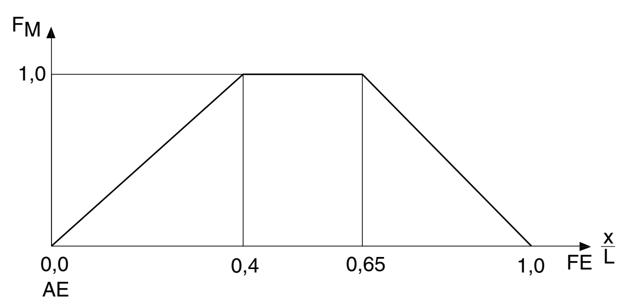
F_M : Distribution factor defined in Tab 1 (see Fig 3).

3.1.2 The effects of bow flare impact are to be taken into account, for the cases specified in [4.1.1], according to [4.2.1].

Table 1 : Distribution factor F_M

Hull transverse section location	Distribution factor F_M
$0 \le x < 0,4 \ L$	$2,5\frac{x}{L}$
$0,4 \ L \le x \le 0,65 \ L$	1
$065 \ L < x \le L$	$2,86\left(1 - \frac{x}{L}\right)$

Figure 3 : Distribution factor F_M



3.2 Horizontal wave bending moment

3.2.1 The horizontal wave bending moment at any hull transverse section is obtained, in kN.m, from the following formula:

$$M_{WH} = 0,42 \ F_M \ n \ H \ L^2 \ T \ C_B$$

where F_M is the distribution factor defined in [3.1.1].

3.3 Wave torque

3.3.1 The wave torque at any hull transverse section is to be calculated considering the ship in two different conditions:

- condition 1: ship direction forming an angle of 60° with the prevailing sea direction
- condition 2: ship direction forming an angle of 120° with the prevailing sea direction.

The values of the wave torques in these conditions, calculated with respect to the section centre of torsion, are obtained, in kN.m, from the following formula:

$$M_{WT} = \frac{HL}{4} n (F_{TM} C_M + F_{TQ} C_Q d)$$

where:

F_{TM}, F_{TQ} : Distribution factors defined in Tab 2 for ship conditions 1 and 2 (see also Fig 4 and Fig 5)

C_M : Wave torque coefficient:

$$C_M = 0,45 \ B^2 \ C_W^2$$

C_Q : Horizontal wave shear coefficient:

$$C_Q = 5 \ T \ C_B$$

C_W : Waterplane coefficient, to be taken not greater than the value obtained from the following formula:

$$C_W = 0,165 + 0,95 \ C_B$$

where C_B is to be assumed not less than 0,6. In the absence of more precise determination, C_W may be taken equal to the value provided by the above formula.

d : Vertical distance, in m, from the centre of torsion to a point located 0,6 T above the baseline.

Table 2 : Distribution factors F_{TM} and F_{TQ}

Ship condition	Distribution factor F_{TM}	Distribution factor F_{TQ}
1	$1 - \cos\frac{2\pi x}{L}$	$\sin\frac{2\pi x}{L}$
2	$1 - \cos\frac{2\pi(L - x)}{L}$	$\sin\frac{2\pi(L - x)}{L}$

Figure 4 : Ship condition 1 Distribution factors F_{TM} and F_{TQ}

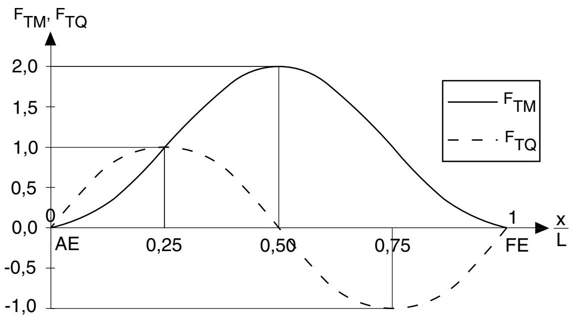
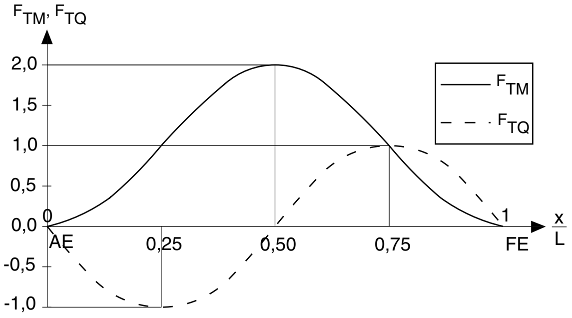


Figure 5 : Ship condition 2 Distribution factors F_{TM} and F_{TQ}



3.4 Vertical wave shear force

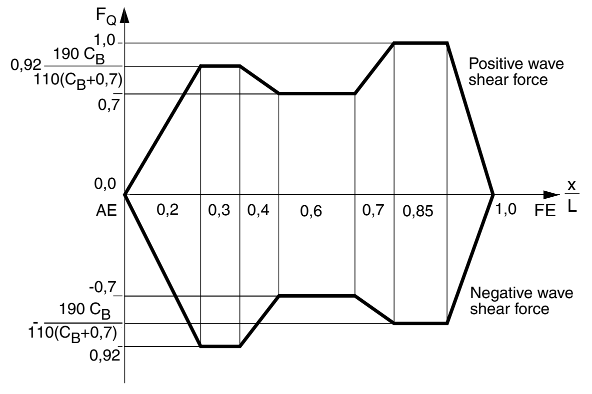
3.4.1 The vertical wave shear force at any hull transverse section is obtained, in kN, from the following formula:

$Q_{WV} = 30\ F_Q\ n\ C\ L\ B\ (C_B + 0{,}7)\ 10^{-2}$

where:

F_Q : Distribution factor defined in Tab 3 for positive and negative shear forces (see also Fig 6).

Figure 6 : Distribution factor F_Q



4 Dynamic loads due to bow flare impact

4.1 Application

4.1.1 The effects of bow flare impact are to be considered where all the following conditions occur:

- $120\ m \leq L \leq 200\ m$
- $V \geq 17{,}5$ knots
- $\dfrac{100 F A_S}{L B} > 1$

where:

A_S : Twice the shaded area shown in Fig 7, which is to be obtained, in m², from the following formula:

$A_S = b\ a_0 + 0{,}1\ L\ (a_0 + 2\ a_1 + a_2)$

b, a_0, a_1, a_2: Distances, in m, shown in Fig 7.

Table 3 : Distribution factor F_Q

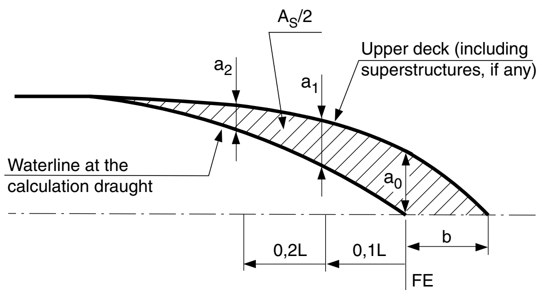
Hull transverse section location	Distribution factor F_Q	
	Positive wave shear force	Negative wave shear force
$0 \leq x < 0{,}2\ L$	$4{,}6 A \frac{x}{L}$	$-4{,}6 \frac{x}{L}$
$0{,}2\ L \leq x \leq 0{,}3\ L$	$0{,}92\ A$	$-0{,}92$
$0{,}3\ L < x < 0{,}4\ L$	$(9{,}2 A - 7)\left(0{,}4 - \frac{x}{L}\right) + 0{,}7$	$-2{,}2\left(0{,}4 - \frac{x}{L}\right) - 0{,}7$
$0{,}4\ L \leq x \leq 0{,}6\ L$	$0{,}7$	$-0{,}7$
$0{,}6\ L < x < 0{,}7\ L$	$3\left(\frac{x}{L} - 0{,}6\right) + 0{,}7$	$-(10 A - 7)\left(\frac{x}{L} - 0{,}6\right) - 0{,}7$
$0{,}7\ L \leq x \leq 0{,}85\ L$	1	$-A$
$0{,}85\ L < x \leq L$	$6{,}67\left(1 - \frac{x}{L}\right)$	$-6{,}67 A\left(1 - \frac{x}{L}\right)$

Note 1:

$A = \dfrac{190 C_B}{110 (C_B + 0{,}7)}$

For multideck ships, the upper deck shown in Fig 7 is to be taken as the deck (including superstructures) which extends up to the extreme forward end of the ship and has the largest breadth forward of 0,2L from the fore end.

Figure 7 : Area A_S



4.1.2 When the effects of bow flare impact are to be considered, according to [4.1.1], the sagging wave bending moment is to be increased as specified in [4.2.1] and [4.2.2].

4.1.3 The Society may require the effects of bow flare impact to be considered also when one of the conditions in [4.1.1] does not occur, if deemed necessary on the basis of the ship's characteristics.

In such cases, the increase in sagging wave bending moment is defined on a case by case basis.

4.2 Increase in sagging wave bending moment

4.2.1 General

The sagging wave bending moment at any hull transverse section, defined in [3.1], is to be multiplied by the coefficient F_D obtained from the formulae in Tab 4, which takes into account the dynamic effects of bow flare impact.

Where at least one of the conditions in [4.1.1] does not occur, the coefficient F_D may be taken equal to 1.

Table 4 : Coefficient F_D

Hull transverse section location	Coefficient F_D
$0 \le x < 0,4\ L$	1
$0,4\ L \le x < 0,5\ L$	$1 + 10(C_D - 1)\left(\frac{x}{L} - 0,4\right)$
$0,5\ L \le x \le L$	C_D

Note 1:

$$C_D = 262,5\frac{A_S}{CLB(C_B + 0,7)} - 0,6 \quad \text{with} \quad 1,0 \le C_D \le 1,2$$

A_S : Area, in m^2, defined in [4.1.1].

4.2.2 Direct calculations

As an alternative to the formulae in [4.2.1], the Society may accept the evaluation of the effects of bow flare impact from direct calculations, when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

SECTION 3 SHIP MOTIONS AND ACCELERATIONS

Symbols

For the symbols not defined in this Section, refer to the list at the beginning of this Chapter.

a_B : Motion and acceleration parameter:

$$a_B = n\left(0{,}76F + 1{,}875\frac{h_W}{L}\right)$$

h_W : Wave parameter, in m:

$$h_W = 11{,}44 - \left|\frac{L-250}{110}\right|^3 \quad \text{for } L < 350\,m$$

$$h_W = \frac{200}{\sqrt{L}} \quad \text{for } L \geq 350\,m$$

a_{SU} : Surge acceleration, in m/s², defined in [2.1]

a_{SW} : Sway acceleration, in m/s², defined in [2.2]

a_H : Heave acceleration, in m/s², defined in [2.3]

α_R : Roll acceleration, in rad/s², defined in [2.4]

α_P : Pitch acceleration, in rad/s², defined in [2.5]

α_Y : Yaw acceleration, in rad/s², defined in [2.6]

T_{SW} : Sway period, in s, defined in [2.2]

T_R : Roll period, in s, defined in [2.4]

T_P : Pitch period, in s, defined in [2.5]

A_R : Roll amplitude, in rad, defined in [2.4]

A_P : Pitch amplitude, in rad, defined in [2.5].

1 General

1.1

1.1.1 Ship motions and accelerations are defined, with their signs, according to the reference co-ordinate system in Ch 1, Sec 2, [4].

1.1.2 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 through amplitudes.

1.1.3 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^{-5}. 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 Surge

2.1.1 The surge acceleration a_{SU} is to be taken equal to 0,5 m/s².

2.2 Sway

2.2.1 The sway period and acceleration are obtained from the formulae in Tab 1.

Table 1 : Sway period and acceleration

Period T_{SW}, in s	Acceleration a_{SW}, in m/s²
$\dfrac{0{,}8\sqrt{L}}{1{,}22F+1}$	$0{,}775\ a_B\ g$

2.3 Heave

2.3.1 The heave acceleration is obtained, in m/s², from the following formula:

$a_H = a_B\ g$

2.4 Roll

2.4.1 The roll amplitude, period and acceleration are obtained from the formulae in Tab 2.

The meaning of symbols in Tab 2 is as follows:

$$E = 1{,}39\frac{GM}{\delta^2}B \quad \text{to be taken not less than 1,0}$$

GM : Distance, in m, from the ship's centre of gravity to the transverse metacentre, for the loading considered; when GM is not known, the values given in Tab 3 may be assumed

δ : Roll radius of gyration, in m, for the loading considered; when δ is not known, the following values may be assumed, in full load and ballast conditions:

δ = 0,35 B in general

δ = 0,30 B for ships with the service notation **ore carrier ESP**.

Table 2 : Roll amplitude, period and acceleration

Amplitude A_R, in rad	Period T_R, in s	Acceleration α_R, in rad/s²
$a_B\sqrt{E}$ without being taken greater than 0,35	$2{,}2\dfrac{\delta}{\sqrt{GM}}$	$A_R\left(\dfrac{2\pi}{T_R}\right)^2$

Table 3 : Values of GM

Service notation	Full load	Ballast
oil tanker ESP	0,12 B	heavy ballast: 0,18 B light ballast: 0,24 B
bulk carrier ESP, **self-uloading bulk carrier ESP**	0,12 B	heavy ballast: 0,18 B light ballast: 0,24 B
ore carrier ESP	0,16 B	heavy ballast: 0,18 B light ballast: 0,24 B
Other	0,07 B	0,18 B

2.5 Pitch

2.5.1 The pitch amplitude, period and acceleration are obtained from the formulae in Tab 4.

Table 4 : Pitch amplitude, period and acceleration

Amplitude A_P, in rad	Period T_P, in s	Acceleration α_P, in rad/s²
$0,328 a_B\left(1,32-\frac{h_W}{L}\right)\left(\frac{0,6}{C_B}\right)^{0,75}$	$0,575\sqrt{L}$	$A_P\left(\frac{2\pi}{T_P}\right)^2$

2.6 Yaw

2.6.1 The yaw acceleration is obtained, in rad/s², from the following formula:

$$\alpha_Y = 1,581\frac{a_B g}{L}$$

3 Ship relative motions and accelerations

3.1 Definitions

3.1.1 Ship relative motions

The ship relative motions are the vertical oscillating translations of the sea waterline on the ship side. They are measured, with their sign, from the waterline at draught T_1.

3.1.2 Accelerations

At any point, the accelerations in X, Y and Z direction are the acceleration components which result from the ship motions defined in [2.1] to [2.6].

3.2 Ship conditions

3.2.1 General

Ship relative motions and accelerations are to be calculated considering the ship in the following conditions:

- upright ship condition
- inclined ship condition.

3.2.2 Upright ship condition

In this condition, the ship encounters waves which produce ship motions in the X-Z plane, i.e. surge, heave and pitch.

3.2.3 Inclined ship condition

In this condition, the ship encounters waves which produce ship motions in the X-Y and Y-Z planes, i.e. sway, roll, yaw and heave.

3.3 Ship relative motions

3.3.1 The reference value of the relative motion in the upright ship condition is obtained, at any hull transverse section, from the formulae in Tab 5.

Table 5 : Reference value of the relative motion h_1 in the upright ship condition

Location	Reference value of the relative motion h_1 in the upright ship condition, in m
x = 0	$0,7\left(\frac{4,35}{\sqrt{C_B}}-3,25\right)h_{1,M}$ if $C_B < 0,875$ $h_{1,M}$ if $C_B \geq 0,875$
x < 0,3 L	$h_{1,AE}-\frac{h_{1,AE}-h_{1,M}}{0,3}\frac{x}{L}$
0,3 L ≤ x ≤ 0,7 L	$0,42\ n\ C\ (C_B + 0,7)$ without being taken greater than the minimum of T_1 and D – 0,9 T
0,7 L < x	$h_{1,M}+\frac{h_{1,FE}-h_{1,M}}{0,3}\left(\frac{x}{L}-0,7\right)$
x = L	$\left(\frac{4,35}{\sqrt{C_B}}-3,25\right)h_{1,M}$

Note 1:
C : Wave parameter defined in Ch 5, Sec 2
$h_{1,AE}$: Reference value h_1 calculated for x = 0
$h_{1,M}$: Reference value h_1 calculated for x = 0,5 L
$h_{1,FE}$: Reference value h_1 calculated for x = L

3.3.2 The reference value, in m, of the relative motion in the inclined ship condition is obtained, at any hull transverse section, from the following formula:

$$h_2 = 0,5 h_1 + A_R\frac{B_W}{2}$$

where:

h_1 : Reference value, in m, of the relative motion in the upright ship, calculated according to [3.3.1]

h_2 : Reference value, in m, without being taken greater than the minimum of T_1 and D – 0,9 T

B_W : Moulded breadth, in m, measured at the waterline at draught T_1 at the hull transverse section considered.

3.4 Accelerations

3.4.1 The reference values of the longitudinal, transverse and vertical accelerations at any point are obtained from the formulae in Tab 6 for upright and inclined ship conditions.

Table 6 : Reference values of the accelerations a_X, a_Y and a_Z

Direction	Upright ship condition	Inclined ship condition
X - Longitudinal a_{X1} and a_{X2} in m/s²	$a_{X1} = \sqrt{a_{SU}^2 + [A_P g + \alpha_p (z - T_1)]^2}$	$a_{x2} = 0$
Y - Transverse a_{Y1} and a_{Y2} in m/s²	$a_{Y1} = 0$	$a_{Y2} = \sqrt{a_{SW}^2 + [A_R g + \alpha_R (z - T_1)]^2 + \alpha_Y^2 K_X L^2}$
Z - Vertical a_{Z1} and a_{Z2} in m/s²	$a_{Z1} = \sqrt{a_H^2 + \alpha_p^2 K_X L^2}$	$a_{Z2} = \sqrt{0,25 a_H^2 + \alpha_R^2 y^2}$

Note 1:

$K_X = 1,2\left(\frac{x}{L}\right)^2 - 1,1\frac{x}{L} + 0,2$ without being taken less than 0,018

SECTION 4 LOAD CASES

Symbols

h_1 : Reference value of the ship relative motion in the upright ship condition, defined in Ch 5, Sec 3, [3.3]

h_2 : Reference value of the ship relative motion in the inclined ship condition, defined in Ch 5, Sec 3, [3.3]

a_{X1}, a_{Y1}, a_{Z1}: Reference values of the accelerations in the upright ship condition, defined in Ch 5, Sec 3, [3.4]

a_{X2}, a_{Y2}, a_{Z2}: Reference values of the accelerations in the inclined ship condition, defined in Ch 5, Sec 3, [3.4]

M_{WV} : Reference value of the vertical wave bending moment, defined in Ch 5, Sec 2, [3.1]

M_{WH} : Reference value of the horizontal wave bending moment, defined in Ch 5, Sec 2, [3.2]

M_T : Reference value of the wave torque, defined in Ch 5, Sec 2, [3.3]

Q_{WV} : Reference value of the vertical wave shear force, defined in Ch 5, Sec 2, [3.4].

1 General

1.1 Load cases for structural analyses based on partial ship models

1.1.1 The load cases described in this section are those to be used for structural element analyses which do not require complete ship modelling. They are:

- the analyses of plating (see Ch 7, Sec 1)
- the analyses of ordinary stiffeners (see Ch 7, Sec 2)
- the analyses of primary supporting members analysed through isolated beam structural models or three dimensional structural models (see Ch 7, Sec 3)
- the fatigue analysis of the structural details of the above elements (see Ch 7, Sec 4).

1.1.2 These load cases are the mutually exclusive load cases "a", "b", "c" and "d" described in [2].

Load cases "a" and "b" refer to the ship in upright conditions (see Ch 5, Sec 3, [3.2]), i.e. at rest or having surge, heave and pitch motions.

Load cases "c" and "d" refer to the ship in inclined conditions (see Ch 5, Sec 3, [3.2]), i.e. having sway, roll and yaw motions.

1.2 Load cases for structural analyses based on complete ship models

1.2.1 When primary supporting members are to be analysed through complete ship models, according to Ch 7, Sec 3, [1.1.2], specific load cases are to be considered.

These load cases are to be defined considering the ship as sailing in regular waves with different length, height and heading angle, each wave being selected in order to maximise a design load parameter. The procedure for the determination of these load cases is specified in Ch 7, App 3.

2 Load cases

2.1 Upright ship conditions (load cases "a" and "b")

2.1.1 Ship condition

The ship is considered to encounter a wave which produces (see Fig 1 for load case "a" and Fig 2 for load case "b") a relative motion of the sea waterline (both positive and negative) symmetric on the ship sides and induces wave vertical bending moment and shear force in the hull girder. In load case "b", the wave is also considered to induce heave and pitch motions.

2.1.2 Local loads

The external pressure is obtained by adding to or subtracting from the still water head a wave head corresponding to the relative motion.

The internal loads are the still water loads induced by the weights carried, including those carried on decks. For load case "b", those induced by the accelerations are also to be taken into account.

2.1.3 Hull girder loads

The hull girder loads are:

- the vertical still water bending moment and shear force
- the vertical wave bending moment and the shear force.

Figure 1 : Wave loads in load case "a"

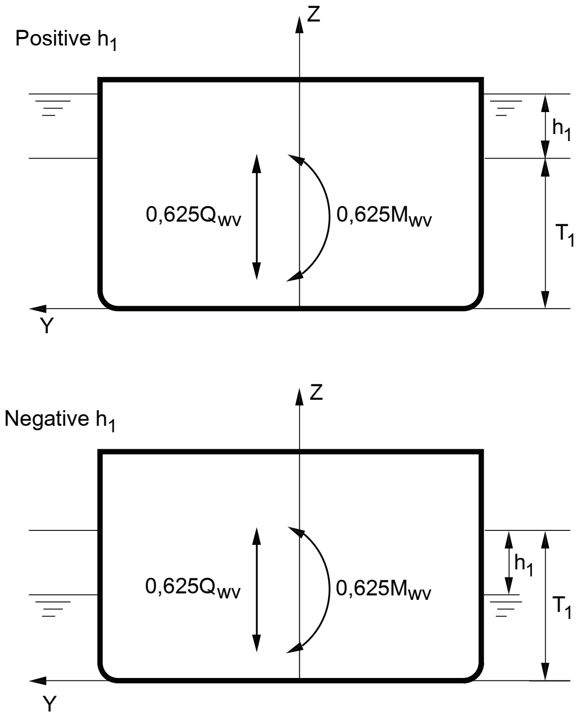
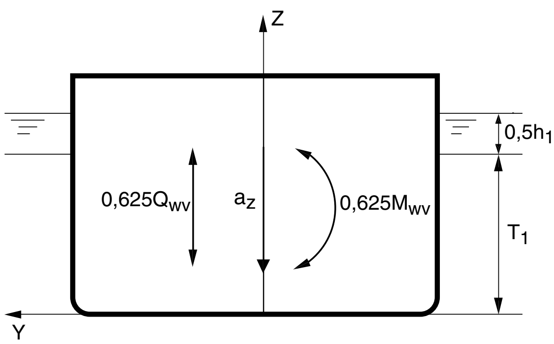


Figure 2 : Wave loads in load case "b"



2.2 Inclined ship conditions (load cases "c" and "d")

2.2.1 Ship condition

The ship is considered to encounter a wave which produces (see Fig 3 for load case "c" and Fig 4 for load case "d"):

- sway, roll and yaw motions
- a relative motion of the sea waterline anti-symmetric on the ship sides

and induces:

- vertical wave bending moment and shear force in the hull girder
- horizontal wave bending moment in the hull girder
- in load case "c", torque in the hull girder.

Figure 3 : Wave loads in load case "c"

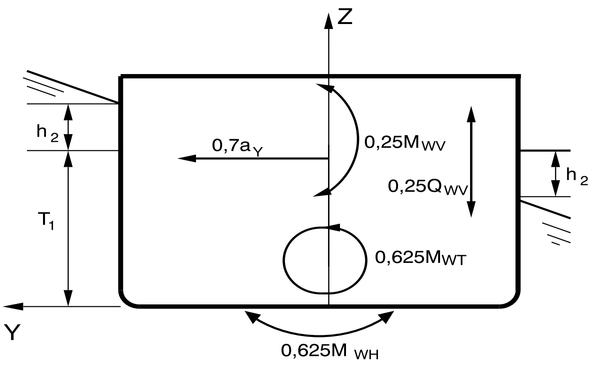
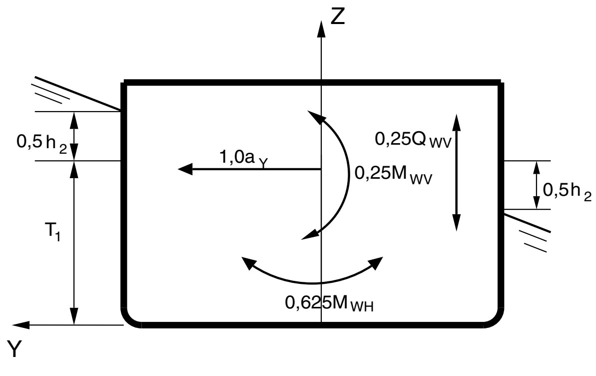


Figure 4 : Wave loads in load case "d"



2.2.2 Local loads

The external pressure is obtained by adding or subtracting from the still water head a wave head linearly variable from positive values on one side of the ship to negative values on the other.

The internal loads are the still water loads induced by the weights carried, including those carried on decks, and the wave loads induced by the accelerations.

2.2.3 Hull girder loads

The hull girder loads are:

- the still water bending moment and shear force
- the vertical wave bending moment and shear force
- the horizontal wave bending moment
- the wave torque (for load case "c").

2.3 Summary of load cases

2.3.1 The wave local and hull girder loads to be considered in each load case are summarised in Tab 1 and Tab 2, respectively.

These loads are obtained by multiplying, for each load case, the reference value of each wave load by the relevant combination factor.

Table 1 : Wave local loads in each load case

Ship condition	Load case	Relative motions		Accelerations a_X, a_Y, a_Z	
		Reference value	Combination factor	Reference value **(3)**	Combination factor
Upright	"a"	h_1	1,0	a_{X1}; 0; a_{Z1}	0,0
	"b" **(1)**	h_1	0,5	a_{X1}; 0; a_{Z1}	1,0
Inclined	"c" **(2)**	h_2	1,0	0; a_{Y2}; a_{Z2}	0,7
	"d" **(2)**	h_2	0,5	0; a_{Y2}; a_{Z2}	1,0

(1) For a ship moving with a positive heave motion:
- h_1 is positive
- the cargo acceleration a_{X1} is directed towards the positive part of the X axis
- the cargo acceleration a_{Z1} is directed towards the negative part of the Z axis

(2) For a ship rolling with a negative roll angle:
- h_2 is positive for the points located in the positive part of the Y axis and, vice-versa, it is negative for the points located in the negative part of the Y axis
- the cargo acceleration a_{Y2} is directed towards the positive part of the Y axis
- the cargo acceleration a_{Z2} is directed towards the negative part of the Z axis for the points located in the positive part of the Y axis and, vice-versa, it is directed towards the positive part of the Z axis for the points located in the negative part of the Y axis.

(3) Accelerations a_X, a_Y and a_Z are to be considered in both directions when assessing onboard equipment foundations and supports.

Table 2 : Wave hull girder loads in each load case

Ship condition	Load case	Vertical bending moment		Vertical shear force		Horizontal bending moment		Torque	
		Reference value	Comb. factor	Reference value	Comb. factor	Reference value	Comb. factor	Reference value	Comb. factor
Upright	"a"	0,625 M_{WV}	1,0	0,625 Q_{WV}	1,0	0,625 M_{WH}	0,0	0,625 M_T	0,0
	"b"	0,625 M_{WV}	1,0	0,625 Q_{WV}	1,0	0,625 M_{WH}	0,0	0,625 M_T	0,0
Inclined	"c"	0,625 M_{WV}	0,4	0,625 Q_{WV}	0,4	0,625 M_{WH}	1,0	0,625 M_T	1,0
	"d"	0,625 M_{WV}	0,4	0,625 Q_{WV}	0,4	0,625 M_{WH}	1,0	0,625 M_T	0,0

Note 1: The sign of the hull girder loads, to be considered in association with the wave local loads for the scantling of plating, ordinary stiffeners and primary supporting members contributing to the hull girder longitudinal strength, is defined in Part B, Chapter 7.

SECTION 5 SEA PRESSURES

Symbols

For the symbols not defined in this Section, refer to the list at the beginning of this Chapter.

- ρ : Sea water density, taken equal to 1,025 t/m^3
- h_1 : Reference values of the ship relative motions in the upright ship condition, defined in Ch 5, Sec 3, [3.3]
- h_2 : Reference values of the ship relative motions in the inclined ship conditions, defined in Ch 5, Sec 3, [3.3].

1 Still water pressure

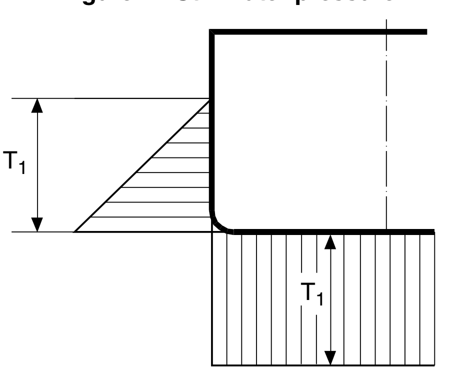
1.1 Pressure on sides and bottom

1.1.1 The still water pressure at any point of the hull is obtained from the formulae in Tab 1 (see also Fig 1).

Table 1 : Still water pressure

Location	Still water pressure p_S, in kN/m^2
Points at and below the waterline ($z \leq T_1$)	$\rho\, g\, (T_1 - z)$
Points above the waterline ($z > T_1$)	0

Figure 1 : Still water pressure



2 Wave pressure

2.1 Upright ship conditions (load cases “a” and “b”)

2.1.1 Pressure on sides and bottom

The wave pressure at any point of the sides and bottom is obtained from the formulae in Tab 4 (see also Fig 2 for load case “a” and Fig 3 for load case “b”).

Figure 2 : Wave pressure in load case “a”

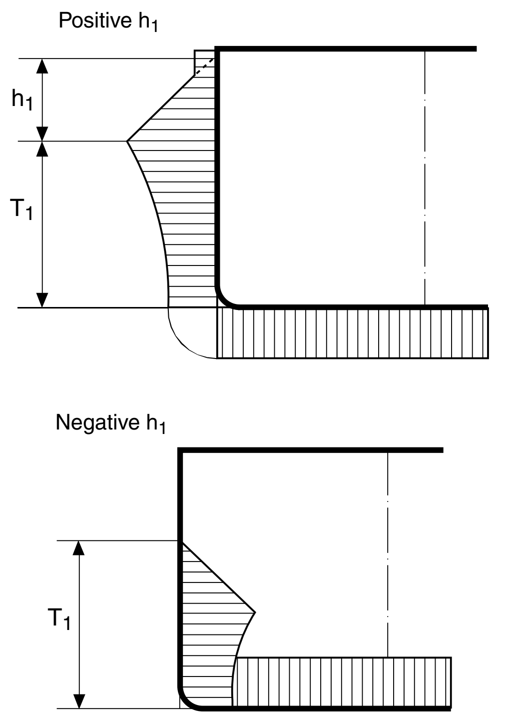
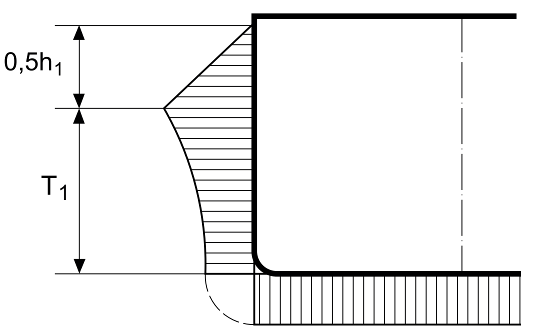


Figure 3 : Wave pressure in load case “b”



2.2 Inclined ship conditions (load cases “c” and “d”)

2.2.1 The wave pressure at any point of the sides and bottom is obtained from the formulae in Tab 5 (see also Fig 5 for load case “c” and Fig 4 for load case “d”).

Figure 4 : Wave pressure in load case “d”

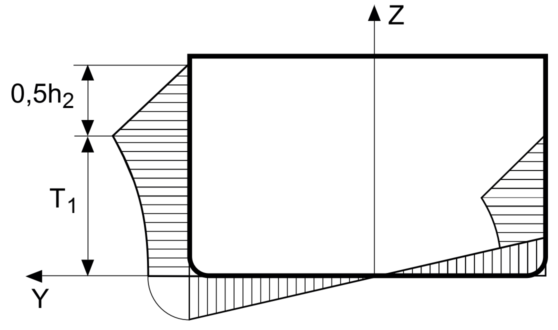
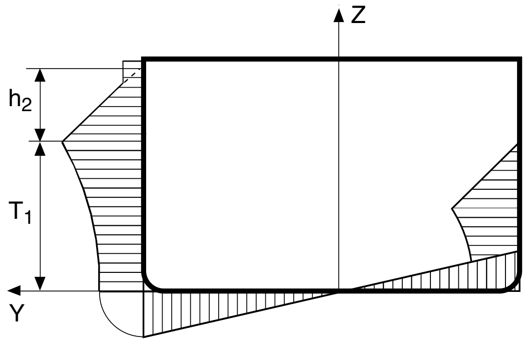


Figure 5 : Wave pressure in load case “c”



3 Exposed decks

3.1 Application

3.1.1 The pressures defined in [3.2] for exposed decks are to be considered independently of the pressures due to dry uniform cargoes, dry unit cargoes or wheeled cargoes, if any, as defined in Ch 5, Sec 6, [4], Ch 5, Sec 6, [5] and Ch 5, Sec 6, [6] respectively.

3.2 Sea pressures on exposed decks

3.2.1 Still water pressure

The still water pressure on exposed decks is to be taken equal to $10.\varphi_1.\varphi_2$, where φ_1 is defined in Tab 2 and φ_2 in Tab 3.

3.2.2 Green sea loads

The wave pressure on exposed decks due to green sea is obtained from the formulae in Tab 3 and Tab 5.

Table 2 : Coefficient for pressure on exposed decks

Exposed deck location	φ_1
Freeboard deck and below	1,00
Top of lowest tier	0,75
Top of second tier	0,56
Top of third tier	0,42
Top of fourth tier	0,32
Top of fifth tier	0,25
Top of sixth tier	0,20
Top of seventh tier	0,15
Top of eighth tier and above	0,10

4 Sea chests

4.1 Design pressure

4.1.1 The pressure to be considered for the scantling of sea chests is the maximum between:

- sea pressure as calculated in Articles [1] and [2] for sides and bottom
- pressure defined by the designer to consider the hazard of an overpressure due to the inlet grating cleaning system, to be taken not less than 200 kN/m².

Table 3 : Wave pressure on exposed decks in upright ship conditions (load cases “a” and “b”)

Location	Wave pressure p_W, in kN/m²	
	Crest	Through
$0 \le x \le 0,5\ L$	$17,5 n \varphi_1 \varphi_2$	0
$0,5\ L < x < 0,75\ L$	$\left\{17,5 + \left[\dfrac{19,6\sqrt{H_F} - 17,5}{0,25}\right]\left(\dfrac{x}{L} - 0,5\right)\right\} n \varphi_1 \varphi_2$	0
$0,75\ L \le x \le L$	$19,6 n \varphi_1 \varphi_2 \sqrt{H}$	0

Note 1:

$$H = C_{F1}\left[2,66\left(\frac{x}{L} - 0,7\right)^2 + 0,14\right]\sqrt{\frac{VL}{C_B}} - (z - T_1)$$ without being taken less than 0,8

φ_1 : Coefficient defined in Tab 2

φ_2 : Coefficient taken equal to:
- $\varphi_2 = 1$ if $L \ge 120$ m
- $\varphi_2 = L/120$ if $L < 120$ m

H_F : Value of H calculated at $x = 0,75\ L$

C_{F1} : Combination factor, to be taken equal to:
- $C_{F1} = 1,0$ for load case “a”
- $C_{F1} = 0,5$ for load case “b”

V : Maximum ahead service speed, in knots, to be taken not less than 13 knots.

Table 4 : Wave pressure on sides and bottom in upright ship conditions (load cases "a" and "b")

Location	Wave pressure p_W, in kN/m²	
	Crest	Trough
Bottom and sides below the waterline ($z \le T_1$)	$\rho g h e^{\frac{-2\pi(T_1 - z)}{L}}$	$-\rho g h e^{\frac{-2\pi(T_1 - z)}{L}}$ without being taken less than $\rho g (z - T_1)$
Sides above the waterline ($z > T_1$)	$\rho g (T_1 + h - z)$ without being taken, for case "a" only, less than $0,15 \varphi_1 \varphi_2 L$	0,0

Note 1:

$h = C_{F1} h_1$

C_{F1} : Combination factor, to be taken equal to:

- $C_{F1} = 1,0$ for load case "a"
- $C_{F1} = 0,5$ for load case "b".

Table 5 : Wave pressure on sides, bottom and exposed decks in inclined ship conditions (load cases "c" and "d")

Location	Wave pressure p_W, in kN/m² (negative roll angle) **(1)**	
	$y \ge 0$	$y < 0$
Bottom and sides below the waterline ($z \le T_1$)	$\beta C_{F2} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{L}} + A_R y e^{\frac{-\pi(T_1 - z)}{L}}\right]$	$\beta C_{F2} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{L}} + A_R y e^{\frac{-\pi(T_1 - z)}{L}}\right]$ without being taken less than $\rho g (z - T_1)$
Sides above the waterline ($z > T_1$)	$\rho g \left[T_1 + \beta C_{F2}\left(\frac{y}{B_W} h_1 + A_R y\right) - z\right]$ without being taken, for case "c" only, less than $0,15 \varphi_1 \varphi_2 L$	0
Exposed decks	$0,4 \rho g \left[T_1 + \beta C_{F2}\left(\frac{y}{B_W} h_1 + A_R y\right) - z\right]$ without being taken, for case "c" only, less than $0,15 \varphi_1 \varphi_2 L$	0

(1) In the formulae giving the wave pressure p_W, the ratio (y / B_W) is not to be taken greater than 0,5.

Note 1:

φ_1 : Coefficient defined in Tab 2

φ_2 : Coefficient defined in Tab 3

C_{F2} : Combination factor, to be taken equal to:

- $C_{F2} = 1,0$ for load case "c"
- $C_{F2} = 0,5$ for load case "d"

β : coefficient, to be taken as the minimum of:

- 1
- $T_1 \Big/ \left(0,5 h_1 + A_R \frac{B_W}{2}\right)$
- $(D - 0.9T) \Big/ \left(0,5 h_1 + A_R \frac{B_W}{2}\right)$

B_W : Moulded breadth, in m, measured at the waterline at draught T_1 , at the hull transverse section considered

A_R : Roll amplitude, defined in Ch 5, Sec 3, [2.4.1].

SECTION 6 INTERNAL PRESSURES AND FORCES

Symbols

For the symbols not defined in this Section, refer to the list at the beginning of this Chapter.

ρ_L : Density, in t/m³, of the liquid carried

ρ_B : Density, in t/m³, of the dry bulk cargo carried; in certain cases, such as spoils, the water held by capillarity is to be taken into account

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank in the z direction

z_L : Z co-ordinate, in m, of the highest point of the liquid:

$z_L = z_{TOP} + 0,5\ (z_{AP} - z_{TOP})$

z_{AP} : Z co-ordinate, in m, of the top of air pipe, to be taken not less than z_{TOP}

p_{PV} : Design vapour pressure, in bar:

Where a pressure relief valve is fitted, p_{PV} is to be taken equal to:

- 1,1 times the safety valve setting pressure in general
- 1,0 times the safety valve setting pressure in case of liquefied gas cargo tank or liquefied gas fuel tank.

Where no pressure relief valve is fitted, p_{PV} is to be taken equal to 0.

p_{drop} : Overpressure, in kN/m², due to sustained liquid flow through air pipe or overflow pipe in case of overfilling or filling during flow-through ballast water exchange.

When the total area of water overflowing openings on the tank is more than twice the sectional area of the related filling pipe, p_{drop} may be taken equal to 0.

Otherwise, p_{drop} is to be defined by the designer, but not to be taken less than 25 kN/m²

M : Mass, in t, of a dry unit cargo carried

a_{X1}, a_{Y1}, a_{Z1}: Reference values of the accelerations in the upright ship condition, defined in Ch 5, Sec 3, [3.4], calculated in way of:

- the centre of gravity of the compartment, in general
- the centre of gravity of any dry unit cargo, in the case of this type of cargo

a_{X2}, a_{Y2}, a_{Z2}: Reference values of the accelerations in the inclined ship condition, defined in Ch 5, Sec 3, [3.4], calculated in way of:

- the centre of gravity of the compartment, in general
- the centre of gravity of any dry unit cargo, in the case of this type of cargo

C_{FA} : Combination factor, to be taken equal to:

- $C_{FA} = 0,7$ for load case "c"
- $C_{FA} = 1,0$ for load case "d"

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

d_F : Filling level, in m, of a tank, to be taken as the vertical distance, measured with the ship at rest, from the bottom of the tank to the free surface of the liquid

ℓ_C : Longitudinal distance, in m, between transverse watertight bulkheads or transverse wash bulkheads, if any, or between a transverse watertight bulkhead and the adjacent transverse wash bulkhead; to this end, wash bulkheads are those satisfying the requirements in Ch 4, Sec 7, [4]

b_C : Transverse distance, in m, between longitudinal watertight bulkheads or longitudinal wash bulkheads, if any, or between a longitudinal watertight bulkhead and the adjacent longitudinal wash bulkhead; to this end, wash bulkheads are those satisfying the requirements in Ch 4, Sec 7, [4]

d_{TB} : Vertical distance, in m, from the baseline to the tank bottom

d_{AP} : Distance from the top of air pipe to the top of compartment, in m

d_0 : Distance, in m, to be taken equal to:

$d_0 = 0,02\ L$ for $65\ m \le L < 120\ m$

$d_0 = 2,4$ for $L \ge 120$ m.

1 Liquids

1.1 Watertight bulkheads

1.1.1 Still water pressure

The still water pressure to be used in combination with the inertial pressure in [1.1.2] is the greater of the values obtained, in kN/m², from the following formulae:

$p_S = \rho_L\ g\ (z_L - z)$

$p_S = \rho_L\ g\ (z_{TOP} - z) + 100\ p_{PV}$

In no case is it to be taken, in kN/m², less than:

$$p_S = \rho_L g\left(\frac{0,8L_1}{420 - L_1}\right)$$

Table 1 : Watertight bulkheads of liquid compartments - Inertial pressure

Ship condition	Load case	Inertial pressure p_W, in kN/m²
Upright	"a"	No inertial pressure
	"b"	$\rho_L[0,5 a_{X1} \ell_B + a_{Z1}(z_{TOP} - z)]$
Inclined (negative roll angle)	"c"	$\rho_L[a_{TY}(y - y_H) + a_{TZ}(z - z_H) + g(z - z_{TOP})]$
	"d"	

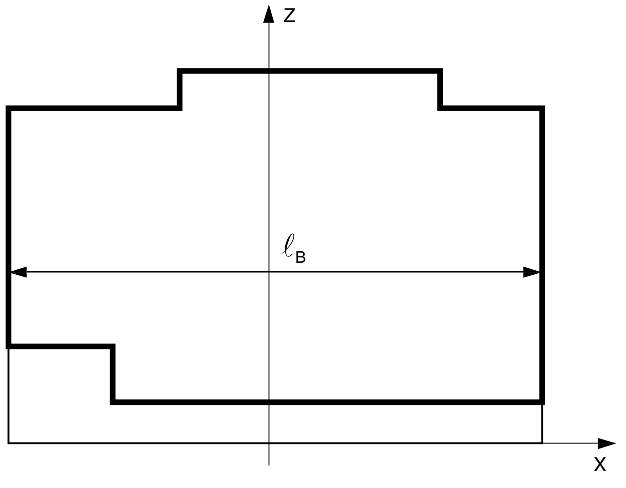
Note 1:

ℓ_B : Longitudinal distance, in m, between the transverse tank boundaries, without taking into account small recesses in the lower part of the tank (see Fig 1)

a_{TY}, a_{TZ} : Y and Z components, in m/s², of the total acceleration vector defined in [1.1.3] for load case "c" and load case "d"

y_H, z_H : Y and Z co-ordinates, in m, of the highest point of the tank in the direction of the total acceleration vector, defined in [1.1.4] for load case "c" and load case "d".

Figure 1 : Upright ship conditions - Distance ℓ_B



1.1.2 Inertial pressure

The inertial pressure is obtained from the formulae in Tab 1 or in Ch 5, App 1 for typical tank arrangements. Moreover, the inertial pressure p_W is to be taken such that:

$p_S + p_W \geq 0$

where p_S is defined in [1.1.1].

1.1.3 Total acceleration vector

The total acceleration vector is the vector obtained from the following formula:

$$\vec{A_T} = \vec{A} + \vec{G}$$

where:

A : Acceleration vector whose absolute values of X, Y and Z components are the longitudinal, transverse and vertical accelerations defined in Ch 5, Sec 3, [3.4]

G : Gravity acceleration vector.

The Y and Z components of the total acceleration vector and the angle it forms with the z direction are defined in Tab 2.

Table 2 : Inclined ship conditions
Y and Z components of the total acceleration vector and angle Φ it forms with the z direction

Components (negative roll angle)		Angle Φ, in rad
a_{TY}, in m/s²	a_{TZ}, in m/s²	
$0,7\ C_{FA}\ a_{Y2}$	$-0,7\ C_{FA}\ a_{Z2} - g$	$\operatorname{atan}\dfrac{a_{TY}}{a_{TZ}}$

1.1.4 Highest point of the tank in the direction of the total acceleration vector

The highest point of the tank in the direction of the total acceleration vector A_T, defined in [1.1.3], is the point of the tank boundary whose projection on the direction forming the angle Φ with the vertical direction is located at the greatest distance from the tank's centre of gravity. It is to be determined for the inclined ship condition, as indicated in Fig 2, where A and G are the vectors defined in [1.1.3] and C is the tank's centre of gravity.

Figure 2 : Inclined ship conditions
Highest point H of the tank in the direction of the total acceleration vector

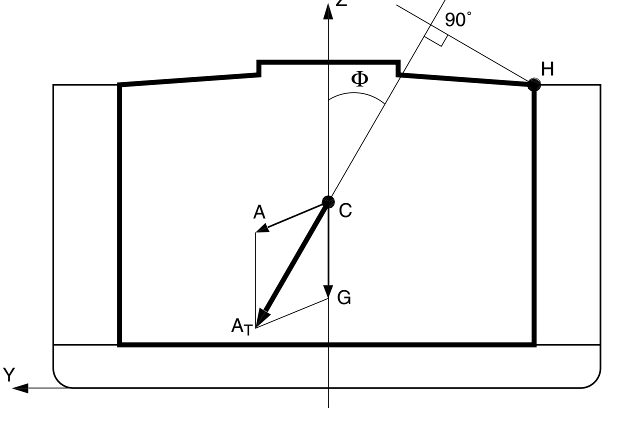


Table 3 : Criteria for the evaluation of the risk of resonance

Ship condition	Risk of resonance if:	Resonance due to:
Upright	$0,6 < \frac{T_X}{T_P} < 1,3$ and $\frac{d_F}{\ell_C} > 0,1$	Pitch
Inclined	$0,8 < \frac{T_Y}{T_R} < 1,2$ and $\frac{d_F}{b_C} > 0,1$	Roll

Note 1:

T_X : Natural period, in s, of the liquid motion in the longitudinal direction:

$$T_X = \sqrt{\frac{4\pi\ell_S}{g\tanh\frac{\pi d_F}{\ell_S}}}$$

T_Y : Natural period, in s, of the liquid motion in the transverse direction:

$$T_Y = \sqrt{\frac{4\pi b_S}{g\tanh\frac{\pi d_F}{b_S}}}$$

ℓ_S : Length, in m, of the free surface of the liquid, measured horizontally with the ship at rest and depending on the filling level d_F, as shown in Fig 3; in this figure, wash bulkheads are those satisfying the requirements in Ch 4, Sec 7, [4]

b_S : Breadth, in m, of the free surface of the liquid, measured horizontally with the ship at rest and depending on the filling level d_F, as shown in Fig 4 for ships without longitudinal watertight or wash bulkheads; for ships fitted with longitudinal watertight or wash bulkheads (see Fig 5), b_S is delimited by these bulkheads (to this end, wash bulkheads are those satisfying the requirements in Ch 4, Sec 7, [4])

T_P : Pitch period, in s, defined in Ch 5, Sec 3, [2]

T_R : Roll period, in s, defined in Ch 5, Sec 3, [2].

2 Partly filled tanks intended for the carriage of liquid cargoes or ballast

2.1 Application

2.1.1 Membrane tanks of liquefied gas carriers

Sloshing pressure in membrane tanks of ships having the service notation **liquefied gas carrier** or **LNG bunkering ship** is defined in Pt D, Ch 9, App 1, [2].

2.1.2 Other tanks

Sloshing assessment in tanks other than membrane tanks of ships having the service notation **liquefied gas carrier** or **LNG bunkering ship** is to be carried out as specified in [2.2] to [2.5].

2.2 Evaluation of the risk of resonance

2.2.1 Where tanks are partly filled at a level d_F such as $0,1H \le d_F \le 0,95H$, the risk of resonance between:

- the ship pitch motion and the longitudinal motion of the liquid inside the tank, for upright ship condition
- the ship roll motion and the transverse motion of the liquid inside the tank, for inclined ship condition

is to be evaluated on the basis of the criteria specified in Tab 3.

2.2.2 The Society may accept that the risk of resonance is evaluated on the basis of dynamic calculation procedures, where deemed necessary in relation to the tank's dimensions and the ship's characteristics. The calculations are to be submitted to the Society for approval.

Figure 3 : Length ℓ_S of the free surface of the liquid

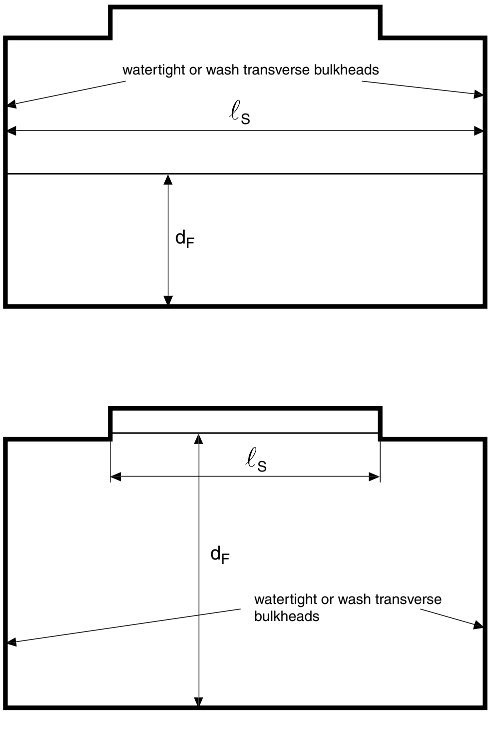


Figure 4 : Breadth b_S of the free surface of the liquid, for ships without longitudinal bulkheads

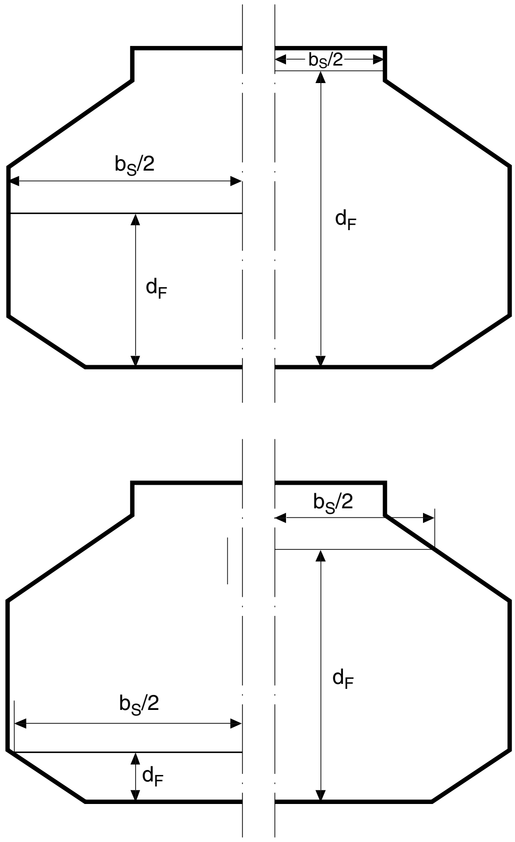
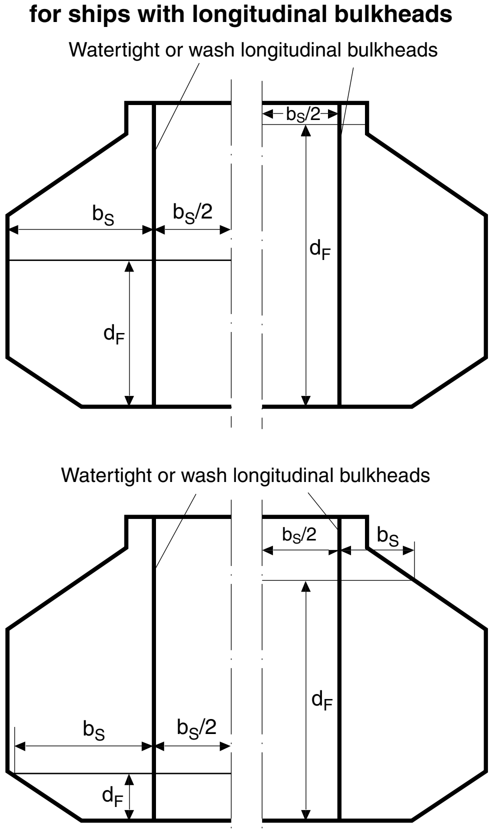


Figure 5 : Breadth b_S of the free surface of the liquid, for ships with longitudinal bulkheads



2.3 Still water pressure

2.3.1 Still water pressure to be used in combination with the dynamic sloshing pressure

The still water pressure to be used in combination with the dynamic sloshing pressure defined in [2.4] is to be obtained, in kN/m², from the following formulae:

- $p_S = \rho_L\, g\, (d_F + d_{TB} - z) + 100\, p_{PV}$ for $z < d_F + d_{TB}$
- $p_S = 100\, p_{PV}$ for $z \geq d_F + d_{TB}$

2.3.2 Still water pressure to be used in combination with the dynamic impact pressure

The still water pressure to be used in combination with the dynamic impact pressure defined in [2.5] is to be obtained, in kN/m², from the following formulae:

- $p_S = \rho_L\, g\, (0{,}7\, H + d_{TB} - z) + 100\, p_{PV}$ for $z < 0{,}7\, H + d_{TB}$
- $p_S = 100\, p_{PV}$ for $z \geq 0{,}7\, H + d_{TB}$

2.4 Dynamic sloshing pressure

2.4.1 Upright ship condition

Where there is a risk of resonance in upright ship condition for a filling level d_F, the dynamic sloshing pressure p_{SL} calculated according to [2.4.3] is to be considered as acting on transverse bulkheads which form tank boundaries, in the area extended vertically 0,2 d_F above and below d_F (see Fig 6).

However, the dynamic sloshing pressure may not be considered where there is a risk of resonance for filling levels d_F lower than 0,5 H.

Where tank bottom transverses or wash transverse bulkheads are fitted, the sloshing pressure calculated according to [2.4.4] is to be considered as acting on them.

The Society may also require the dynamic sloshing pressure to be considered when there is no risk of resonance, but the tank arrangement is such that $\ell_C / L > 0{,}15$.

Figure 6 : Sloshing pressure p_{SL}

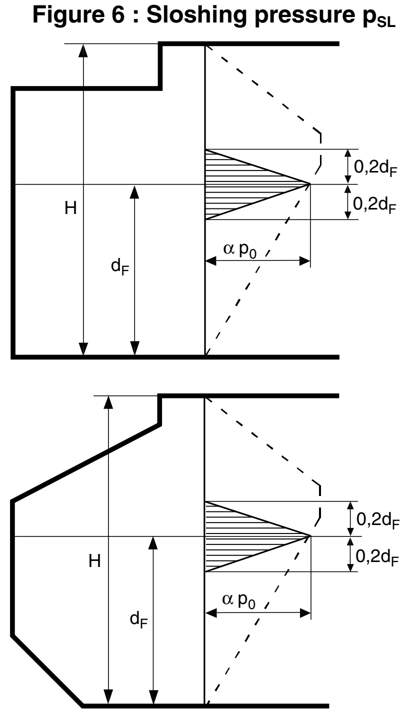


Table 4 : Reference pressure for calculation of sloshing pressures

Ship condition	Reference pressure p_0, in kN/m²	Meaning of symbols used in the definition of p_0
Upright	$0,84\varphi_U\rho_L g S \ell_C A_P$	φ_U : Coefficient defined as follows: φ_U = 1,0 in the case of smooth tanks or tanks with bottom transverses whose height, in m, measured from the tank bottom, is less than 0,1 H φ_U = 0,4 in the case of tanks with bottom transverses whose height, in m, measured from the tank bottom, is not less than 0,1 H S : Coefficient defined as follows: S = 1 + 0,02 L if $L \le 200$ m S = 3 + 0,01 L if $L > 200$ m A_P : Pitch amplitude, in rad, defined in Ch 5, Sec 3, [2].
Inclined	$1,93\varphi_I\rho_L g b_C A_R\sqrt{B}\left(1-0,3\dfrac{B}{b_C}\right)$	φ_I : Coefficient defined as follows: • if $b_C / B \le 0,3$: $\varphi_I = 0$ • if $b_C / B > 0,3$: φ_I = 1,0 in the case of smooth tanks or tanks with bottom girders whose height, in m, measured from the tank bottom, is less than 0,1 H φ_I = 0,4 in the case of tanks with bottom girders whose height, in m, measured from the tank bottom, is not less than 0,1 H A_R : Roll amplitude, in rad, defined in Ch 5, Sec 3, [2].

2.4.2 Inclined ship condition

Where there is a risk of resonance in inclined ship condition for a filling level d_F, the dynamic sloshing pressure p_{SL} calculated according to [2.4.3] is to be considered as acting on longitudinal bulkheads, inner sides or sides which, as the case may be, form tank boundaries, in the area extended vertically 0,2 d_F above and below d_F (see Fig 6).

However, the dynamic sloshing pressure may not be considered where there is a risk of resonance for filling levels d_F lower than 0,5 H.

If sloped longitudinal topsides are fitted, they are to be considered as subjected to the sloshing pressure if their height is less than 0,3 H.

2.4.3 Sloshing pressure

Where there is a risk of resonance for a filling level d_F, the sloshing pressure is obtained, in kN/m², from the following formulae (see Fig 6):

$p_{SL} = 0$ for $z \le 0,8d_F + d_{TB}$

$p_{SL} = \left(5\dfrac{z-d_{TB}}{d_F} - 4\right)\alpha p_0$ for $0,8d_F + d_{TB} < z \le d_F + d_{TB}$

$p_{SL} = \left(6-5\dfrac{z-d_{TB}}{d_F}\right)\alpha p_0$ for $d_F + d_{TB} < z < 1,2d_F + d_{TB}$

$p_{SL} = 0$ for $z \ge 1,2d_F + d_{TB}$

where:

p_0 : Reference pressure defined in Tab 4 for upright and inclined ship conditions

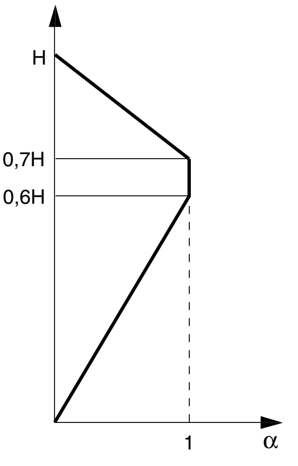
α : Coefficient taken equal to (see Fig 7):

$\alpha = \dfrac{d_F}{0,6H}$ for $d_F < 0,6H$

$\alpha = 1$ for $0,6H \le d_F \le 0,7H$

$\alpha = \dfrac{H-d_F}{0,3H}$ for $d_F > 0,7H$

Figure 7 : Coefficient α



2.4.4 Sloshing pressure on tank bottom transverses in the case of resonance in upright ship condition

Where there is a risk of resonance in upright ship condition, the sloshing pressure to be considered as acting on tank bottom transverses is obtained, in kN/m², from the following formula:

$$p_{SL,W} = 0,84\rho_L g(1,95 - 0,12n)(z - d_{TB})$$

where n is the number of bottom transverses in the tank.

2.4.5 Alternative methods

The Society may accept that the dynamic sloshing pressure is evaluated on the basis of dynamic calculation procedures, where deemed necessary in relation to the tank's dimensions and the ship's characteristics. The calculations are to be submitted to the Society for verification.

2.5 Dynamic impact pressure

2.5.1 Upright ship condition

Where there is a risk of resonance in upright ship condition, for tanks having arrangements such that ℓ_S is greater than 0,13 L at any filling level d_F from 0,05 H to 0,95 H, the dynamic impact pressure due to liquid motions is to be considered as acting on:

- transverse bulkheads which form tank boundaries, in the area extended vertically 0,15 H from the tank top
- the tank top in the area extended longitudinally 0,3 ℓ_C from the above transverse bulkheads.

However, the dynamic impact pressure may not be considered for filling levels d_F lower than 0,5 H.

Where the upper part of a transverse bulkhead is sloped, the impact pressure is to be considered as acting on the sloped part of the transverse bulkhead and the tank top (as the case may be) in the area extended longitudinally 0,3 ℓ_C from the transverse bulkhead.

The impact pressure is obtained, in kN/m², from the following formula:

$$p_{I,U} = \varphi_U \rho_L g \ell_C A_P \left(0{,}9 + \frac{\ell_C}{L}\right)(5 + 0{,}015L)$$

where:

φ_U : Coefficient defined in Tab 4

A_P : Pitch amplitude, in rad, defined in Ch 5, Sec 3, [2].

Where the upper part of a transverse bulkhead is sloped, the pressure $p_{I,U}$ may be multiplied by the coefficient ϕ obtained from the following formula:

$$\phi = 1 - \frac{h_T}{0{,}3H} \quad \text{to be taken not less than zero}$$

where:

h_T : Height, in m, of the sloped part of the transverse bulkhead.

2.5.2 Inclined ship condition

Where there is a risk of resonance in inclined ship condition, for tanks having arrangements such that b_S is greater than 0,56 B at any filling level d_F from 0,05 H to 0,95 H, the dynamic impact pressure due to liquid motions is to be considered as acting on:

- longitudinal bulkheads, inner sides or sides which, as the case may be, form tank boundaries, in the area extended vertically 0,15 H from the tank top
- the tank top in the area extended transversely 0,3b_C from the above longitudinal bulkheads, inner sides or sides.

However, the dynamic impact pressure may not be considered for filling levels d_F lower than 0,5H.

Where the upper part of a longitudinal bulkhead, inner side or side is sloped, the impact pressure is to be considered as acting on this sloped part and the tank top (as the case may be) in the area extended transversely 0,3 b_C from the longitudinal bulkhead, inner side or side.

The impact pressure is obtained, in kN/m², from the following formula:

$$p_{I,I} = 0{,}61 \varphi_I \rho_L g (0{,}75B - 8) b_C A_R$$

where:

φ_I : Coefficient defined in Tab 4.

Where the upper part of a longitudinal bulkhead, inner side or side is sloped, the pressure $p_{I,I}$ may be multiplied by the coefficient ϕ obtained from the following formula:

$$\phi = 1 - \frac{h_T}{0{,}3H} \quad \text{to be taken not less than zero}$$

where:

h_T : Height, in m, of the sloped part of the longitudinal bulkhead, inner side or side.

2.5.3 Alternative methods

The Society may accept that the dynamic impact pressure is evaluated on the basis of dynamic calculation procedures, where deemed necessary in relation to the tank's dimensions and the ship's characteristics. The calculations are to be submitted to the Society for verification.

3 Dry bulk cargoes

3.1 Still water and inertial pressures

3.1.1 Pressures transmitted to the hull structures

The still water and inertial pressures (excluding those acting on the sloping plates of topside tanks, which may be taken equal to zero) are obtained, in kN/m², as specified in Tab 5.

3.1.2 Rated upper surface of the bulk cargo

The Z co-ordinate of the rated upper surface of the bulk cargo is obtained, in m, from the following formula (see Fig 8):

$$z_B = \frac{\dfrac{M_C}{\rho_B \ell_H} + \dfrac{V_{LS}}{\ell_H} + (h_{HT} - h_{DB}) b_{HT}}{2 y_{HT}} + h_{DB}$$

where:

M_C : Mass of cargo, in t, in the hold considered

ℓ_H : Length, in m, of the hold, to be taken as the longitudinal distance between the transverse bulkheads which form boundaries of the hold considered

V_{LS} : Volume, in m³, of the transverse bulkhead lower stool (above the inner bottom), to be taken equal to zero in the case of bulkheads fitted without lower stool

h_{HT} : Height, in m, of the hopper tank, to be taken as the vertical distance from the baseline to the top of the hopper tank

h_{DB} : Height, in m, of the double bottom, to be taken as the vertical distance from the baseline to the inner bottom

b_{HT} : Breadth, in m, of the hopper tank, to be taken as the transverse distance from the outermost double bottom girder to the outermost point of the hopper tank

y_{HT} : Half breadth, in m, of the hold, measured at the middle of ℓ_H and at a vertical level corresponding to the top of the hopper tank.

Table 5 : Dry bulk cargoes - Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water		$p_S = \rho_B g (z_B - z)\left\{(\sin\alpha)^2\left[\tan\left(45^\circ - \frac{\varphi}{2}\right)\right]^2 + (\cos\alpha)^2\right\}$
Upright	"a"	No inertial pressure
	"b"	$p_W = \rho_B a_{Z1} (z_B - z)\left\{(\sin\alpha)^2\left[\tan\left(45^\circ - \frac{\varphi}{2}\right)\right]^2 + (\cos\alpha)^2\right\}$
Inclined	"c"	The inertial pressure transmitted to the hull structures in inclined condition may generally be disregarded. Specific cases in which this simplification is not deemed permissible by the Society are considered individually.
	"d"	

Note 1:

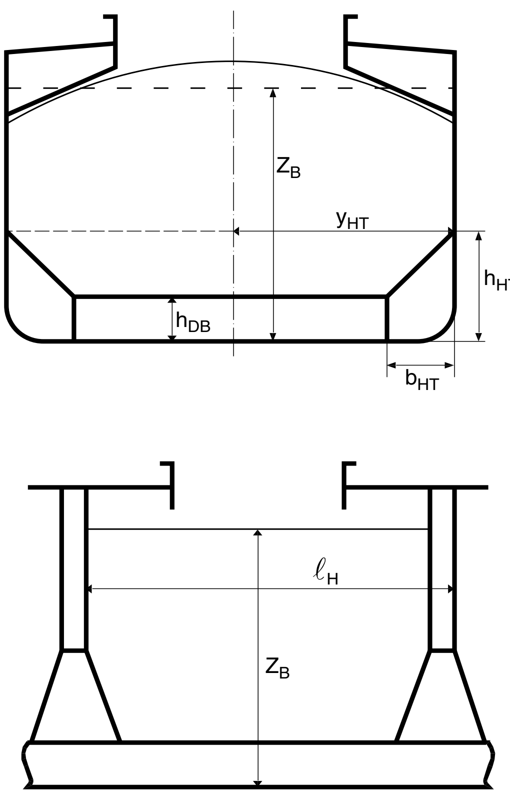
z_B : Z co-ordinate, in m, of the rated upper surface of the bulk cargo (horizontal ideal plane of the volume filled by the cargo); see [3.1.2]

α : Angle, in degrees, between the horizontal plane and the surface of the hull structure to which the calculation point belongs

φ : Angle of repose, in degrees, of the bulk cargo (considered drained and removed); in the absence of more precise evaluation, the following values may be taken:

- $\varphi = 30°$ in general
- $\varphi = 35°$ for iron ore
- $\varphi = 25°$ for cement.

Figure 8 : Rated upper surface of the bulk cargo



4 Dry uniform cargoes

4.1 Still water and inertial pressures

4.1.1 General

The still water and inertial pressures are obtained, in kN/m², as specified in Tab 6.

Table 6 : Dry uniform cargoes Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water		The value of p_S is generally specified by the Designer; in any case, it may not be taken less than 10 kN/m². When the value of p_S is not specified by the Designer, it may be taken, in kN/m², equal to 6,9 h_{TD} , where h_{TD} is the compartment 'tweendeck height at side, in m.
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_{W,Z} = p_S \frac{a_{Z1}}{g}$ in z direction
Inclined (negative roll angle)	"c"	$p_{W,Y} = p_S \frac{C_{FA} a_{Y2}}{g}$ in y direction
	"d"	$p_{W,Z} = p_S \frac{C_{FA} a_{Z2}}{g}$ in z direction

4.1.2 Ships with the additional service feature heavycargo

For ships with the additional service feature **heavycargo [AREA1, X1 kN/m² - AREA2, X2 kN/m² - ....]** (see Pt A, Ch 1, Sec 2, [4.2.2]), the values of p_S, in kN/m², are to be specified by the Designer for each AREAi, according to [4.1.1], and introduced as Xi values in the above service feature.

5 Dry unit cargoes

5.1 Still water and inertial forces

5.1.1 The still water and inertial forces transmitted to the hull structures are to be determined on the basis of the forces obtained, in kN, as specified in Tab 7, taking into account the elastic characteristics of the lashing arrangement and/or the structure which contains the cargo.

Table 7 : Dry unit cargoes - Still water and inertial forces

Ship condition	Load case	Still water force F_S and inertial force F_W, in kN
Still water		$F_S = M\ g$
Upright (positive heave motion)	"a"	No inertial force
	"b"	$F_{W,X} = M\ a_{X1}$ in x direction $F_{W,Z} = M\ a_{Z1}$ in z direction
Inclined (negative roll angle)	"c"	$F_{W,Y} = M\ C_{FA}\ a_{Y2}$ in y direction
	"d"	$F_{W,Z} = M\ C_{FA}\ a_{Z2}$ in z direction

Table 8 : Wheeled cargoes - Still water and inertial forces

Ship condition	Load case	Still water force F_S and inertial force F_W, in kN
Still water **(1)** **(2)**		$F_S = M\ g$
Upright (positive heave motion) **(1)**	"a"	No inertial force
	"b"	$F_{W,Z} = \alpha\ M\ a_{Z1}$ in z direction
Inclined (negative roll angle) **(2)**	"c"	$F_{W,Y} = M\ C_{FA}\ a_{Y2}$ in y direction
	"d"	$F_{W,Z} = \alpha\ M\ C_{FA}\ a_{Z2}$ in z direction
Loading/ unloading **(3)**		$F_{W,X} = 0{,}035\ M\ g$ in x direction $F_{W,Y} = 0{,}087\ M\ g$ in y direction $F_{W,Z} = 0{,}100\ M\ g$ in z direction

(1) This condition defines the force, applied by one wheel, to be considered for the determination of scantlings of plating, ordinary stiffeners and primary supporting members, as defined in Part B, Chapter 7, where:

α : Coefficient taken equal to:
- 0,5 in general
- 1,0 for landing gears of trailers

M : Mass, in t, taken equal to

$$M = \frac{Q_A}{n_W}$$

Q_A : Axle load, in t. For fork-lift trucks, the value of Q_A is to be taken equal to the total mass of the vehicle, including that of the cargo handled, applied to one axle only.

n_W : Number of wheels for the axle considered.

(2) This condition is to be considered for the racking analysis of ships with the service notation **ro-ro cargo ship**, **PCT carrier** or **ro-ro passenger ship**, as defined in Ch 7, App 1, with M taken equal to the mass, in t, of wheeled loads located on the structural member under consideration.

(3) Loading/unloading condition is to be considered only for fork-lift trucks.

6 Wheeled cargoes

6.1 Still water and inertial forces

6.1.1 General

Caterpillar trucks and unusual vehicles are considered by the Society on a case by case basis.

The load supported by the crutches of semi-trailers, handling machines and platforms is considered by the Society on a case by case basis.

6.1.2 Tyred vehicles

The forces transmitted through the tyres are comparable to pressure uniformly distributed on the tyre print, whose dimensions are to be indicated by the Designer together with information concerning the arrangement of wheels on axles, the load per axles and the tyre pressures.

With the exception of dimensioning of plating, such forces may be considered as concentrated in the tyre print centre.

The still water and inertial forces transmitted to the hull structures are to be determined on the basis of the forces obtained, in kN, as specified in Tab 8.

6.1.3 Non-tyred vehicles

The requirements of [6.1.2] also apply to tracked vehicles; in this case the print to be considered is that below each wheel or wheelwork.

For vehicles on rails, all the forces transmitted are to be considered as concentrated at the contact area centre.

7 Accommodation

7.1 Still water and inertial pressures

7.1.1 The still water and inertial pressures transmitted to the deck structures are obtained, in kN/m², as specified in Tab 9.

Table 9 : Accommodation Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water		The value of p_S is to be defined by the Designer, without being taken less than the values in Tab 10 depending on the type of the accommodation compartment.
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_W = p_S \frac{a_{Z1}}{g}$
Inclined	"c"	The inertial pressure transmitted to the deck structures in inclined condition may generally be disregarded. Specific cases in which this simplification is not deemed permissible by the Society are considered individually.
	"d"	

Table 10 : Minimum still water deck pressure in accommodation compartments

Type of accommodation compartment	p_S , in kN/m²
Large public spaces, such as: restaurants, halls, cinemas, lounges	5,0
Large rooms, such as: • rooms with fixed furniture • games and hobbies rooms, hospitals	3,0
Cabins	3,0
Other compartments	2,5

8 Machinery

8.1 Still water and inertial pressures

8.1.1 The still water and inertial pressures transmitted to the deck structures are obtained, in kN/m², as specified in Tab 11.

Table 11 : Machinery Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W , in kN/m²
Still water		The value of p_S is to be defined by the Designer, without being taken less than 10 kN/m².
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_W = p_S \frac{a_{Z1}}{g}$
Inclined	"c"	The inertial pressure transmitted to the deck structures in inclined condition may generally be disregarded. Specific cases in which this simplification is not deemed permissible by the Society are considered individually.
	"d"	

9 Flooding

9.1 Still water and inertial pressures

9.1.1 Ships for which damage stability calculations are required

Unless otherwise specified, the still water pressure p_{SF}, in kN/m², and the inertial pressure p_{WF}, in kN/m², to be considered as acting on structural watertight elements defined as per Internal Watertight Plan and located below the deepest equilibrium waterline (excluding side shell structural elements) which constitute boundaries intended to stop vertical and horizontal flooding are obtained from the following formulae:

- $p_{SF} = \rho\ g\ d_F$ without being taken less than 0,4 g d_0
- $p_{WF} = 0{,}6\ \rho\ a_{Z1}\ d_F$ without being taken less than 0,4 g d_0

where:

d_F : Distance, in m, from the calculation point to the deepest equilibrium waterline.

The deepest equilibrium waterlines are to be provided by the Designer under his own responsibility.

9.1.2 Ships for which damage stability calculations are not required

Unless otherwise specified, the still water pressure p_{SF}, in kN/m², and the inertial pressure p_{WF}, in kN/m², to be considered as acting on structural watertight elements (excluding side shell structural elements) which constitute boundaries intended to stop vertical and horizontal flooding are obtained from the formulae in Tab 12.

10 Testing

10.1 Still water pressures

10.1.1 The still water pressure to be considered as acting on plates and stiffeners subject to tank testing is obtained, in kN/m², from the formulae in Tab 13.

No inertial pressure is to be considered as acting on plates and stiffeners subject to tank testing.

11 Flow-through ballast water exchange

11.1 Still water pressures

11.1.1 The still water pressure p_{SB}, in kN/m², to be considered as acting on watertight elements of ballast tanks subject to flow-through ballast water exchange is to be obtained from the following formula:

$p_{SB} = \rho_L\ g\ (z_{TOP} - z + d_{AP}) + p_{drop}$

11.2 Inertial pressures

11.2.1 The inertial pressure p_{WB}, in kN/m², to be considered for flow-through ballast water exchange is to be obtained by obtained from the following formula:

$p_{WB} = 0.8\ p_W$

where:

p_W : inertial pressure as defined in [1.1.2]

Table 12 : Flooding - Still water and inertial pressures for ships for which damage stability calculations are not required

Still water pressure p_{SF} , in kN/m²	Inertial pressure p_{WF} , in kN/m²
• Compartment located below bulkhead deck: $\rho\ g\ (z_{BD} - z)$ without being taken less than 0,4 g d_0 • Compartment located immediately above the bulkhead deck: 0,32 g d_0	• Compartment located below bulkhead deck: $0{,}6\ \rho\ a_{Z1}\ (z_{BD} - z)$ without being taken less than 0,4 g d_0 • Compartment located immediately above the bulkhead deck: 0,32 g d_0

Note 1:
z_{BD} : Z co-ordinate, in m, of the bulkhead deck.

Table 13 : Testing - Still water pressures

Compartment or structure to be tested	Still water pressure p_{ST} , in kN/m²
Double bottom tanks	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ $p_{ST} = 10\ (z_{BD} - z)$
Double side tanks	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ $p_{ST} = 10\ (z_{BD} - z)$
Deep tanks other than those listed elsewhere in this Table	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$
Cargo oil tanks	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 holds of ships with service notation **bulk carrier** or **bulk carrier ESP** or **self-unloading bulk carrier ESP**	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ (z_h - z)$ where: z_h : Z co-ordinate, in m, of the top of hatch coaming
Peak tanks	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$
Chain locker	$p_{ST} = 10\ (z_{CP} - z)$ where: z_{CP} : Z co-ordinate, in m, of the top of chain pipe
Ballast ducts	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + 10\ p_{PV}]$ Ballast pump maximum pressure
Integral or independent cargo tanks of ships with service notation **chemical tanker**	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ $p_{ST} = 10\ [(z_{TOP} - z) + 10\ p_{PV}]$
Fuel oil tanks	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ $p_{ST} = 10\ [(z_{TOP} - z) + 10\ p_{PV}]$ $p_{ST} = 10\ (z_{BD} - z)$
Note 1: z_{BD} : Z co-ordinate, in m, of the bulkhead deck z_{TOP} : Z co-ordinate, in m, of the deck forming the top of the tank excluding any hatchways.	

APPENDIX 1 INERTIAL PRESSURE FOR TYPICAL TANK ARRANGEMENT

1 Liquid cargoes and ballast - Inertial pressure

1.1 Introduction

1.1.1 Ch 5, Sec 6, [1] defines the criteria to calculate the inertial pressure p_W induced by liquid cargoes and ballast in any type of tank. The relevant formulae are specified in Ch 5, Sec 6, Tab 1 and entail the definition of the highest point of the tank in the direction of the total acceleration vector. As specified in Ch 5, Sec 6, [1.1.4], this point depends on the geometry of the tank and the values of the acceleration. For typical tank arrangements, the highest point of the tank in the direction of the total acceleration vector can easily be identified and the relevant formulae written using the tank geometric characteristics.

1.1.2 This Appendix provides the formulae for calculating the inertial pressure p_W in the case of typical tank arrangements.

1.2 Formulae for the inertial pressure calculation

1.2.1 For typical tank arrangements, the inertial pressure transmitted to the hull structures at the calculation point P in inclined ship condition may be obtained from the formulae in Tab 1, obtained by applying to those tanks the general formula in Ch 5, Sec 6, Tab 1.

Table 1 : Liquid cargoes and ballast - Inertial pressure for typical tank arrangements

Ship condition	Load case	Inertial pressure p_W , in kN/m²
Inclined (negative roll angle)	"c"	$0,7 C_{FA} \rho_L (a_{Y2} b_L + a_{Z2} d_H)$
	"d"	

Note 1:
C_{FA} : Combination factor, to be taken equal to:
- C_{FA} = 0,7 for load case "c"
- C_{FA} = 1,0 for load case "d"

ρ_L : Density, in t/m³, of the liquid cargo carried
a_{Y2}, a_{Z2} : Reference values of the acceleration in the inclined ship condition, defined in Ch 5, Sec 3, [3.4], calculated in way of the centre of gravity of the tank
b_L, d_H : Transverse and vertical distances, in m, to be taken as indicated in Fig 1 to Fig 6 for various types of tanks; for the cases in Fig 1 to Fig 4, where the central cargo area is divided into two or more tanks by longitudinal bulkheads, b_L and d_H for calculation points inside each tank are to be taken as indicated in Fig 5 for the double side. The angle Φ which appears in Fig 3 and Fig 4 is defined in Ch 5, Sec 6, Tab 2.

Figure 1 : Distances b_L and d_H

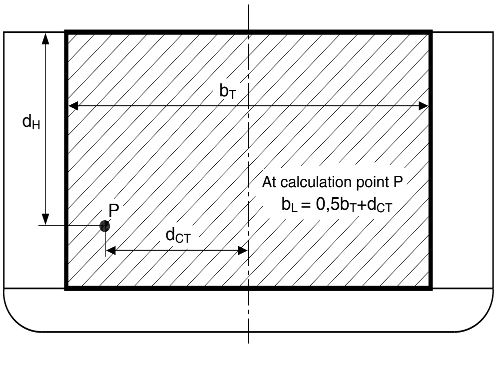


Figure 2 : Distances b_L and d_H

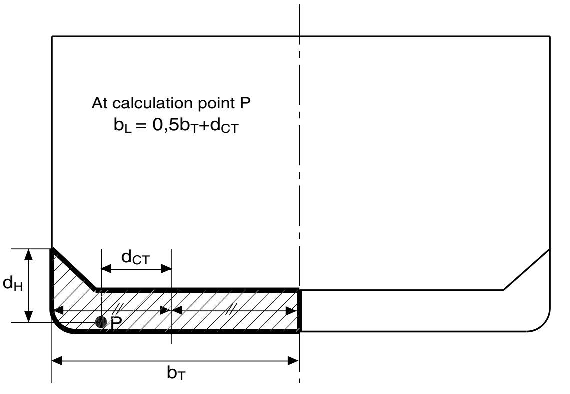


Figure 3 : Distances b_L and d_H

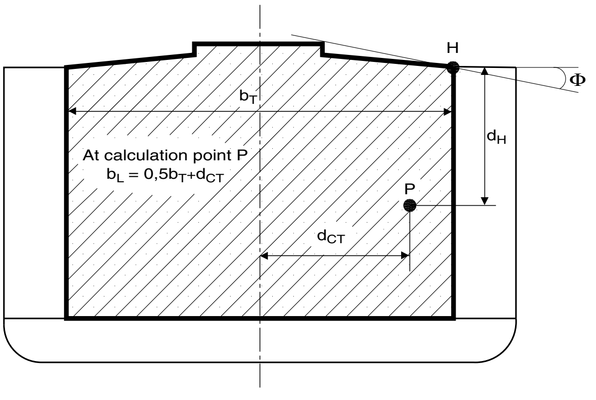


Figure 5 : Distances b_L and d_H

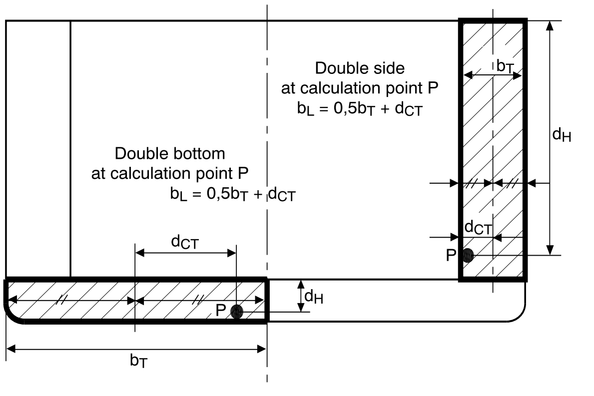


Figure 4 : Distances b_L and d_H

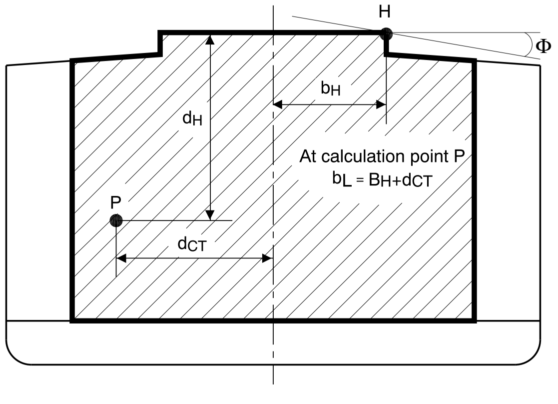
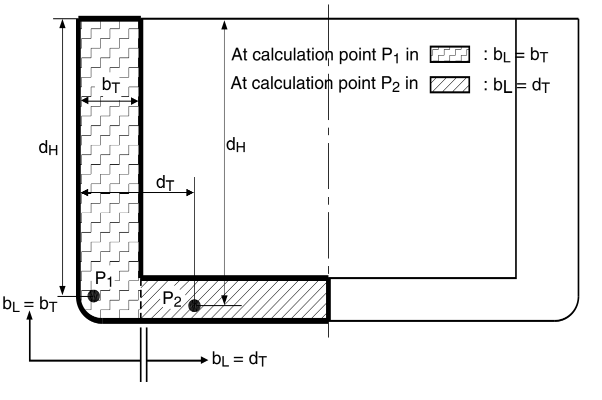


Figure 6 : Distances b_L and d_H



Part B

Hull and Stability

Chapter 6

HULL GIRDER STRENGTH

Symbols used in this Chapter

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

- for steels in general:

  $E = 2,06.10^5$ N/mm^2

- for stainless steels:

  $E = 1,95.10^5$ N/mm^2

- for aluminium alloys:

  $E = 7,0.10^4$ N/mm^2

M_{SW} : Still water bending moment, in kN.m:

- in hogging conditions:

  $M_{SW} = M_{SW,H}$

- in sagging conditions:

  $M_{SW} = M_{SW,S}$

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2]

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2], when the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0

M_{WV} : Vertical wave bending moment, in kN.m:

- in hogging conditions:

  $M_{WV} = M_{WV,H}$

- in sagging conditions:

  $M_{WV} = M_{WV,S}$

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1]

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1]

g : Gravity acceleration, in m/s^2:

$g = 9,81$ m/s^2.

SECTION 1 STRENGTH CHARACTERISTICS OF THE HULL GIRDER TRANSVERSE SECTIONS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

1 Application

1.1

1.1.1 This Section specifies the criteria for calculating the hull girder strength characteristics to be used for the checks in Ch 6, Sec 2 and Ch 6, Sec 3, in association with the hull girder loads specified in Ch 5, Sec 2.

2 Calculation of the strength characteristics of hull girder transverse sections

2.1 Hull girder transverse sections

2.1.1 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 [2.2], taking into account the requirements in [2.1.2] to [2.1.9].

These members are to be considered as having (see also Ch 4, Sec 2):

- gross scantlings, when the hull girder strength characteristics to be calculated are used for the yielding checks in Ch 6, Sec 2
- net scantlings, when the hull girder strength characteristics to be calculated are used for the ultimate strength checks in Ch 6, Sec 3 and for calculating the hull girder stresses for the strength checks of plating, ordinary stiffeners and primary supporting members in Part B, Chapter 7.

2.1.2 Continuous trunks and continuous longitudinal hatch coamings

Continuous trunks and continuous longitudinal hatch commons may be included in the hull girder transverse sections, provided they are effectively supported by longitudinal bulkheads or primary supporting members.

2.1.3 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 [2.1.2]) may be included in the hull girder transverse sections.

2.1.4 Longitudinal girders between hatchways

Where longitudinal girders are fitted between hatchways, the sectional area that can be included in the hull girder transverse sections is obtained, in m², from the following formula:

$$A_{EFF} = A_{LG}\, a$$

where:

A_{LG} : Sectional area, in m², of longitudinal girders

a : Coefficient:

- for longitudinal girders effectively supported by longitudinal bulkheads or primary supporting members:

  $a = 1$

- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0 / r \le 60$:

  $$a = 0{,}6\left(\frac{s}{b_1} + 0{,}15\right)^{0{,}5}$$

- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0 / r > 60$:

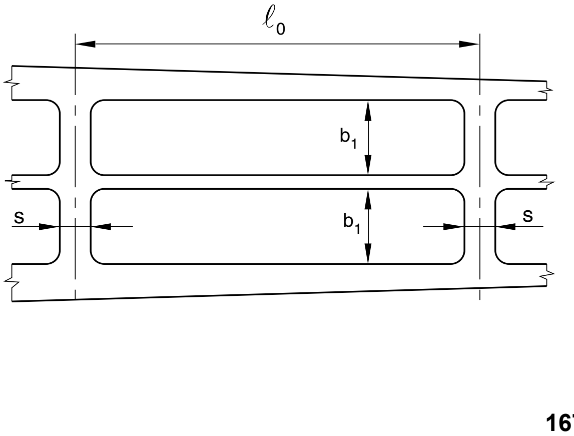
  $a = 0$

ℓ_0 : Span, in m, of longitudinal girders, to be taken as shown in Fig 1

r : Minimum radius of gyration, in m, of the longitudinal girder transverse section

s, b_1 : Dimensions, in m, defined in Fig 1.

Figure 1 : Longitudinal girders between hatchways



2.1.5 Longitudinal bulkheads with vertical corrugations

Longitudinal bulkheads with vertical corrugations may not be included in the hull girder transverse sections.

2.1.6 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/mm², the steel equivalent sectional area that may be included in the hull girder transverse sections is obtained, in m², from the following formula:

$$A_{SE} = \frac{E}{2{,}06.10^5} A_M$$

where:

A_M : Sectional area, in m², of the member under consideration.

2.1.7 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.

2.1.8 Small openings

Smaller openings than those in [2.1.7] 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:

$\Sigma b_S \le 0{,}06\,(B - \Sigma b)$

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 2

Σb : Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Fig 2

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.

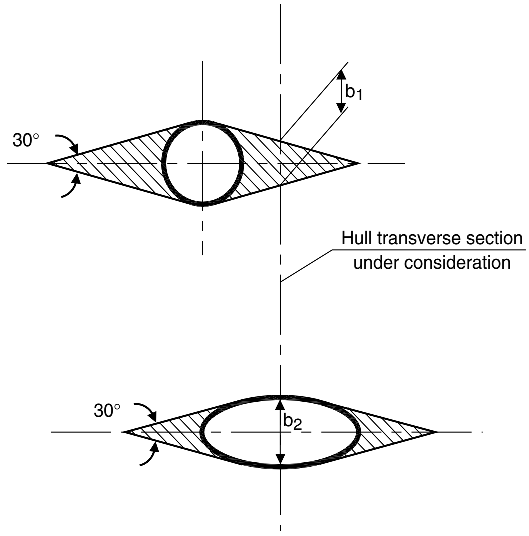
Additionally, individual small openings which do not comply with the arrangement requirements given in Ch 4, Sec 6, [6.1], are to be deducted from the sectional areas included in the hull girder transverse sections.

2.1.9 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, defined in Ch 4, Sec 3.

Otherwise, the excess is to be deducted from the sectional area or compensated.

Figure 2 : Calculation of Σb and Σb_S



b1 and b2 included in Σb and Σbs

2.1.10 Bilge keels

Bilge keels may not be included in the hull girder transverse sections, as they are considered not contributing to the hull girder sectional area.

2.2 Strength deck

2.2.1 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.

2.2.2 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, through a finite element analysis of the whole ship, which takes into account the general arrangement of the longitudinal elements (side, decks, bulkheads).

The presence of openings in the side shell and longitudinal bulkheads is to be taken into account in the analysis. This may be done in two ways:

- by including these openings in the finite element model
- by assigning to the plate panel between the side frames beside each opening an equivalent thickness, in mm, obtained from the following formula:

$$t_{EQ} = 10^3 \left[\ell_P \left(\frac{Gh^2}{12EI_J} + \frac{1}{A_J} \right) \right]^{-1}$$

where (see Fig 3):

ℓ_P : Longitudinal distance, in m, between the frames beside the opening

h : Height, in m, of openings

I_J : Moment of inertia, in m⁴, of the opening jamb about the transverse axis y-y

A_J : Shear area, in m², of the opening jamb in the direction of the longitudinal axis x-x

G : Coulomb's modulus, in N/mm², of the material used for the opening jamb, to be taken equal to:

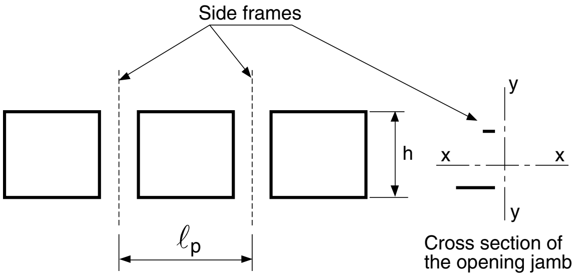
- for steels:

  $G = 8{,}0.10^4$ N/mm²

- for aluminium alloys:

  $G = 2{,}7.10^4$ N/mm².

Figure 3 : Side openings



2.3 Section modulus

2.3.1 The section modulus at any point of a hull transverse section is obtained, in m³, from the following formula:

$$Z_A = \frac{I_Y}{|z - N|}$$

where:

I_Y : Moment of inertia, in m⁴, of the hull transverse section defined in [2.1], 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 2, [4]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section defined in [2.1], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4].

2.3.2 The section moduli at bottom and at deck are obtained, in m³, 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 [2.3.1]

V_D : Vertical distance, in m:

- in general:

  $V_D = z_D - N$

  where:

  z_D : Z co-ordinate, in m, of strength deck, defined in [2.2], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

- if continuous trunks or hatch coamings are taken into account in the calculation of I_Y, as specified in [2.1.2]:

$$V_D = (z_T - N)\left(0{,}9 + 0{,}2\frac{y_T}{B}\right) \geq z_D - N$$

  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 2, [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 [2.1.3], 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 2, [4].

2.4 Moments of inertia

2.4.1 The moments of inertia I_Y and I_Z, in m⁴, are those, calculated about the horizontal and vertical neutral axes, respectively, of the hull transverse sections defined in [2.1].

2.5 First moment

2.5.1 The first moment S, in m³, 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 [2.1] located above the z level.

2.6 Structural models for the calculation of normal warping stresses and shear stresses

2.6.1 The structural models that can be used for the calculation of normal warping stresses, induced by torque, and shear stresses, induced by shear forces or torque, are:

- three dimensional finite element models
- thin walled beam models

representing the members which constitute the hull girder transverse sections according to [2.1].

SECTION 2 YIELDING CHECKS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

M_{WH} : Horizontal wave bending moment, in kN.m, defined in Ch 5, Sec 2, [3.2]

M_{WT} : Wave torque, in kN.m, defined in Ch 5, Sec 2, [3.3]

Q_{SW} : Design still water shear force, in kN, defined in Ch 5, Sec 2, [2.3]

Q_{WV} : Vertical wave shear force, to be calculated according to Ch 5, Sec 2, [3.4]:

- 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

k : Material factor, as defined in Ch 4, Sec 1, [2.3]

x : X co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

I_Y : Moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to Ch 6, Sec 1, [2.4]

I_Z : Moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to Ch 6, Sec 1, [2.4]

S : First moment, in m^3, of the hull transverse section, to be calculated according to Ch 6, Sec 1, [2.5]

Z_A : Gross section modulus, in m^3, at any point of the hull transverse section, to be calculated according to Ch 6, Sec 1, [2.3.1]

Z_{AB}, Z_{AD} : Gross section moduli, in m^3, at bottom and deck, respectively, to be calculated according to Ch 6, Sec 1, [2.3.2]

n_1 : Navigation coefficient defined in Ch 5, Sec 1, Tab 1

C : Wave parameter defined in Ch 5, Sec 2

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm^2, defined in [3.1.2]

$\tau_{1,ALL}$: Allowable shear stress, in N/mm^2, defined in [3.2.1].

1 Application

1.1

1.1.1 The requirements of this Section apply to ships having the following characteristics:

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

Ships not having one or more of these characteristics, ships intended for the carriage of heated cargoes and ships of unusual type or design are considered by the Society on a case by case basis.

2 Hull girder stresses

2.1 Normal stresses induced by vertical bending moments

2.1.1 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:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AD}} 10^{-3}$$

2.1.2 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 Ch 6, Sec 1, [2.1.6], 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 [2.1.1] considering this member as having the steel equivalent sectional area A_{SE} defined in Ch 6, Sec 1, [2.1.6].

Table 1 : Torque and bending moments

Still water loads		Wave loads					
Vertical bending moment		Torque		Vertical bending moment		Horizontal bending moment	
Reference value	Comb. factor	Reference value	Comb. factor	Reference value	Comb. factor	Reference value	Comb. factor
M_{SW}	1,0	M_{WT}	1,0	M_{WV}	0,4	M_{WH}	1,0

2.2 Normal stresses induced by torque and bending moments

2.2.1 Ships having large openings in the strength deck

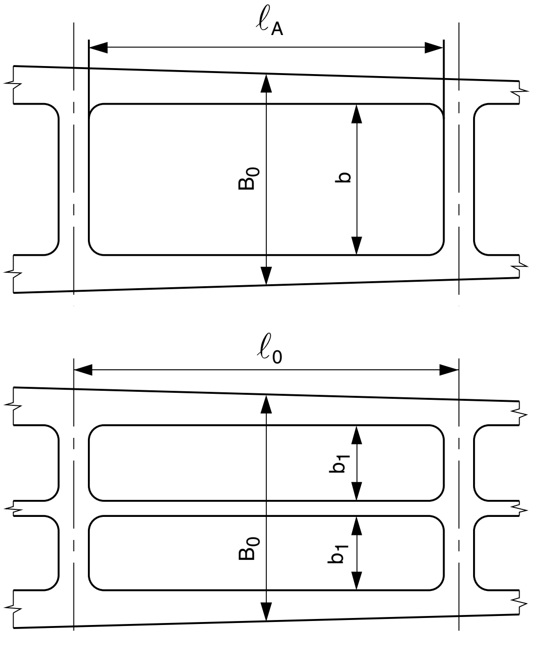
The normal stresses induced by torque and bending moments are to be considered for ships having large openings in the strength decks, i.e. ships for which at least one of the three following conditions occur:

- $b / B_0 > 0,7$
- $\ell_A / \ell_0 > 0,89$
- $b / B_0 > 0,6$ and $\ell_A / \ell_0 > 0,7$

where b, B_0, ℓ_A and ℓ_0 are the dimensions defined in Fig 1.

In the case of two or more openings in the same hull transverse section, b is to be taken as the sum of the breadth b_1 of each opening.

Figure 1 : Ships with large openings



2.2.2 Normal stresses

The normal stresses are to be calculated for the load case constituted by the hull girder loads specified in Tab 1 together with their combination factors. They are to be obtained, in N/mm², from the following formula:

$$\sigma_1 = \left\{\frac{M_{SW}}{Z_A} + \frac{0.4 M_{WV}}{Z_A} + \frac{M_{WH}}{I_Z}|y|\right\}10^{-3} + \sigma_\Omega$$

where:

σ_Ω : Warping stress, in N/mm², induced by the torque M_{WT} and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6].

y : Y co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4].

2.3 Shear stresses

2.3.1 The shear stresses induced by shear forces and torque are obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6].

The shear force corrections ΔQ_C and ΔQ are to be taken into account, in accordance with [2.4.1] and [2.4.2], respectively.

2.3.2 The vertical shear forces to be considered in these analyses are:

- for all ships, the vertical shear forces Q_{SW} and Q_{WV}, taking into account the combination factors defined in Ch 5, Sec 4, Tab 2
- in addition, for ships having large openings in the strength deck, the shear forces due to the torques M_{WT} and $M_{SW,T}$ as specified in [2.2].

When deemed necessary by the Society on the basis of the ship's characteristics and intended service, the horizontal shear force is also to be calculated, using direct calculations, and taken into account in the calculation of shear stresses.

2.3.3 As an alternative to the above procedure, the shear stresses induced by the vertical shear forces Q_{SW} and Q_{WV} may be obtained through the simplified procedure in [2.4].

2.4 Simplified calculation of shear stresses induced by vertical shear forces

2.4.1 Ships without effective longitudinal bulkheads or with one effective longitudinal bulkhead

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:

$$\tau_1 = (Q_{SW} + Q_{WV} - \varepsilon \Delta Q_C)\frac{S}{I_Y t}\delta$$

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 2

$\varepsilon = sgn(Q_{SW})$

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:

$\Delta Q_C = 0$

with:

$$\alpha = g\frac{\ell_0 b_0}{2 + \varphi\frac{\ell_0}{b_0}}$$

$$\varphi = 1{,}38 + 1{,}55\frac{\ell_0}{b_0} \le 3{,}7$$

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

P : Total mass of cargo, in t, in the hold

ρ : Sea water density, in t/m³:

$\rho = 1{,}025$ t/m³

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

B_H : Ship's breadth, in m, measured on the hull transverse section at the middle of the hold considered

ℓ_C : Length, in m, of the hold considered, measured between transverse bulkheads.

Figure 2 : Shear force correction ΔQ_C

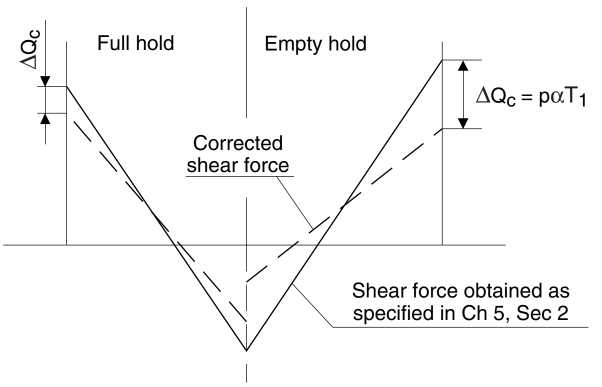


Figure 3 : Ship typologies (with reference to Tab 2)

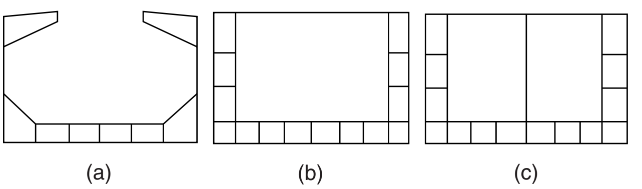


Table 2 : Shear stresses induced by vertical shear forces

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	$(1 - \Phi) / 2$	$\Phi = 0{,}275 + 0{,}25\,\alpha$ $\alpha = t_{ISM} / t_{SM}$
	Inner sides	t_{IS}	$\Phi / 2$	
Double side ships with one effective longitudinal bulkhead See Fig 3 (c)	Sides	t_S	$(1 - \Phi)\Psi / 2$	$\Phi = 0{,}275 + 0{,}25\,\alpha$ $\alpha = t_{ISM} / t_{SM}$ $\Psi = 1{,}9\beta\left[\gamma\left(2\delta + 1 + \frac{1}{\alpha_0}\right) - 0{,}17\right]$ $\chi = \frac{\Psi}{0{,}85 + 0{,}17\alpha}$ $\alpha_0 = \frac{0{,}5 t_{BM}}{t_{SM} + t_{ISM}}$ $\beta = \frac{0{,}75}{3\delta + \alpha_0 + 1}$ $\gamma = \frac{2\delta + 1}{4\delta + 1 + \frac{1}{\alpha_0}}$ $\delta = \frac{B}{2D}$
	Inner sides	t_{IS}	$\Phi\Psi / 2$	
	Longitudinal bulkhead	t_B	$1 - \chi$	

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.

2.4.2 Ships with two effective longitudinal bulkheads

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 force in the calculation point are obtained, in N/mm², from the following formula:

$$\tau_1 = [(Q_{SW} + Q_{WV})\delta + \varepsilon_Q \Delta Q]\frac{S}{I_Y t}$$

where:

δ : Shear distribution coefficient defined in Tab 3

$$\varepsilon_Q = \text{sgn}\left(\frac{Q_F - Q_A}{\ell_C}\right)$$

with : Q_F, Q_A : Value of Q_{SW}, in kN, in way of the forward and aft transverse bulkhead, respectively, of the hold considered

ℓ_C : Length, in m, of the hold considered, measured between transverse bulkheads

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable according to Tab 3

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:

$$\Delta Q = \frac{\varepsilon(p_C - p_W)\ell_C b_C}{4}\left[\frac{n}{3(n+1)} - (1-\Phi)\right]$$

- in longitudinal bulkheads:

$$\Delta Q = \frac{\varepsilon(p_C - p_W)\ell_C b_C}{4}\left[\frac{2n}{3(n+1)} - \Phi\right]$$

with:

$\varepsilon = \text{sgn}(Q_{SW})$

p_C : Pressure, in kN/m², acting on the inner bottom in way of the centre hold in the loading condition considered

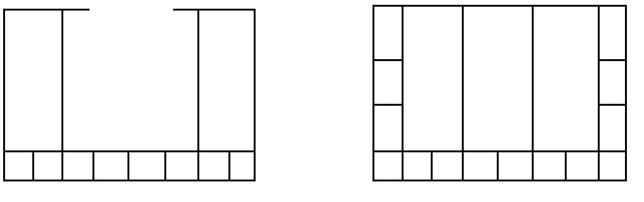
p_W : Pressure, in kN/m², acting on the inner bottom in way of the wing hold in the loading condition considered, to be taken not greater than p_C

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 3.

Figure 4 : Ship typologies (with reference to Tab 3)



(a) (b)

Table 3 : 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 with two effective longitudinal bulkheads - see Fig 4 (a)	Sides	t_S	$(1 - \Phi) / 2$	$\Phi = 0{,}3 + 0{,}21\,\alpha$ $\alpha = t_{BM} / t_{SM}$
	Longitudinal bulkheads	t_B	$\Phi / 2$	
Double side ships with two effective longitudinal bulkheads - see Fig 4 (b)	Sides	t_S	$(1 - \Phi) / 4$	$\Phi = 0{,}275 + 0{,}25\,\alpha$ $\alpha = \frac{t_{BM}}{t_{SM} + t_{ISM}}$
	Inner sides	t_{IS}	$(1 - \Phi) / 4$	
	Longitudinal bulkheads	t_B	$\Phi / 2$	

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 bulkheads.

3 Checking criteria

3.1 Normal stresses

3.1.1 Hull girder bending strength checks are to be carried out within 0,4L amidships according to [3.1.2] and [3.1.3] if relevant.

Outside 0,4L amidships, hull girder bending strength checks are to be carried out according to [3.1.2] and [3.1.3] if relevant, as a minimum at the following locations:

- in way of the forward end of the engine room
- in way of the forward end of the foremost cargo hold
- at any locations where there are significant changes in hull cross-section
- at any locations where there are changes in the framing system.

In addition, for ships with large openings in the strength deck, sections at, or near to, the aft and forward quarter length positions are to be checked. For such ships with cargo holds aft of the superstructure, deckhouse or engine room, strength checks of sections in way of the aft end of the aft-most holds, and the aft end of the deckhouse or engine room are to be performed.

3.1.2 It is to be checked that the normal stress σ_1 calculated according to [2.1] is 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:

$$\sigma_{1,ALL} = \frac{125}{k} \quad \text{for } \frac{x}{L} \le 0,1$$

$$\sigma_{1,ALL} = \frac{125}{k} + \frac{250}{k}\left(\frac{x}{L} - 0,1\right) \quad \text{for } 0,1 < \frac{x}{L} < 0,3$$

$$\sigma_{1,ALL} = \frac{175}{k} \quad \text{for } 0,3 \le \frac{x}{L} \le 0,7$$

$$\sigma_{1,ALL} = \frac{175}{k} - \frac{250}{k}\left(\frac{x}{L} - 0,7\right) \quad \text{for } 0,7 < \frac{x}{L} < 0,9$$

$$\sigma_{1,ALL} = \frac{125}{k} \quad \text{for } \frac{x}{L} \ge 0,9$$

3.1.3 In addition, for ships having large openings in the strength deck, it is to be checked that the normal stress σ_1 calculated according to [2.2] is in compliance with the following formula:

$\sigma_1 \le \sigma_{1,ALL}$

where:

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm², taken equal to:

$$\sigma_{1,ALL} = \frac{175}{k}$$

3.2 Shear stresses

3.2.1 It is to be checked that the shear stresses τ_1 calculated according to [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:

$\tau_{1,ALL} = 110/k$

3.3 Buckling check

3.3.1 Buckling strength of members contributing to the longitudinal strength and subjected to compressive and shear stresses is to be checked, especially in regions where changes in the framing system or significant changes in the hull cross-section occur. The buckling evaluation criteria used for this check are determined according to:

- for platings: Ch 7, Sec 1, [5]
- for stiffeners: Ch 7, Sec 2, [4]
- for primary supporting members: Ch 7, Sec 3, [7].

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 Ch 6, Sec 1, [2]. 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 m³, from the following formulae:

- $Z_{R,MIN} = n_1 C L^2 B (C_B + 0,7) k 10^{-6}$
- $Z_R = \frac{M_{SW} + M_{WV}}{\sigma_{1,ALL}} 10^{-3}$

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 m³, 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 m³, from the following formula:

$$Z_R = \frac{M_{SW} + M_{WV}}{\sigma_{1,ALL}} 10^{-3}$$

4.2.3 Where the total breadth Σb_S of small openings, as defined in Ch 6, Sec 1, [2.1.8], 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 Ch 6, Sec 1, [2]) 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 m³, from the following formula:

$$Z_R = \frac{M_{SW} + M_{WV}}{\sigma_{1,ALL}} 10^{-3}$$

4.3.2 Scantlings of members contributing to the hull girder longitudinal strength (see Ch 6, Sec 1, [2]) may be gradually reduced, outside 0,4L amidships, to the minimum required for local strength purposes at fore and aft parts, as specified in Part B, Chapter 8.

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 m⁴, from the following formula:

$$I_{YR} = 3\frac{n}{n_1} Z'_{R,MIN} L \cdot 10^{-2}$$

where $Z'_{R,MIN}$ is the required midship section modulus $Z_{R,MIN}$, in m³, 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 Ch 6, Sec 1, [2]), 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 Ch 6, Sec 1, [2.3.2]) 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/mm², at bottom and deck, respectively, calculated according to [2.1.1]

z_D : Z co-ordinate, in m, of the strength deck, defined in Ch 6, Sec 1, [2.2], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section defined in Ch 6, Sec 1, [2.3.1], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

V_D : Vertical distance, in m, defined in Ch 6, Sec 1, [2.3.2].

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 provisions of Part B.

5 Permissible still water bending moment and shear force during navigation

5.1 Permissible still water bending moment

5.1.1 The permissible still water bending moment at any hull transverse section during navigation, 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.

5.2 Permissible still water shear force

5.2.1 Direct calculations

Where the shear stresses are obtained through calculation analyses according to [2.3], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \varepsilon\,|Q_T| - Q_{WV}$$

where:

$\varepsilon = \text{sgn}(Q_{SW})$

Q_T : Shear force, in kN, which produces a shear stress τ = 110/k N/mm² in the most stressed point of the hull transverse section, taking into account the shear force correction ΔQ_C and ΔQ in accordance with [2.4.1] and [2.4.2], respectively.

5.2.2 Ships without effective longitudinal bulkheads or with one effective longitudinal bulkhead

Where the shear stresses are obtained through the simplified procedure in [2.4.1], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \varepsilon\left(\frac{110}{k\delta} \cdot \frac{I_Y t}{S} + \Delta Q_C\right) - Q_{WV}$$

where:

$\varepsilon = \text{sgn}(Q_{SW})$

δ : Shear distribution coefficient defined in Tab 2

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable according to Tab 2

ΔQ_C : Shear force correction defined in [2.4.1].

5.2.3 Ships with two effective longitudinal bulkheads

Where the shear stresses are obtained through the simplified procedure in [2.4.2], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \frac{1}{\delta}\left(\varepsilon\frac{110}{k}\cdot\frac{I_Y t}{S} - \varepsilon_Q \Delta Q\right) - Q_{WV}$$

where:

δ : Shear distribution coefficient defined in Tab 3

$\varepsilon = \text{sgn}(Q_{SW})$

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable according to Tab 3

ε_Q : Defined in [2.4.2]

ΔQ : Shear force correction defined in [2.4.2].

6 Permissible still water bending moment and shear force in harbour conditions

6.1 Permissible still water bending moment

6.1.1 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:

$$M_{P,H} = \frac{130}{k} Z_{A,M} 10^3$$

where $Z_{A,M}$ is the lesser of Z_{AB} and Z_{AD} defined in [4.2.1] or [4.2.2].

6.2 Permissible shear force

6.2.1 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:

$$Q_{P,H} = \varepsilon\, Q_P + 0{,}7\, Q_{WV}$$

where:

$\varepsilon = \text{sgn}(Q_{SW})$

Q_P : Permissible still water shear force during navigation, in kN, to be calculated according to [5.2].

SECTION 3 ULTIMATE STRENGTH CHECK

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

1 Application

1.1

1.1.1 The requirements of this Section apply to ships equal to or greater than 170 m in length.

2 General

2.1 Net scantlings

2.1.1 As specified in Ch 4, Sec 2, [1], the ultimate strength of the hull girder is to be checked on the basis of the net strength characteristics of the transverse section which is to be calculated according to Ch 4, Sec 2, [2].

2.2 Partial safety factors

2.2.1 The partial safety factors to be considered for checking the ultimate strength of the hull girder are specified in Tab 1.

Table 1 : Partial safety factors

Partial safety factor covering uncertainties on:	Symbol	Value
Still water hull girder loads	γ_{S1}	1,00
Wave induced hull girder loads	γ_{W1}	1,10
Material	γ_m	1,02
Resistance	γ_R	1,03

3 Hull girder ultimate strength check

3.1 Hull girder loads

3.1.1 Bending moments in navigation

The bending moment in navigation, in sagging and hogging conditions, to be considered in the ultimate strength check of the hull girder, is to be obtained, in kN.m, from the following formula:

$$M = \gamma_{S1} M_{SW} + \gamma_{W1} M_{WV}$$

3.1.2 Bending moments in harbour conditions

The bending moment in harbour conditions, in sagging and hogging conditions, to be considered in the ultimate strength check of the hull girder, is to be obtained, in kN.m, from the following formula:

$$M_H = \gamma_{S1} M_{P,H} + 0,1\ \gamma_{W1} M_{WV}$$

where $M_{P,H}$ is the permissible still water bending moment in harbour conditions, defined in Ch 6, Sec 2, [6.1.1].

3.2 Hull girder ultimate bending moment capacities

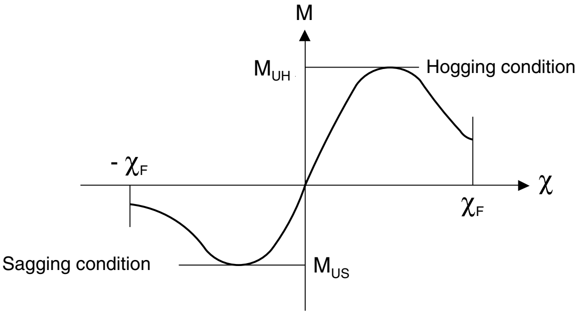
3.2.1 Curve M-χ

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 through an incremental-iterative procedure according to the criteria specified in Ch 6, App 1.

Figure 1 : Curve bending moment capacity M versus curvature χ



3.2.2 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 scantlings, according to Ch 6, Sec 1, [2].

3.3 Checking criteria

3.3.1 It is to be checked that the hull girder ultimate bending capacity at any hull transverse section is in compliance with the following formulae:

$$\frac{M_U}{\gamma_R \gamma_m} \geq M$$

$$\frac{M_U}{\gamma_R \gamma_m} \geq M_H$$

where:

M_U : Ultimate bending moment capacity of the hull transverse section considered, 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 [3.2.1]

M_{US} : Ultimate bending moment capacity in sagging conditions, defined in [3.2.1]

M : Bending moment in navigation, in kN.m, defined in [3.1.1]

M_H : Bending moment in harbour conditions, in kN.m, defined in [3.1.2].

APPENDIX 1 HULL GIRDER ULTIMATE STRENGTH

Symbols

For symbols not defined in this Appendix, refer to the list at the beginning of this Chapter.

R_{eH} : Minimum upper yield stress, in N/mm², of the material

I_Y : Moment of inertia, in m⁴, of the hull transverse section around its horizontal neutral axis, to be calculated according to Ch 6, Sec 1, [2.4]

Z_{AB} ,Z_{AD} : Section moduli, in cm³, at bottom and deck, respectively, defined in Ch 6, Sec 1, [2.3.2]

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members (see Ch 4, Sec 3, Fig 2 to Ch 4, Sec 3, Fig 5)

h_w : Web height, in mm, of an ordinary stiffener

t_w : Web net thickness, in mm, of an ordinary stiffener

b_f : Face plate width, in mm, of an ordinary stiffener

t_f : Face plate net thickness, in mm, of an ordinary stiffener

A_S : Net sectional area, in cm², of an ordinary stiffener

t_p : Net thickness, in mm, of the plating attached to an ordinary stiffener.

1 Hull girder ultimate strength check

1.1 Introduction

1.1.1 Ch 6, Sec 3, [2] defines the criteria for calculating the ultimate bending moment capacities in hogging condition M_{UH} and sagging condition M_{US} of a hull girder transverse section.

As specified in Ch 6, Sec 3, [2], the ultimate bending moment capacities 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).

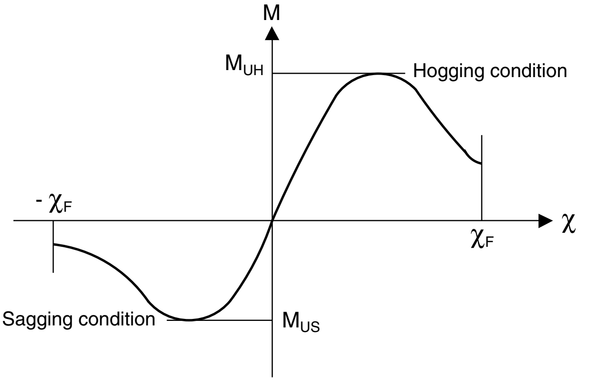
1.1.2 This Appendix provides the criteria for obtaining the curve M-χ.

1.2 Criteria for the calculation of the curve M-χ

1.2.1 Procedure

The curve M-χ is to be obtained by means of an incremental-iterative approach, summarised in the flow chart in Fig 2.

Figure 1 : Curve bending moment capacity M versus curvature χ



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.

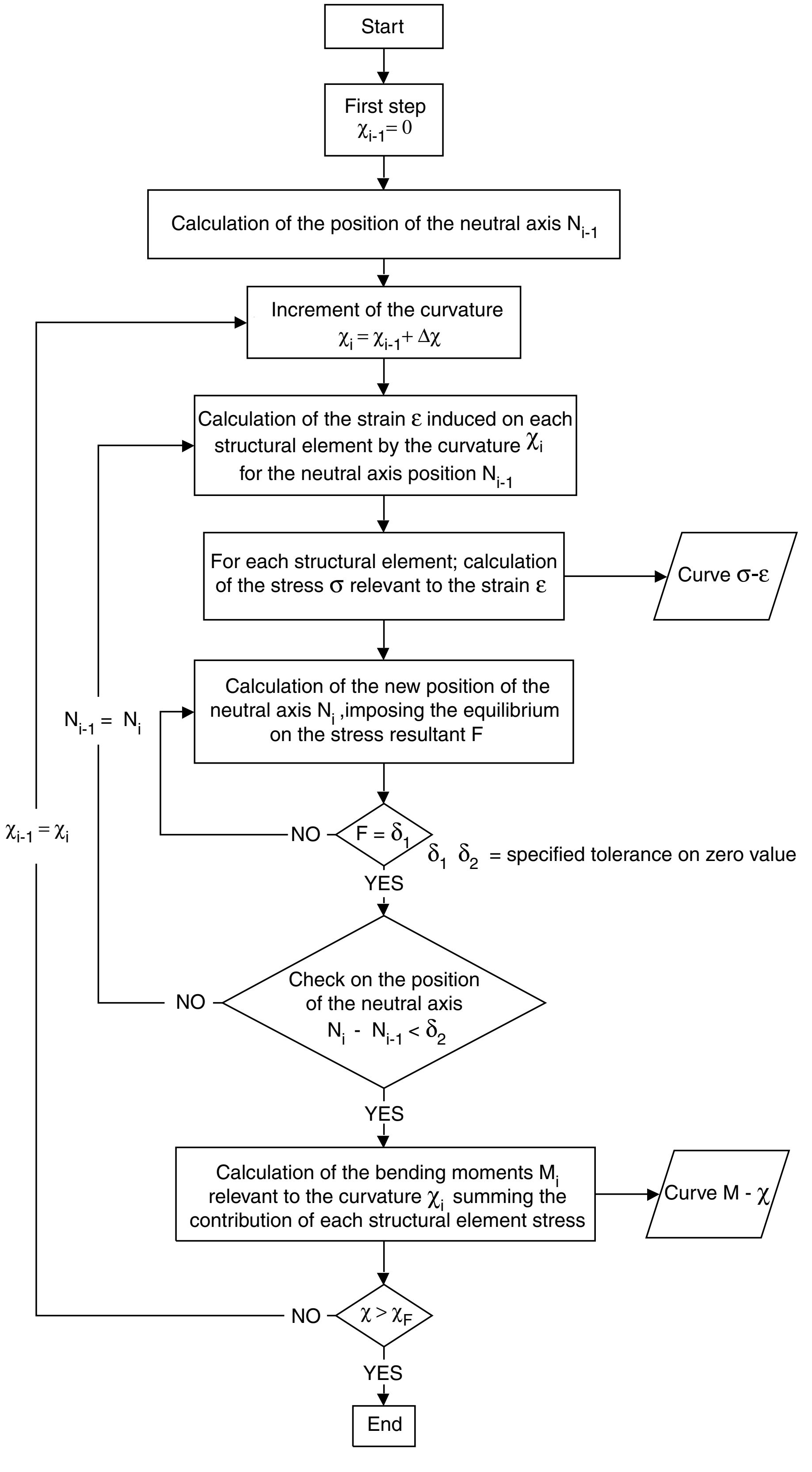
This rotation increment induces axial strains ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened. Vice-versa in sagging condition.

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.

Figure 2 : Flow chart of the procedure for the evaluation of the curve M-χ



1.2.2 Assumption

In applying the procedure described in [1.2.1], the following assumptions are generally to be made:

- the ultimate strength is calculated at hull transverse sections between two adjacent reinforced rings.
- 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 [1.3.1]
  - hard corners, constituted by plating crossing, whose structural behaviour is described in [1.3.2].
- according to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i 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-ε of the element.

  These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in [1.3]. 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.

1.3 Load-end shortening curves σ-ε

1.3.1 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.

1.3.2 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 [1.3.3].

Table 1 : Modes of failure of plate panels and ordinary stiffeners

Element	Mode of failure	Curve σ–ε defined in
Lengthened plate panel or ordinary stiffener	Elasto-plastic collapse	[1.3.3]
Shortened ordinary stiffener	Beam column buckling	[1.3.4]
	Torsional buckling	[1.3.5]
	Web local buckling of flanged profiles	[1.3.6]
	Web local buckling of flat bars	[1.3.7]
Shortened transversely framed plate panel	Plate buckling	[1.3.8]
Shortened transversely framed curved plate panel	Curved plate buckling	[1.3.9]

1.3.3 Elasto-plastic collapse

The equation describing the load-end shortening curve σ-ε for 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 3):

$$\sigma = \Phi R_{eH}$$

where:

Φ : Edge function:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 < \varepsilon < 1$

$\Phi = 1$ for $\varepsilon > 1$

ε : Relative strain:

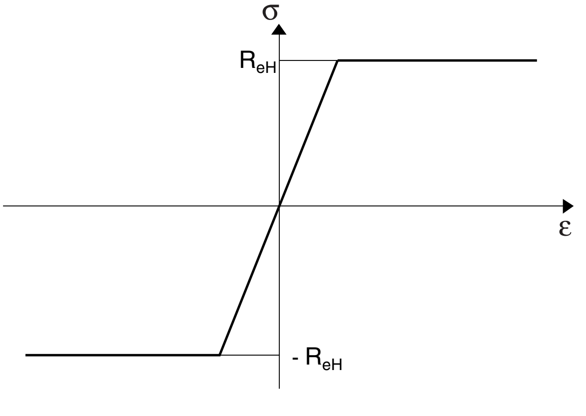
$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E : Element strain

ε_Y : Strain inducing yield stress in the element:

$$\varepsilon_Y = \frac{R_{eH}}{E}$$

Figure 3 : Load-end shortening curve σ-ε for elasto-plastic collapse



1.3.4 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 4):

$$\sigma_{CR1} = \Phi\sigma_{C1}\frac{A_S + 10b_E t_P}{A_S + 10st_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{C1} : Critical stress, in N/mm²:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \quad \text{for } \sigma_{E1} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{C1} = R_{eH}\left(1 - \frac{R_{eH}\varepsilon}{4\sigma_{E1}}\right) \quad \text{for } \sigma_{E1} > \frac{R_{eH}}{2}\varepsilon$$

ε : Relative strain defined in [1.3.3]

σ_{E1} : Euler column buckling stress, in N/mm²:

$$\sigma_{E1} = \pi^2 E\frac{I_E}{A_E \ell^2}10^{-4}$$

I_E : Net moment of inertia of ordinary stiffeners, in cm⁴, with attached shell plating of width b_E

A_E : Net sectional area, in cm², of ordinary stiffeners with attached shell plating of width b_E

b_E : Width, in m, of the attached shell plating:

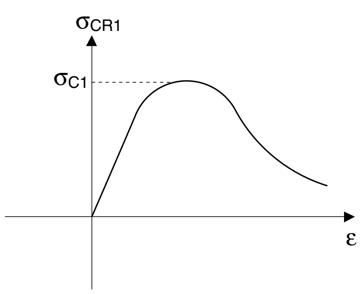
$$b_E = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right)s \quad \text{for } \beta_E > 1,25$$

$$b_E = s \quad \text{for } \beta_E \le 1,25$$

β_E : Generalized slenderness parameter:

$$\beta_E = 10^3\frac{s}{t_p}\sqrt{\frac{\varepsilon R_{eH}}{E}}$$

Figure 4 : Load-end shortening curve σ_{CR1}-ε for beam column buckling



1.3.5 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 5):

$$\sigma_{CR2} = \Phi\frac{A_S\sigma_{C2} + 10st_P\sigma_{CP}}{A_S + 10st_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{C2} : Critical stress, in N/mm²:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \quad \text{for } \sigma_{E2} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{C2} = R_{eH}\left(1 - \frac{R_{eH}\varepsilon}{4\sigma_{E2}}\right) \quad \text{for } \sigma_{E2} > \frac{R_{eH}}{2}\varepsilon$$

σ_{E2} : Euler torsional buckling stress, in N/mm², defined in Ch 7, Sec 2, [4.3.3]

ε : Relative strain defined in [1.3.3]

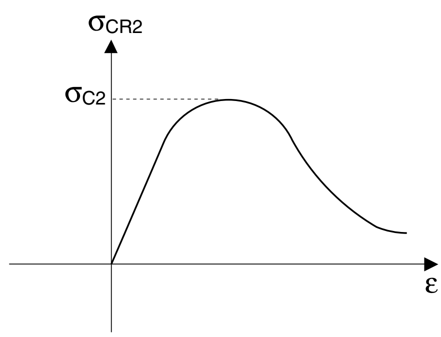
σ_{CP} : Buckling stress of the attached plating, in N/mm²:

$$\sigma_{CP} = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right)R_{eH} \quad \text{for } \beta_E > 1,25$$

$$\sigma_{CP} = R_{eH} \quad \text{for } \beta_E \le 1,25$$

β_E : Coefficient defined in [1.3.4].

Figure 5 : Load-end shortening curve σ_{CR2}-ε for flexural-torsional buckling



1.3.6 Web local buckling of flanged ordinary stiffeners

The equation describing the load-end shortening curve σ_{CR3}-ε for the web local buckling of flanged ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi R_{eH}\frac{10^3 b_E t_P + h_{WE}t_W + b_F t_F}{10^3 st_P + h_W t_W + b_F t_F}$$

where:

Φ : Edge function defined in [1.3.3]

b_E : Width, in m, of the attached shell plating, defined in [1.3.4]

h_{WE} : Effective height, in mm, of the web:

$$h_{WE} = \left(\frac{2,25}{\beta_W} - \frac{1,25}{\beta_W^2}\right)h_W \quad \text{for } \beta_W > 1,25$$

$$h_{WE} = h_W \quad \text{for } \beta_W \le 1,25$$

$$\beta_W = \frac{h_W}{t_W}\sqrt{\frac{\varepsilon R_{eH}}{E}}$$

ε : Relative strain defined in [1.3.3].

1.3.7 Web local buckling of flat bar ordinary stiffeners

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 6):

$$\sigma_{CR4} = \Phi\frac{10st_P\sigma_{CP} + A_S\sigma_{C4}}{A_S + 10st_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{CP} : Buckling stress of the attached plating, in N/mm², defined in [1.3.5]

σ_{C4} : Critical stress, in N/mm²:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \qquad \text{for } \sigma_{E4} \le \frac{R_{eH}}{2}\varepsilon$$

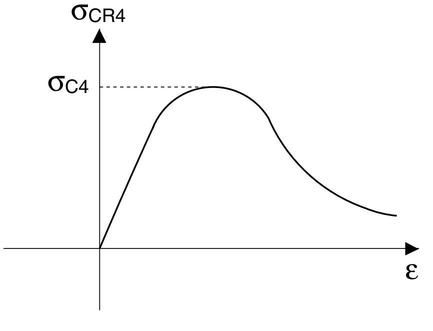
$$\sigma_{C4} = R_{eH}\left(1 - \frac{R_{eH}\varepsilon}{4\sigma_{E4}}\right) \quad \text{for } \sigma_{E4} > \frac{R_{eH}}{2}\varepsilon$$

σ_{E4} : Local Euler buckling stress, in N/mm²:

$$\sigma_{E4} = 160000\left(\frac{t_W}{h_W}\right)^2$$

ε : Relative strain defined in [1.3.3].

Figure 6 : Load-end shortening curve σ_{CR4}-ε for web local buckling of flat bars



1.3.8 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:

$$\sigma_{CR5} = \min\begin{cases} \Phi R_{eH} \\ \Phi R_{eH}\left[\frac{s}{\ell}\left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right) + 0,1\left(1 - \frac{s}{\ell}\right)\left(1 + \frac{1}{\beta_E^2}\right)^2\right] \end{cases}$$

where:

β_E : Coefficient defined in [1.3.4].

1.3.9 Transversely stiffened curved panels

The equation describing the load-end shortening curve $\sigma_{CR6} - \varepsilon$ for the buckling of transversely stiffened curved panels is to be obtained from the following formulae:

$$\sigma_{CR6} = \frac{\Phi\sigma_{EC}}{\varepsilon} \qquad \text{for } \sigma_{EC} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{CR6} = \Phi R_{eH}\left(1 - \frac{R_{eH}\varepsilon}{4\sigma_{EC}}\right) \quad \text{for } \sigma_{EC} > \frac{R_{eH}}{2}\varepsilon$$

where:

σ_{EC} : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_{EC} = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2 K_3 10^{-6}$$

b : Width of curved panel, in m, measured on arc between two adjacent supports

K_3 : Buckling factor to be taken equal to:

$$K_3 = 2\left\{1 + \sqrt{1 + \frac{12(1-\nu^2)}{\pi^4}\frac{b^4}{r^2t^2}10^6}\right\}$$

r : Radius of curvature, in m.

Part B
Hull and Stability

Chapter 7
HULL SCANTLINGS

Symbols used in this Chapter

L_1, L_2 : Lengths, in m, defined in Pt B, Ch 1, Sec 2, [2.1.1]

E : Young's modulus, in N/mm², to be taken equal to:
- for steels in general:
  $E = 2{,}06.10^5$ N/mm²
- for stainless steels:
  $E = 1{,}95.10^5$ N/mm²
- for aluminium alloys:
  $E = 7{,}0.10^4$ N/mm²

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

k : Material factor, defined in:
- Pt B, Ch 4, Sec 1, [2.3], for steel
- Pt B, Ch 4, Sec 1, [4.4], for aluminium alloys

R_y : Minimum yield stress, in N/mm², of the material, to be taken equal to 235/k N/mm², unless otherwise specified

t_c : Corrosion addition, in mm, defined in Pt B, Ch 4, Sec 2, Tab 2

I_Y : Net moment of inertia, in m⁴, of the hull transverse section around its horizontal neutral axis, to be calculated according to Pt B, Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings

I_Z : Net moment of inertia, in m⁴, of the hull transverse section around its vertical neutral axis, to be calculated according to Pt B, Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [4]

N : Z co-ordinate, in m, with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [4], of the centre of gravity of the hull transverse section constituted by members contributing to the hull girder longitudinal strength considered as having their net scantlings (see Pt B, Ch 6, Sec 1, [2])

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2]

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2]

$M_{SW,Hmin}$: Minimum still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, without being taken greater than $0{,}3M_{WV,S}$

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1]

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1]

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.2]

M_{WT} : Wave torque, in kN.m, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.3].

SECTION 1 PLATING

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m², see [3.2.2]

p_W : Wave pressure and, if necessary, dynamic pressures, in kN/m² (see [3.2.2])

p_{SF}, p_{WF} : Still water and wave pressure, in kN/m², in flooding conditions, defined in Ch 5, Sec 6, [9] (see [3.2.3])

F_S : Still water wheeled force, in kN, see [4.2.2]

$F_{W,Z}$: Inertial wheeled force, in kN, see [4.2.2]

σ_{X1} : In-plane hull girder normal stress, in N/mm², defined in:

- [3.2.6] for the strength check of plating subjected to lateral pressure
- [5.2.2] for the buckling check of plating

τ_1 : In-plane hull girder shear stress, in N/mm², defined in [3.2.7]

R_{eH} : Minimum yield stress, in N/mm², of the plating material, defined in Ch 4, Sec 1, [2]

ℓ : Length, in m, of the longer side of the plate panel

s : Length, in m, of the shorter side of the plate panel

a, b : Lengths, in m, of the sides of the plate panel, as shown in Fig 5 to Fig 6

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:

$c_r = 1 - 0,5\ s / r$

to be taken not less than 0,5

r : Radius of curvature, in m

t : Net thickness, in mm, of a plate panel.

1 General

1.1 Net thicknesses

1.1.1 As specified in Ch 4, Sec 2, [1], all thicknesses referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross thicknesses are obtained as specified in Ch 4, Sec 2.

1.2 Partial safety factors

1.2.1 The partial safety factors to be considered for the checking of the plating are specified in Tab 1.

1.3 Elementary plate panel

1.3.1 The elementary plate panel is the smallest unstiffened part of plating.

Table 1 : Plating - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Strength check of plating subjected to lateral pressure				Buckling check
		General	Sloshing pressure	Flooding pressure **(1)**	Testing check	
		see [3.2], [3.3.1], [3.4.1], [3.5.1] and [4]		see [3.3.2], [3.4.2] and [3.5.2]	see [3.3.3], [3.4.3] [3.5.3]	see [5]
Still water hull girder loads	γ_{S1}	1,00	0	1,00	N.A.	1,00
Wave hull girder loads	γ_{W1}	1,15	0	1,15	N.A.	1,15
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00	N.A.
Wave pressure	γ_{W2}	1,20	1,05	1,20	N.A.	N.A.
Material	γ_m	1,02	1,02	1,02	1,02	1,02
Resistance	γ_R	1,20	1,10	1,05 **(2)**	1,05	1,10

(1) Applies only to plating to be checked in flooding conditions
(2) For plating of the collision bulkhead, γ_R =1,25
Note 1: N.A. = not applicable

1.4 Load 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 or, in the case of horizontal plating, at the point of minimum y-value among those of the elementary plate panel considered
- for transverse framing, at the lower edge of elementary plate panel or at the lower strake welding joint, if any.

2 General requirements

2.1 General

2.1.1 The requirements in [2.2] to [2.6] are to be applied to plating in addition of those in [3] to [5].

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, where L need not be taken greater than 300 m.

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 greater of:

- value obtained from [3.3.1]
- value obtained from [5], to be checked as curved panel.

2.3.2 The net thickness of the transversely framed bilge plating, in mm, is to be not less than the greater of:

- $t = 0,7\ [\ \gamma_R\ \gamma_m\ (\gamma_{S2}\ p_S + \gamma_{W2}\ p_W)\ s_b\ ]^{0,4}\ R^{0,6}\ k^{1/2}$

  where:

  R : Bilge radius, in m

  s_b : Spacing of floors or transverse bilge brackets, in m

  p_s : Still water sea pressure, defined in Ch 5, Sec 5, [1]

  p_w : Wave pressure, defined in Ch 5, Sec 5, [2] for each load case "a", "b", "c" and "d"

- value obtained from [5], to be checked as curved panel.

2.3.3 The net thickness bilge plating is to be not less than the actual thicknesses of the adjacent bottom or side plating, whichever is the greater.

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	$1,9 + 0,032\ L\ k^{1/2} + 4,5\ s$
• transverse framing	$2,8 + 0,032\ L\ k^{1/2} + 4,5\ s$
Inner bottom	
• outside the engine room **(1)**	$1,9 + 0,024\ L\ k^{1/2} + 4,5\ s$
• engine room	$3,0 + 0,024\ L\ k^{1/2} + 4,5\ s$
Side	
• below freeboard deck **(1)**	$2,1 + 0,031\ L\ k^{1/2} + 4,5\ s$
• between freeboard deck and strength deck	$2,1 + 0,013\ L\ k^{1/2} + 4,5\ s$
Inner side	
• L < 120 m	$1,7 + 0,013\ L\ k^{1/2} + 4,5\ s$
• L ≥ 120 m	$3,6 + 2,20\ k^{1/2} + s$
Weather strength deck and trunk deck, if any **(2)**	
• area within 0,4 L amidships	
- longitudinal framing	$1,6 + 0,032\ L\ k^{1/2} + 4,5\ s$
- transverse framing	$1,6 + 0,040\ L\ k^{1/2} + 4,5\ s$
• area outside 0,4 L amidships	**(3)**
• between hatchways	$2,1 + 0,013\ L\ k^{1/2} + 4,5\ s$
• at fore and aft part	$2,1 + 0,013\ L\ k^{1/2} + 4,5\ s$
Cargo deck	
• general	$8\ s\ k^{1/2}$
• wheeled load only	4,5
Accommodation deck	
• L < 120 m	$1,3 + 0,004\ L\ k^{1/2} + 4,5\ s$
• L ≥ 120 m	$2,1 + 2,20\ k^{1/2} + s$
Platform in engine room	
• L < 120 m	$1,7 + 0,013\ L\ k^{1/2} + 4,5\ s$
• L ≥ 120 m	$3,6 + 2,20\ k^{1/2} + s$
Transv. watertight bulkhead **(4)**	
• L < 120 m	$1,3 + 0,004\ L\ k^{1/2} + 4,5\ s$
• L ≥ 120 m	$2,1 + 2,20\ k^{1/2} + s$
Longitud. watertight bulkhead **(4)**	
• L < 120 m	$1,7 + 0,013\ L\ k^{1/2} + 4,5\ s$
• L ≥ 120 m	$3,6 + 2,20\ k^{1/2} + s$
Tank and wash bulkheads **(4)**	
• L < 120 m	$1,7 + 0,013\ L\ k^{1/2} + 4,5\ s$
• L ≥ 120 m	$3,6 + 2,20\ k^{1/2} + s$

(1) Not applicable to ships with one of the service notations **passenger ship** and **ro-ro passenger ship**. For such ships, refer to the applicable requirements of Part D.

(2) Not applicable to ships with one of the following service notations (for such ships, refer to the applicable requirements of Part D):
- **ro-ro cargo ship** or **PCT carrier**
- **liquefied gas carrier** or **LNG bunkering ship**
- **passenger ship**
- **ro-ro passenger ship**.

(3) 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.

(4) Not applicable to ships with the service notation **liquefied gas carrier** or **LNG bunkering ship**.

2.4 Inner bottom of cargo holds intended to carry dry cargo

2.4.1 For ships with one of the following service notations:

- **general cargo ship**, intended to carry dry bulk cargo in holds
- **bulk carrier**
- **bulk carrier ESP**
- **ore carrier ESP**
- **combination carrier ESP**

the inner bottom net thickness is to be increased by 2 mm unless it is protected by a continuous wooden ceiling.

2.5 Sheerstrake

2.5.1 Welded sheerstrake

The net thickness of a welded sheerstrake is to be not less than that of the adjacent side plating, taking into account higher strength steel corrections if needed.

In general, the required net thickness of the adjacent side plating is to be taken as a reference. In specific case, depending on its actual net thickness, this latter may be required to be considered when deemed necessary by the Society.

2.5.2 Rounded sheerstrake

The net thickness of a rounded sheerstrake is to be not less than the actual net thickness of the adjacent deck plating.

2.5.3 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.

2.5.4 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.

2.6 Stringer plate

2.6.1 General

The net thickness of the stringer plate is to be not less than the actual net thickness of the adjacent deck plating.

2.6.2 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 0,5 L amidships, the increase in net thickness may be reduced to 30%, but need not exceed 2,5 mm.

2.6.3 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.

2.7 Deck plating protected by wood sheathing or deck composition

2.7.1 The net thickness of deck plating protected by wood sheathing, deck composition or other arrangements deemed suitable by the Society may be reduced on a case by case basis. In any case this net thickness is to be not less than the minimum value given in Tab 2.

2.7.2 The sheathing is to be secured to the deck to the satisfaction of the Society.

2.8 Corrugated bulkhead

2.8.1 Unless otherwise specified, the net plating thickness of a corrugated bulkhead is to be not less than that obtained from [3] and [5] with s equal to the greater of b and c, where b and c are defined in Ch 4, Sec 7, Fig 3.

3 Strength check of plating subjected to lateral pressure

3.1 General

3.1.1 The requirements of this Article 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 and shear stresses.

3.2 Load model

3.2.1 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, in accordance with Ch 5, Sec 1, [2.4].

The plating located below the deepest equilibrium waterline (excluding side shell plating) which constitute boundaries intended to stop vertical and horizontal flooding is to be subjected to lateral pressure in flooding conditions.

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases "a", "b", "c" and "d" in Ch 5, Sec 4.

3.2.2 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 still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case "a", "b", "c" and "d"
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case "a", "b", "c" and "d"
- the dynamic pressures, according to the criteria in Ch 5, Sec 6, [2].

Sloshing and impact pressures are to be applied to plating of tank structures, when such tanks are partly filled and if a risk of resonance exists (see Ch 5, Sec 6, [2]).

3.2.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and wave pressure p_{WF} defined in Ch 5, Sec 6, [9].

3.2.4 Lateral pressure in testing conditions

The lateral pressure (p_T) in testing conditions is taken equal to:

- $p_{ST} - p_S$ for bottom shell plating and side shell plating
- p_{ST} otherwise

where:

p_{ST} : Still water pressure defined in Ch 5, Sec 6, Tab 13

p_S : Still water sea pressure defined in Ch 5, Sec 5, [1.1.1] for the draught T_1 at which the testing is carried out.

If the draught T_1 is not defined by the Designer, it may be taken equal to the light ballast draught T_B defined in Ch 5, Sec 1, [2.4.3].

3.2.5 Lateral pressure in flow-through ballast water exchange operations for ships assigned with additional class notation BWE

The lateral pressure in flow-through ballast water exchange operations is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure p_{SB}, defined in Ch 5, Sec 6, [11.1] for ballast.

Wave pressure (p_W) includes:

- 80 percent of the wave pressure, defined in Ch 5, Sec 5, [2] for each load case "a", "b", "c" and "d"
- the inertial pressure p_{WB}, defined in Ch 5, Sec 6, [11.2], and for each load case "a", "b", "c" and "d".

3.2.6 In-plane hull girder normal stresses

The in-plane hull girder normal stresses to be considered for the strength check of plating are obtained, in N/mm², from the following formulae:

- for plating contributing to the hull girder longitudinal strength:

$$\sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}C_{FT}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1} + C_{F\Omega}\sigma_{\Omega})$$

- for plating not contributing to the hull girder longitudinal strength:

$$\sigma_{X1} = 0$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 3

σ_{Ω} : Absolute value of the warping stress, in N/mm², induced by the torque 0,625 M_{WT} and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6]

C_{FV}, C_{FH}, $C_{F\Omega}$: Combination factors defined in Tab 4

C_{FT} : Reduction factor for tanks subject to flow-through ballast water exchange, to be taken equal to:

- 1,0 for normal operations
- 0,8 for flow-through ballast water exchange operations

3.2.7 In-plane hull girder shear stresses

The in-plane hull girder shear stresses to be considered for the strength check of plating, subjected to lateral loads, which contributes to the longitudinal strength are obtained, in N/mm², from the following formula:

$$\tau_1 = \gamma_{S1}\tau_{S1} + 0{,}625 C_{FV}\gamma_{W1}\tau_{W1}$$

where:

C_{FV} : Combination factor defined in Tab 4

τ_{S1} : Absolute value of the hull girder shear stresses, in N/mm², induced by the maximum still water hull girder vertical shear force in the section considered

τ_{W1} : Absolute value of the hull girder shear stresses, in N/mm², induced by the maximum wave hull girder vertical shear force in the section considered.

When the shear forces distribution in plating according to the theory of bidimensional flow of shear stresses is not known, τ_{S1} and τ_{W1} may be taken equal to the values indicated in Tab 5.

Table 3 : Hull girder normal stresses

Condition	σ_{S1} , in N/mm² **(1)**	σ_{WV1} , in N/mm²	σ_{WH1} , in N/mm²
$\frac{\lvert\gamma_{S1}M_{SW,S}+0,625\gamma_{W1}C_{FV}F_DM_{WV,S}\rvert}{\gamma_{S1}M_{SW,H}+0,625\gamma_{W1}C_{FV}M_{WV,H}} \geq 1$	$\left\lvert\frac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625F_DM_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$\frac{\lvert\gamma_{S1}M_{SW,S}+0,625\gamma_{W1}C_{FV}F_DM_{WV,S}\rvert}{\gamma_{S1}M_{SW,H}+0,625\gamma_{W1}C_{FV}M_{WV,H}} < 1$	$\left\lvert\frac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 4 : Combination factors C_{FV}, C_{FH} and $C_{F\Omega}$

Load case	C_{FV}	C_{FH}	$C_{F\Omega}$
"a"	1,0	0	0
"b"	1,0	0	0
"c"	0,4	1,0	1,0
"d"	0,4	1,0	0
flooding	0,6	0	0

Table 5 : Hull girder shear stresses

Structural element	τ_{S1}, τ_{W1} in N/mm²
Bottom, inner bottom and decks (excluding possible longitudinal sloping plates)	0
Bilge, side, inner side and longitudinal bulkheads (including possible longitudinal sloping plates):	
• $0 \leq z \leq 0,25\ D$	$\tau_0\left(0,5+2\frac{z}{D}\right)$
• $0,25\ D < z \leq 0,75\ D$	τ_0
• $0,75\ D < z \leq D$	$\tau_0\left(2,5-2\frac{z}{D}\right)$

Note 1:

$$\tau_0 = \frac{47}{k}\left\{1-\frac{6,3}{\sqrt{L_1}}\right\} \text{ N/mm}^2$$

3.3 Longitudinally framed plating contributing to the hull girder longitudinal strength

3.3.1 General

The net thickness of laterally loaded plate panels subjected to in-plane normal stress acting on the shorter sides is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,9c_ac_rs\sqrt{\gamma_R\gamma_m\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{\lambda_LR_y}}$$

where:

$$\lambda_L = \sqrt{1-3\left(\gamma_m\frac{\tau_1}{R_y}\right)^2-0,95\left(\gamma_m\frac{\sigma_{x1}}{R_y}\right)^2}-0,225\gamma_m\frac{\sigma_{x1}}{R_y}$$

3.3.2 Flooding conditions

The net thickness of plating subject to flooding is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,9c_ac_rs\sqrt{\gamma_R\gamma_m\frac{\gamma_{S2}p_{SF}+\gamma_{W2}p_{WF}}{\lambda_LR_y}}$$

where λ_L is defined in [3.3.1].

3.3.3 Testing conditions

The plating of compartments or structures as defined in Ch 5, Sec 6, Tab 13 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:

$$t = 14,9c_ac_rs\sqrt{\gamma_R\gamma_m\frac{\gamma_{S2}p_T}{R_y}}$$

3.4 Transversely framed plating contributing to the hull girder longitudinal strength

3.4.1 General

The net thickness of laterally loaded plate panels subjected to in-plane normal stress acting on the longer sides is to be not less than the value obtained, in mm, from the following formula:

$$t = 17,2c_ac_rs\sqrt{\gamma_R\gamma_m\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{\lambda_TR_y}}$$

where:

$$\lambda_T = \sqrt{1-3\left(\gamma_m\frac{\tau_1}{R_y}\right)^2}-0,89\gamma_m\frac{\sigma_{x1}}{R_y}$$

3.4.2 Flooding conditions

The net thickness of plating subject to flooding is to be not less than the value obtained, in mm, from the following formula:

$$t = 17,2c_ac_rs\sqrt{\gamma_R\gamma_m\frac{\gamma_{S2}p_{SF}+\gamma_{W2}p_{WF}}{\lambda_TR_y}}$$

where λ_T is defined in [3.4.1].

3.4.3 Testing conditions

The plating of compartments or structures as defined in Ch 5, Sec 6, Tab 13 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:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_T}{R_y}}$$

3.5 Plating not contributing to the hull girder longitudinal strength

3.5.1 General

The net thickness of plate panels subjected to lateral pressure is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$$

3.5.2 Flooding conditions

The net thickness of plating subject to flooding is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y}}$$

3.5.3 Testing conditions

The plating of compartments or structures as defined in Ch 5, Sec 6, Tab 13 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:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_T}{R_y}}$$

3.6 Plating subject to impact loads

3.6.1 General

Unless otherwise specified, the net thickness of plate panels subject to impact generated by fluids is to be not less than the value obtained, in mm, from the following formula:

$$t = \frac{15,8 \alpha s}{C_d} \sqrt{\frac{P_I}{R_{eH}}}$$

where:

α : Coefficient defined as follows:

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

without being taken greater than 1,0

C_d : Plate capacity correction coefficient:

- C_d = 1,0 for sloshing and flat bottom forward impact
- C_d = 1,2 for bow flare impact
- C_d = 1,3 for flat area of the bottom aft

P_I : Any impact pressure defined in the Rules, including:

- bottom impact pressure, as defined in Ch 8, Sec 1, [3.2]
- bow impact pressure, as defined in Ch 8, Sec 1, [4.2]
- dynamic impact pressure, as defined in Ch 5, Sec 6, [2.5]
- stern impact pressure, as defined in Ch 8, Sec 2, [4.2].

If deemed necessary by the Society and depending on specific natures of loadings, different calculation methods may be applied, on a case-by-case basis.

4 Strength check of plating subjected to wheeled loads

4.1 General

4.1.1 The requirements of this Article apply for the strength check of plating subjected to wheeled loads.

4.1.2 If needed, the Society may require a fatigue assessment of plating subjected to wheeled loads.

4.2 Load model

4.2.1 General

The still water and inertial forces induced by the sea and the various types of wheeled vehicles are to be considered, depending on the location of the plating.

The inertial forces induced by the sea are to be calculated in load case "b", as defined in Ch 5, Sec 4.

4.2.2 Wheeled forces

The wheeled force applied by one wheel is constituted by still water force and inertial force.

Still water force is the vertical force (F_S) defined in Ch 5, Sec 6, [6.1].

Inertial force is the vertical force ($F_{W,Z}$) defined in Ch 5, Sec 6, [6.1], for load case "b".

4.3 Plating

4.3.1 Single wheel or group of wheels

The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained, in mm, from the following formula:

$$t = 0{,}9\, C_{WL} \sqrt{\frac{n P_0 k}{\lambda}}$$

where:

C_{WL} : Coefficient to be taken equal to:

$$C_{WL} = 2,15 - 0,05 \frac{\ell}{s} + 0{,}02 \left(4 - \frac{\ell}{s}\right) \alpha^{0,5} - 1{,}75 \alpha^{0,25}$$

where ℓ/s is to be taken not greater than 3

$$\alpha = \frac{A_T}{\ell s}$$

A_T : Tyre print area, in m². In the case of double or triple wheels, A_T is the print area of the group of wheels. A_T is not to be taken greater than the value given in [4.3.2]

ℓ , s : Lengths, in m, of, respectively, the longer and the shorter sides of the plate panel

n : Number of wheels on the plate panel, taken equal to:

- 1 in the case of a single wheel
- the number of wheels in a group of wheels in the case of double or triple wheels

P_0 : Wheeled force, in kN, taken equal to:

$$P_0 = \gamma_{S2} F_S + \gamma_{W2} F_{W,Z}$$

λ : Coefficient taken equal to:

- for longitudinally framed plating:

  $\lambda = \lambda_L$ as defined in [3.3.1]
- for transversely framed plating:

  $\lambda = \lambda_T$ as defined in [3.4.1].

4.3.2 Tyre print area

When the tyre print area is not known, it may be taken equal to:

$$A_T = 9,81 \frac{nQ_A}{n_W p_T}$$

where:

n : Number of wheels on the plate panel, defined in [4.3.1]

Q_A : Axle load, in t

n_W : Number of wheels for the axle considered

p_T : Tyre pressure, in kN/m². When the tyre pressure is not indicated by the designer, it may be taken as defined in Tab 6.

Table 6 : Tyre pressures p_T for vehicles

Vehicle type	Tyre pressure p_T , in kN/m²	
	Pneumatic tyres	Solid rubber tyres
Private cars	250	Not applicable
Vans	600	Not applicable
Trucks and trailers	800	Not applicable
Handling machines	1100	1600

4.3.3 Wheels spread along the panel length

In the case where two to four wheels of the same properties (load and tyre print area) are spread along the plate panel length as shown in Fig 1, the net thickness of deck plating is to be not less than the value obtained, in mm, from the following formulae:

$$t = t_1 \sqrt{1 + \sum_{i=2}^{n} \beta_i}$$

where:

n : Number of wheels on the plate panel, to be taken not less than 2

t_1 : Net thickness obtained, in mm, from [4.3.1] for n = 1, considering one wheel located on the plate panel

β_i : Coefficients obtained from the following formula, replacing i respectively by 2, 3 and 4 (see Fig 1):

- for $\alpha_i < 2$:

  $\beta_i = 0,8\,(1,2 - 2,02\,\alpha_i + 1,17\,\alpha_i^2 - 0,23\,\alpha_i^3)$
- for $\alpha_i \geq 2$:

  $\beta_i = 0$

with:

$$\alpha_i = \frac{x_i}{s}$$

x_i : Distance, in m, from the wheel considered to the reference wheel (see Fig 1)

4.3.4 Wheels spread along the panel breadth

In the case where two wheels of the same properties (load and tyre print area) are spread along the plate panel breadth as shown in Fig 2, the net thickness of deck plating is to be not less than the value obtained, in mm, from the following formula:

$$t = t_2 \sqrt{\delta}$$

where:

t_2 : Net thickness obtained, in mm, from [4.3.1] for n = 2, considering one group of two wheels located on the plate panel

δ : Coefficient obtained from the following formula:

$$\delta = \frac{\delta_1 + \delta_2}{2}$$

$$\delta_1 = 1 - \frac{w_s}{s - v}$$

$$\delta_2 = 1 - \frac{3w_s^2 + 6w_s v}{3s^2 - 4v^2}$$

w_s : Distance between the two wheels, as shown in Fig 2

v : Individual wheel breadth, as shown in Fig 2.

When this two-wheel arrangement is repeated several times over the panel length (2, 3 or 4 times), the required net thickness calculated in [4.3.4] is to be mutliplied by:

$$\sqrt{1 + \sum_{i=2}^{n} \beta_i}$$

as calculated in [4.3.3], where n is the number of two wheels groups.

4.3.5 Wheels larger than plate panel

In the particular case of wheels or group of wheel where u > s, the tyre print outside of the plate panel is to be disregarded. The load and the area to be considered are to be adjusted accordingly (see Fig 3).

Figure 1 : Wheels spread along the panel length

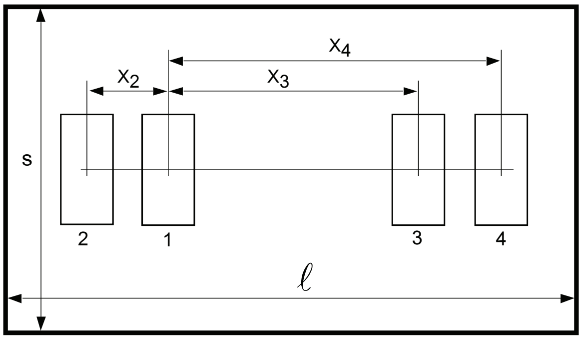


Figure 2 : Wheels spread along the panel breadth

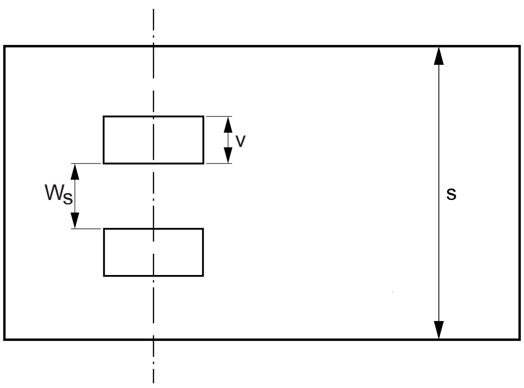
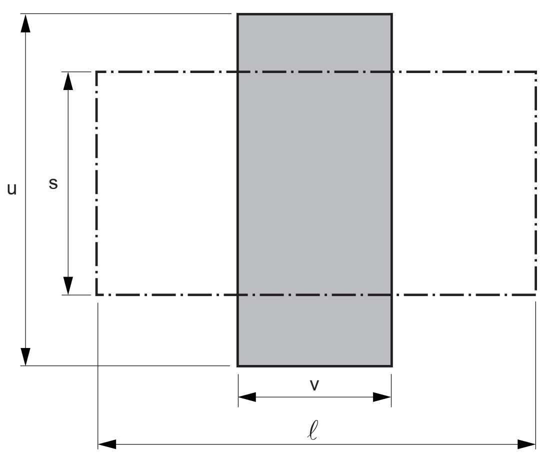


Figure 3 : Tyre print with u > s



5 Buckling check

5.1 General

5.1.1 Application

The requirements of this Article apply for the buckling check of plating subjected to in-plane compression stresses, acting on one or two sides, or to shear stress.

Rectangular plate panels are considered as being simply supported. For specific designs, other boundary conditions may be considered, at the Society's discretion, provided that the necessary information is submitted for review.

5.1.2 Compression and bending with or without shear

For plate panels subjected to compression and bending along one side, with or without shear, as shown in Fig 5, side "b" is to be taken as the loaded side. In such case, the compression stress varies linearly from σ_1 to $\sigma_2 = \psi \sigma_1$ ($\psi \leq 1$) along edge "b".

5.1.3 Shear

For plate panels subjected to shear, as shown in Fig 4, side "b" may be taken as either the longer or the shorter side of the panel.

5.1.4 Bi-axial compression and shear

For plate panels subjected to bi-axial compression along sides "a" and "b", and to shear, as shown in Fig 6, side "a" is to be taken as the side in the direction of the primary supporting members.

Figure 4 : Buckling of a simply supported rectangular plate panel subjected to shear

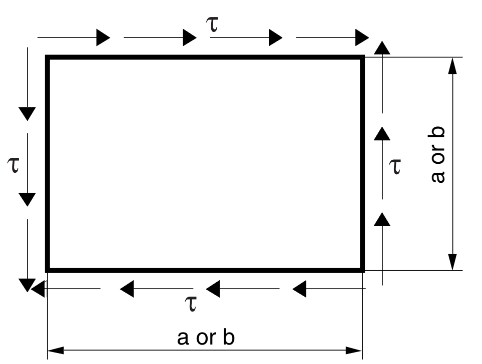


Figure 5 : Buckling of a simply supported rectangular plate panel subjected to compression and bending, with and without shear

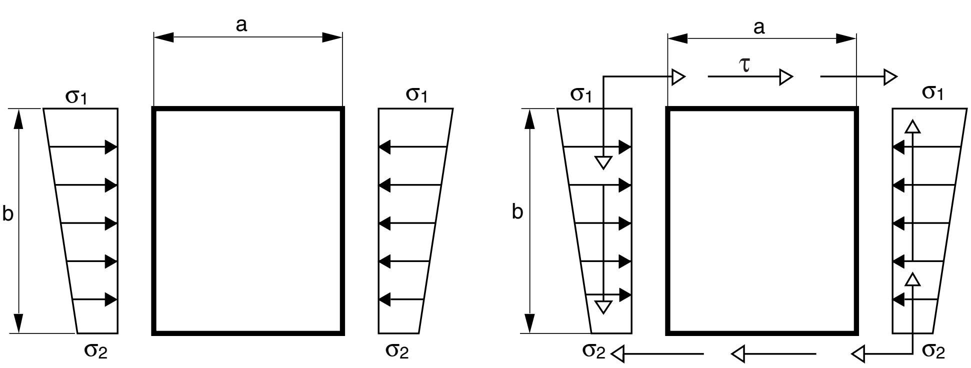
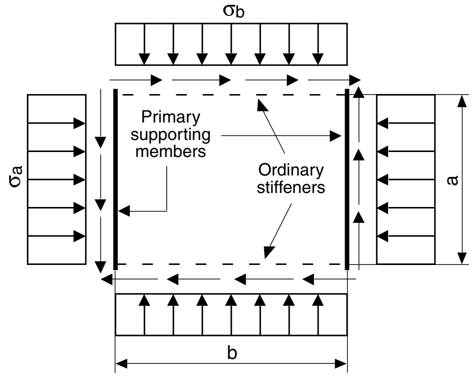


Figure 6 : Buckling of a simply supported rectangular plate panel subjected to bi-axial compression and shear



5.2 Load model

5.2.1 Sign convention for normal stresses

The sign convention for normal stresses is as follows:

- tension: positive
- compression: negative.

5.2.2 In-plane hull girder compression normal stresses

The in-plane hull girder compression normal stresses to be considered for the buckling check of plating contributing to the longitudinal strength are obtained, in N/mm², from the following formula:

$$\sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1} + C_{F\Omega}\sigma_{\Omega})$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 7

σ_{Ω} : Compression warping stress, in N/mm², induced by the torque 0,625 M_{WT} and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6]

C_{FV}, C_{FH}, $C_{F\Omega}$: Combination factors defined in Tab 4.

σ_{X1} is to be taken as the maximum compression stress on the plate panel considered.

When the ship in still water is always in hogging condition, σ_{X1} may be evaluated by means of direct calculations when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

Where deemed necessary, the buckling check is to be carried out in harbour conditions by considering a reduced wave bending moment equal to 0,1 M_{WV} given in Ch 5, Sec 2, [3.1].

5.2.3 In-plane hull girder shear stresses

The in-plane hull girder shear stresses to be considered for the buckling check of plating are obtained as specified in [3.2.7] for the strength check of plating subjected to lateral pressure, which contributes to the longitudinal strength.

5.2.4 Combined in-plane hull girder and local compression normal stresses

The combined in-plane compression normal stresses to be considered for the buckling check of plating are to take into account the hull girder stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis using the design loads given in Part B, Chapter 5.

With respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4.1], the combined stresses in x and y direction are obtained, in N/mm², from the following formulae:

$$\sigma_X = \sigma_{X1} + \gamma_{S2}\sigma_{X2,S} + \gamma_{W2}\sigma_{X2,W}$$

$$\sigma_Y = \gamma_{S2}\sigma_{Y2,S} + \gamma_{W2}\sigma_{Y2,W}$$

where:

σ_{X1} : Compression normal stress, in N/mm², induced by the hull girder still water and wave loads, defined in [5.2.2]

$\sigma_{X2,S}$,$\sigma_{Y2,S}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the still water design loads given in Part B, Chapter 5

$\sigma_{X2,W}$,$\sigma_{Y2,W}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the wave design loads given in Part B, Chapter 5

γ_{S2}, γ_{W2} : Partial safety factors as defined in Ch 7, Sec 3, [1.4] for the buckling check of primary supporting members.

Table 7 : Hull girder normal compression stresses

Condition	σ_{S1} in N/mm² **(1)**	σ_{WV1} in N/mm²	σ_{WH1} in N/mm²
$z \geq N$	$\frac{M_{SW,S}}{I_Y}(z-N)10^{-3}$	$\frac{0,625F_D M_{WV,S}}{I_Y}(z-N)10^{-3}$	$-\left\lvert\frac{0,625M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$z < N$	$\frac{M_{SW,H}}{I_Y}(z-N)10^{-3}$	$\frac{0,625M_{WV,H}}{I_Y}(z-N)10^{-3}$	

(1) When the ship in still water is always in hogging condition, σ_{S1} for $z \geq N$ is to be obtained, in N/mm², from the following formula, unless σ_{X1} is evaluated by means of direct calculations (see [5.2.2]):

$$\sigma_{S1} = \frac{M_{SW,Hmin}}{I_Y}(z-N)10^{-3}$$

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 8 : Buckling factor K_1 for plane panels

Load pattern	Aspect ratio	Buckling factor K_1
$0 \le \psi \le 1$	$\alpha \ge 1$	$\dfrac{8{,}4}{\psi + 1{,}1}$
	$\alpha < 1$	$\left(\alpha + \dfrac{1}{\alpha}\right)^2 \dfrac{2{,}1}{\psi + 1{,}1}$
$-1 < \psi < 0$		$(1+\psi)K_1' - \psi K_1'' + 10\psi(1+\psi)$
$\psi \le -1$	$\alpha\dfrac{1-\psi}{2} \ge \dfrac{2}{3}$	$23{,}9\left(\dfrac{1-\psi}{2}\right)^2$
	$\alpha\dfrac{1-\psi}{2} < \dfrac{2}{3}$	$\left(15{,}87 + \dfrac{1{,}87}{\left(\alpha\dfrac{1-\psi}{2}\right)^2} + 8{,}6\left(\alpha\dfrac{1-\psi}{2}\right)^2\right)\left(\dfrac{1-\psi}{2}\right)^2$

Note 1:

$\psi = \dfrac{\sigma_2}{\sigma_1}$

K_1' : Value of K_1 calculated for $\psi = 0$

K_1'' : Value of K_1 calculated for $\psi = -1$

5.2.5 Combined in-plane hull girder and local shear stresses

The combined in-plane shear stresses to be considered for the buckling check of plating are to take into account the hull girder stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis using the design loads given in Part B, Chapter 5.

The combined stresses are obtained, in N/mm², from the following formula:

$$\tau = \tau_1 + \gamma_{S2}\tau_{2,S} + \gamma_{W2}\tau_{2,W}$$

where:

τ_1 : Shear stress, in N/mm², induced by the hull girder still water and wave loads, defined in [5.2.3]

$\tau_{2,S}$: Shear stress, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the still water design loads given in Part B, Chapter 5

$\tau_{2,W}$: Shear stress, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the wave design loads given in Part B, Chapter 5

γ_{S2}, γ_{W2} : Partial safety factors as defined in Ch 7, Sec 3, [1.4] for the buckling check of primary supporting members.

5.3 Critical stresses

5.3.1 Compression and bending for plane panel

The critical buckling stress is to be obtained, in N/mm², from the following formulae:

$$\sigma_c = \sigma_E \quad \text{for } \sigma_E \le \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \quad \text{for } \sigma_E > \frac{R_{eH}}{2}$$

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2 K_1 \varepsilon 10^{-6}$$

K_1 : Buckling factor defined in Tab 8

ε : Coefficient to be taken equal to:

- $\varepsilon = 1{,}00$ for $\alpha \ge 1$
- $\varepsilon = 1{,}05$ for $\alpha < 1$ and side "b" stiffened by flat bar
- $\varepsilon = 1{,}10$ for $\alpha < 1$ and side "b" stiffened by bulb section
- $\varepsilon = 1{,}21$ for $\alpha < 1$ and side "b" stiffened by angle or T-section
- $\varepsilon = 1{,}30$ for $\alpha < 1$ and side "b" stiffened by primary supporting members

with $\alpha = a / b$.

5.3.2 Shear for plane panel

The critical shear buckling stress is to be obtained, in N/mm², from the following formulae:

$$\tau_c = \tau_E \quad \text{for } \tau_E \le \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_c = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\tau_E}\right) \quad \text{for } \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

where:

τ_E : Euler shear buckling stress, to be obtained, in N/mm², from the following formula:

$$\tau_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2 K_2 10^{-6}$$

K_2 : Buckling factor to be taken equal to:

$$K_2 = 5{,}34 + \frac{4}{\alpha^2} \quad \text{for } \alpha > 1$$

$$K_2 = \frac{5{,}34}{\alpha^2} + 4 \quad \text{for } \alpha \le 1$$

α : Coefficient defined in [5.3.1].

5.3.3 Bi-axial compression and shear for plane panel

The critical buckling stress $\sigma_{c,a}$ for compression on side "a" of the panel is to be obtained, in N/mm², from the following formula:

$$\sigma_{c,a} = \left(\frac{2{,}25}{\beta} - \frac{1{,}25}{\beta^2}\right) R_{eH}$$

where:

β : Slenderness of the panel, to be taken equal to:

$$\beta = 10^3 \frac{a}{t}\sqrt{\frac{R_{eH}}{E}}$$

without being taken less than 1,25.

The critical buckling stress $\sigma_{c,b}$ for compression on side "b" of the panel is to be obtained, in N/mm², from the formulae in [5.3.1].

The critical shear buckling stress is to be obtained, in N/mm², from the formulae in [5.3.2].

5.3.4 Compression and shear for curved panels

The critical buckling stress of curved panels subjected to compression perpendicular to curved edges is to be obtained, in N/mm², from the following formulae:

$$\sigma_c = \sigma_E \quad \text{for } \sigma_E \le \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \quad \text{for } \sigma_E > \frac{R_{eH}}{2}$$

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2 K_3 10^{-6}$$

b : Width of curved panel, in m, measured on arc between two adjacent supports

K_3 : Buckling factor to be taken equal to:

$$K_3 = 2\left\{1 + \sqrt{1 + \frac{12(1-\nu^2)}{\pi^4}\frac{b^4}{r^2 t^2}10^6}\right\}$$

r : Radius of curvature, in m.

The critical shear buckling stress is to be obtained, in N/mm², from the following formulae:

$$\tau_c = \tau_E \quad \text{for } \tau_E \le \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_c = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\tau_E}\right) \quad \text{for } \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

where:

τ_E : Euler shear buckling stress, to be obtained, in N/mm², from the following formula:

$$\tau_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2 K_4 10^{-6}$$

K_4 : Buckling factor to be taken equal to:

$$K_4 = \frac{12(1-\nu^2)}{\pi^2}\left(5 + \frac{b^2}{rt}10^2\right)$$

b, r : Defined above.

5.3.5 Compression for corrugation flanges

The critical buckling stress is to be obtained, in N/mm², from the following formulae:

$$\sigma_c = \sigma_E \quad \text{for } \sigma_E \le \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \quad \text{for } \sigma_E > \frac{R_{eH}}{2}$$

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_f}{V}\right)^2 K_5 10^{-6}$$

K_5 : Buckling factor to be taken equal to:

- for the first flange of the corrugation connected to a bulkhead plating or similar

  $K_5 = 4$

- for the other flanges of the corrugation

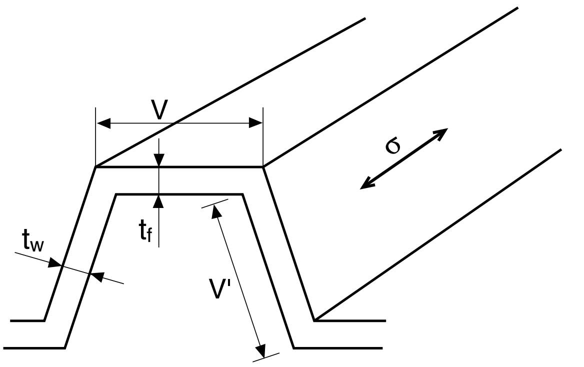
$$K_5 = \left(1 + \frac{t_w}{t_f}\right)\left\{3 + 0{,}5\frac{V'}{V} - 0{,}33\left(\frac{V'}{V}\right)^2\right\}$$

t_f : Net thickness, in mm, of the corrugation flange

t_w : Net thickness, in mm, of the corrugation web

V, V' : Dimensions of a corrugation, in m, shown in Fig 7.

Figure 7 : Dimensions of a corrugation



5.4 Checking criteria

5.4.1 Acceptance of results

The net thickness of plate panels is to be such as to satisfy the buckling check, as indicated in [5.4.2] to [5.4.5] depending on the type of stresses acting on the plate panel considered. When the buckling criteria is exceeded, the scantlings may still be considered as acceptable, provided that the stiffeners located on the plate panel satisfy the buckling and the ultimate strength checks as specified in Ch 7, Sec 2, [4] and Ch 7, Sec 2, [5].

5.4.2 Compression and bending

For plate panels subjected to compression and bending on one side, the critical buckling stress is to comply with the following formula:

$$\frac{\sigma_c}{\gamma_R\gamma_m} \geq |\sigma_b|$$

where:

- σ_c : Critical buckling stress, in N/mm², defined in [5.3.1], [5.3.4] or [5.3.5], as the case may be
- σ_b : Compression stress, in N/mm², acting on side "b" of the plate panel, to be calculated, as specified in [5.2.2] or [5.2.4], as the case may be.

In equivalence to the previous criteria on the critical buckling stress, the net thickness, in mm, is to comply with the following formulae:

$$t = \frac{b}{\pi}\sqrt{\frac{12\gamma_R\gamma_m|\sigma_b|(1-\nu^2)}{EK_i\varepsilon}}10^3 \quad \text{for} \quad \sigma_E \leq \frac{R_{eH}}{2}$$

$$t = \frac{b}{\pi}\sqrt{\frac{3R_{eH}^2(1-\nu^2)}{EK_i\varepsilon(R_{eH}-\gamma_R\gamma_m|\sigma_b|)}}10^3 \quad \text{for} \quad \sigma_E > \frac{R_{eH}}{2}$$

where:

$K_i = K_1$, defined in [5.3.1] for a plane panel

$K_i = K_3$, defined in [5.3.4] for a curved panel.

5.4.3 Shear

For plate panels subjected to shear, the critical shear buckling stress is to comply with the following formula:

$$\frac{\tau_c}{\gamma_R\gamma_m} \geq |\tau_b|$$

where:

- τ_c : Critical shear buckling stress, in N/mm², defined in [5.3.2] or [5.3.4], as the case may be
- τ_b : Shear stress, in N/mm², acting on the plate panel, to be calculated as specified in [5.2.3] or [5.2.5], as the case may be.

In equivalence to the previous criteria on the critical shear buckling stress, the net thickness, in mm, is to comply with the following formulae:

$$t = \frac{b}{\pi}\sqrt{\frac{12\gamma_R\gamma_m|\tau_b|(1-\nu^2)}{EK_i}}10^3 \quad \text{for} \quad \tau_E \leq \frac{R_{eH}}{2\sqrt{3}}$$

$$t = \frac{b}{\pi}\sqrt{\frac{R_{eH}^2(1-\nu^2)}{EK_i\left(\frac{R_{eH}}{\sqrt{3}}-\gamma_R\gamma_m|\tau_b|\right)}}10^3 \quad \text{for} \quad \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

where:

$K_i = K_2$, defined in [5.3.2] for a plane panel

$K_i = K_4$, defined in [5.3.4] for a curved panel.

5.4.4 Compression, bending and shear

For plate panels subjected to compression, bending and shear, the combined critical stress is to comply with the following formulae:

$$F \leq 1 \qquad \text{for} \quad \frac{\sigma_{comb}}{F} \leq \frac{R_{eH}}{2\gamma_R\gamma_m}$$

$$F \leq \frac{4\sigma_{comb}}{R_{eH}/\gamma_R\gamma_m}\left(1-\frac{\sigma_{comb}}{R_{eH}/\gamma_R\gamma_m}\right) \quad \text{for} \quad \frac{\sigma_{comb}}{F} > \frac{R_{eH}}{2\gamma_R\gamma_m}$$

where:

$$\sigma_{comb} = \sqrt{\sigma_1^2 + 3\tau^2}$$

$$F = \gamma_R\gamma_m\left[\frac{1+\psi}{4}\frac{|\sigma_1|}{\sigma_E} + \sqrt{\left(\frac{3-\psi}{4}\right)^2\left(\frac{\sigma_1}{\sigma_E}\right)^2 + \left(\frac{\tau}{\tau_E}\right)^2}\right]$$

- σ_E : Euler buckling stress, in N/mm², defined in [5.3.1], [5.3.4] or [5.3.5] as the case may be
- τ_E : Euler shear buckling stress, in N/mm², defined in [5.3.2] or [5.3.4], as the case may be

$$\psi = \frac{\sigma_2}{\sigma_1}$$

σ_1, σ_2 and τ are defined in Fig 5 and are to be calculated, in N/mm², as specified in [5.2].

5.4.5 Bi-axial compression, taking account of shear stress

For plate panels subjected to bi-axial compression and shear, the critical buckling stresses are to comply with the following formula:

$$\left|\frac{\gamma_R\gamma_m\sigma_a}{\sigma_{c,a}}\right|^{1,9} + \left|\frac{\gamma_R\gamma_m\sigma_b}{\sigma_{c,b}}\right|^{1.9} + \left|\frac{\gamma_R\gamma_m\tau}{\tau_c}\right|^{1.9} \leq 1$$

where:

- $\sigma_{c,a}$: Critical buckling stress for compression on side "a", in N/mm², defined in [5.3.3]
- $\sigma_{c,b}$: Critical buckling stress for compression on side "b", in N/mm², defined in [5.3.3]
- σ_a : Compression stress acting on side "a", in N/mm², to be calculated as specified in [5.2.2] or [5.2.4], as the case may be
- σ_b : Compression stress acting on side "b", in N/mm², to be calculated as specified in [5.2.2] or [5.2.4], as the case may be

$\alpha = a / b$

- τ : Shear stress, in N/mm², to be calculated as specified in [5.2.3] or [5.2.5], as the case may be
- τ_c : Critical shear buckling stress, in N/mm², defined in [5.3.2].

SECTION 2 ORDINARY STIFFENERS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m², see [3.3.2] and [5.3.2]

p_W : Wave pressure and, if necessary, dynamic pressures, according to the criteria in Ch 5, Sec 5, [2] and Ch 5, Sec 6, [2], in kN/m² (see [3.3.2] and [5.3.2])

p_{SF}, p_{WF} : Still water and wave pressures, in kN/m², in flooding conditions, defined in Ch 5, Sec 6, [9]

F_S : Still water wheeled force, in kN, see [3.3.6]

$F_{W,Z}$: Inertial wheeled force, in kN, see [3.3.6]

σ_{X1} : Hull girder normal stress, in N/mm², defined in:
- [3.3.7] for the yielding check of ordinary stiffeners
- [4.2.2] for the buckling check of ordinary stiffeners
- [5.3.3] for the ultimate strength check of ordinary stiffeners

$R_{eH,P}$: Minimum yield stress, in N/mm², of the plating material, defined in Ch 4, Sec 1, [2]

$R_{eH,S}$: Minimum yield stress, in N/mm², of the stiffener material, defined in Ch 4, Sec 1, [2]

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 4, Sec 3, [3.2]

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 4, Sec 3, [3.3.1]

b_e : Width, in m, of the plating attached to the stiffener, for the buckling check, defined in [4.1]

b_U : Width, in m, of the plating attached to the stiffener, for the ultimate strength check, defined in [5.2]

t_p : Net thickness, in mm, of the attached plating

w : Net section modulus, in cm³, of the stiffener, with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [3.4]

A : Net sectional area, in cm², of the stiffener without attached plating

A_S : Net sectional area, in cm², of the stiffener with attached plating of width s

A_e : Net sectional area, in cm², of the stiffener with attached plating of width b_e

A_U : Net sectional area, in cm², of the stiffener with attached plating of width b_U

A_{Sh} : Net shear sectional area, in cm², of the stiffener, to be calculated as specified in Ch 4, Sec 3, [3.4]

I : Net moment of inertia, in cm⁴, of the stiffener without attached plating, about its neutral axis parallel to the plating (see Ch 4, Sec 3, Fig 4 and Ch 4, Sec 3, Fig 5)

I_S : Net moment of inertia, in cm⁴, of the stiffener with attached shell plating of width s, about its neutral axis parallel to the plating

I_e : Net moment of inertia, in cm⁴, of the stiffener with attached shell plating of width b_e, about its neutral axis parallel to the plating

I_U : Net moment of inertia, in cm⁴, of the stiffener with attached shell plating of width b_U, about its neutral axis parallel to the plating

ρ_S : Radius of gyration, in cm, of the stiffener with attached plating of width s

ρ_U : Radius of gyration, in cm, of the stiffener with attached plating of width b_U.

m : Boundary coefficient, to be taken equal to:
- m = 12 for stiffeners clamped at both ends, whose end connections comply with the requirements in [3.2.2]
- m = 8 for stiffeners clamped at one end and simply supported at the other end, with the clamped end connection complying with the requirements in [3.2.2]
- m = 8 for stiffeners simply supported at both ends.

1 General

1.1 Net scantlings

1.1.1 As specified in Ch 4, Sec 2, [1], 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 4, Sec 2.

1.2 Partial safety factors

1.2.1 The partial safety factors to be considered for the checking of ordinary stiffeners are specified in Tab 1.

Table 1 : Ordinary stiffeners - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check				Buckling check	Ultimate strength check
		General	Sloshing pressure	Flooding pressure (1)	Testing check		
		(see [3.3] to [3.7])		(see [3.8])	(see [3.9])	(see [4])	(see [5])
Still water hull girder loads	γ_{S1}	1,00	0	1,00	N.A.	1,00	1,00
Wave hull girder loads	γ_{W1}	1,15	0	1,15	N.A.	1,15	1,30
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00	N.A.	1,00
Wave pressure	γ_{W2}	1,20	1,10	1,05	N.A.	N.A.	1,40
Material	γ_m	1,02	1,02	1,02	1,02	1,02	1,02
Resistance	γ_R	1,02	1,02	1,02 (2)	1,20	1,10	1,02

(1) Applies only to ordinary stiffeners to be checked in flooding conditions.
(2) For ordinary stiffeners of the collision bulkhead, γ_R =1,25.
Note 1: N.A. = Not applicable.

1.3 Load point

1.3.1 Lateral pressure

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the ordinary stiffener considered.

1.3.2 Hull girder stresses

For longitudinal ordinary stiffeners contributing to the hull girder longitudinal strength, the hull girder normal stresses are to be calculated in way of the attached plating of the stiffener considered.

1.4 Net dimensions of ordinary stiffeners

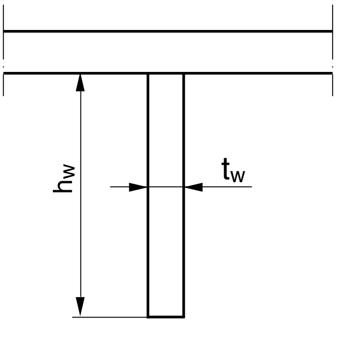
1.4.1 The requirements relative to the net dimensions of ordinary stiffeners, as indicated in [1.4.2] to [1.4.3], are applicable when the buckling assessment is not carried out for such stiffeners in accordance with [4].

1.4.2 Flat bar

The net dimensions of a flat bar ordinary stiffener (see Fig 1) are to comply with the following requirement:

$$\frac{h_w}{t_w} \le 20\sqrt{k}$$

Figure 1 : Net dimensions of a flat bar



1.4.3 T-section

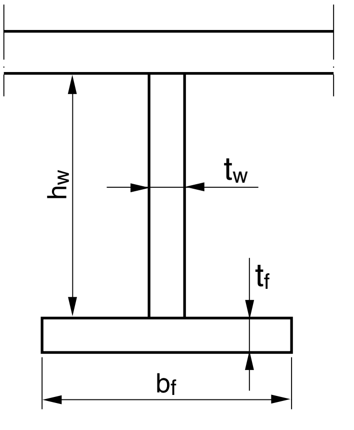
The net dimensions of a T-section ordinary stiffener (see Fig 2) are to comply with the following requirements:

$$\frac{h_w}{t_w} \le 55\sqrt{k}$$

$$\frac{b_f}{t_f} \le 33\sqrt{k}$$

$$b_f t_f \ge \frac{h_w t_w}{6}$$

Figure 2 : Net dimensions of a T-section



1.4.4 Angle

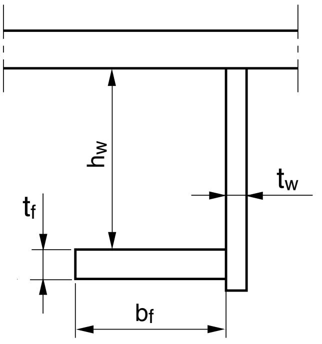
The net dimensions of an angle ordinary stiffener (see Fig 3) are to comply with the following requirements:

$$\frac{h_w}{t_w} \le 55\sqrt{k}$$

$$\frac{b_f}{t_f} \le 16,5\sqrt{k}$$

$$b_f t_f \ge \frac{h_w t_w}{6}$$

Figure 3 : Net dimensions of an angle



2 General requirements

2.1 General

2.1.1 The requirements in [2.2] and [2.3] are to be applied to ordinary stiffeners in addition of those in [3] to [5].

2.2 Minimum net thicknesses

2.2.1 The net thickness of the web of ordinary stiffeners is to be not less than the lesser of:

- the value obtained, in mm, from the following formulae:

  $t_{MIN} = 0,8 + 0,004\ L\ k^{1/2} + 4,5\ s$ for $L < 120$ m

  $t_{MIN} = 1,6 + 2,2\ k^{1/2} + s$ for $L \geq 120$ m

- the net as built thickness of the attached plating.

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, equal to:

$p_{SR1} = \gamma_{S2}\ p_S + \gamma_{W2}\ p_W$

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, equal to:

$p_{SR2} = \gamma_{S2}\ p_S + \gamma_{W2}\ p_W$

p_{SR3} : Internal pressure at mid-span of the strut, in kN/m², in the compartment in which the strut is located, equal to:

$p_{SR3} = \gamma_{S2}\ p_S + \gamma_{W2}\ p_W$

ℓ : Span, in m, of ordinary stiffeners connected by the strut (see Ch 4, Sec 3, [3.2.2])

ℓ_{SR} : Length, in m, of the strut

A_{ASR} : Actual net sectional area, in cm², of the strut.

2.4 Corrugated bulkhead

2.4.1 Unless otherwise specified, the net section modulus and the net shear sectional area of a corrugation are to be not less than those obtained from [3] to [5] with s equal to the greater of (a + b), where a and b are defined in Ch 4, Sec 7, Fig 3.

2.5 Deck ordinary stiffeners in way of launching appliances used for survival craft or rescue boat

2.5.1 The scantlings of deck ordinary stiffeners are to be determined by direct calculations.

2.5.2 The loads exerted by launching appliance are to correspond to the SWL of the launching appliance.

2.5.3 The combined stress, in N/mm², is not to exceed the smaller of $R_{eH}/2,2$ and $R_m/4,5$ where R_m is the ultimate minimum tensile strength of the ordinary stiffener material, in N/mm².

3 Yielding check

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of ordinary stiffeners subjected to lateral pressure or to wheeled loads and, for ordinary stiffeners contributing to the hull girder longitudinal strength, to hull girder normal stresses.

3.1.2 When tanks are partly filled and if a risk of resonance exists, the yielding check of vertical ordinary stiffeners of tank structures subjected to sloshing and impact pressures is to be carried out by direct calculation.

3.1.3 The yielding check is also to be carried out for ordinary stiffeners subjected to specific loads, such as concentrated loads.

3.2 Structural model

3.2.1 Boundary conditions

- The requirements in [3.4], [3.7.3], [3.7.4], [3.8] and [3.9] apply to stiffeners considered either:
  - clamped at both ends with end connections complying with the requirements in [3.2.2]
  - clamped at one end and simply supported at the other end with the clamped end connection complying with the requirements in [3.2.2]
  - simply supported at both ends

- The requirements in [3.5] and [3.7.5] apply to stiffeners considered as simply supported at both ends. Other boundary conditions may be considered by the Society on a case by case basis, depending on the distribution of wheeled loads.

For other boundary conditions, the yielding check is to be considered on a case by case basis.

3.2.2 Bracket arrangement

The requirements of this Article apply to ordinary stiffeners without end brackets, with a bracket at one end or with two end brackets, where the bracket length is not greater than 0,2 ℓ.

In the case of ordinary stiffeners with end brackets of length greater than 0,2 ℓ, the determination of normal and shear stresses due to design loads and the required section modulus and shear sectional area are considered by the Society on a case by case basis.

3.3 Load model

3.3.1 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 compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

Ordinary stiffeners located on platings below the deepest equilibrium waterline (excluding those on side shell platings) which constitute boundaries intended to stop vertical and horizontal flooding are to be subjected to lateral pressure in flooding conditions.

The wave lateral loads and hull girder loads are to be calculated in the mutually exclusive load cases "a", "b", "c" and "d" in Ch 5, Sec 4.

3.3.2 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 still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case "a", "b", "c" and "d"
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case "a", "b", "c" and "d"
- the dynamic pressures, according to the criteria in Ch 5, Sec 6, [2].

Sloshing and impact pressures are to be applied to ordinary stiffeners of tank structures, when such tanks are partly filled and if a risk of resonance exists (see Ch 5, Sec 6, [2]).

3.3.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and wave pressure p_{WF} defined in Ch 5, Sec 6, [9].

3.3.4 Lateral pressure in testing conditions

The lateral pressure (p_T) in testing conditions is taken equal to:

- $p_{ST} - p_S$ for bottom shell plating and side shell plating
- p_{ST} otherwise.

where:

p_{ST} : Still water pressure defined in Ch 5, Sec 6, Tab 13

p_S : Still water sea pressure defined in Ch 5, Sec 5, [1.1.1] for the draught T_1 at which the testing is carried out.
If the draught T_1 is not defined by the Designer, it may be taken equal to the light ballast draught T_B defined in Ch 5, Sec 1, [2.4.3].

3.3.5 Lateral pressure in flow-through ballast water exchange operations for ships assigned with additional class notation BWE

The lateral pressure in flow-through ballast water exchange operations is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure p_{SB}, defined in Ch 5, Sec 6, [11.1] for ballast.

Wave pressure (p_W) includes:

- 80 percent of the wave pressure, defined in Ch 5, Sec 5, [2] for each load case "a", "b", "c" and "d"
- the inertial pressure p_{WB}, defined in Ch 5, Sec 6, [11.2], and for each load case "a", "b", "c" and "d".

3.3.6 Wheeled forces

The wheeled force applied by one wheel is constituted by still water force and inertial force:

- Still water force is the vertical force (F_S) defined in Ch 5, Sec 6, [6.1]
- Inertial force is the vertical force ($F_{W,Z}$) defined in Ch 5, Sec 6, [6.1], for load case "b".

3.3.7 Hull girder normal stresses

The hull girder normal stresses to be considered for the yielding check of ordinary stiffeners are obtained, in N/mm², from the following formulae:

- for longitudinal stiffeners contributing to the hull girder longitudinal strength and subjected to lateral pressure:
  $\sigma_{X1} = \gamma_{S1}\,\sigma_{S1} + \gamma_{W1}\,C_{FT}\,(C_{FV}\,\sigma_{WV1} + C_{FH}\,\sigma_{WH1} + C_{F\Omega}\,\sigma_{\Omega})$
- for longitudinal stiffeners contributing to the hull girder longitudinal strength and subjected to wheeled loads:
  $\sigma_{X1,Wh} = \text{Max}\,(\sigma_{X1H}\,;\,\sigma_{X1S})$
- for longitudinal stiffeners not contributing to the hull girder longitudinal strength:
  $\sigma_{X1} = 0$

- for transverse stiffeners:

$\sigma_{X1} = 0$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 3

σ_{Ω} : Absolute value of the warping stress, in N/mm², induced by the torque 0,625 M_{WT} and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6]

σ_{X1H}, σ_{X1S}: Hull girder normal stresses, in N/mm², respectively in hogging and in sagging, defined in Tab 4

C_{FV}, C_{FH}, $C_{F\Omega}$: Combination factors defined in Tab 2

C_{FT} : Reduction factor for tanks subject to flow-through ballast water exchange, to be taken equal to:

- 1,0 for normal operations
- 0,8 for flow-through ballast water exchange operations

Table 2 : Combination factors C_{FV}, C_{FH} and $C_{F\Omega}$

Load case	C_{FV}	C_{FH}	$C_{F\Omega}$
“a”	1,0	0	0
“b”	1,0	0	0
“c”	0,4	1,0	1,0
“d”	0,4	1,0	0
Flooding	0,6	0	0

3.4 Normal and shear stresses due to lateral pressure in intact conditions

3.4.1 General

Normal and shear stresses, induced by lateral pressures, in ordinary stiffeners are to be obtained from the formulae in:

- [3.4.2] in the case of single span longitudinal and transverse stiffeners
- [3.4.3] in the case of single span vertical stiffeners
- [3.4.4] in the case of multispan stiffeners.

Table 3 : Hull girder normal stresses - Ordinary stiffeners subjected to lateral pressure

Condition	σ_{S1}, in N/mm² **(1)**	σ_{WV1}, in N/mm²	σ_{WH1}, in N/mm²
Lateral pressure applied on the side opposite to the ordinary stiffener, with respect to the plating:			$\left\lvert\frac{0,625M_{WH}}{I_Z}y\right\rvert 10^{-3}$
• z ≥ N in general ; z < N for stiffeners simply supported at both ends	$\left\lvert\frac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625F_DM_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	
• z < N in general ; z ≥ N for stiffeners simply supported at both ends	$\left\lvert\frac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	
Lateral pressure applied on the same side as the ordinary stiffener:			
• z ≥ N in general ; z < N for stiffeners simply supported at both ends	$\left\lvert\frac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	
• z < N in general ; z ≥ N for stiffeners simply supported at both ends	$\left\lvert\frac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625F_DM_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 4 : Hull girder normal stresses - Ordinary stiffeners subjected to wheeled loads

Condition	Hull girder normal stresses, in N/mm²
• Hogging	$\sigma_{X1H} = \left\lvert\gamma_{S1}\frac{M_{SW,H}}{I_Y}(z-N)10^{-3}+\gamma_{W1}\left(C_{FV}\frac{0,625M_{WV,H}}{I_Y}(z-N)10^{-3}+C_{FH}\frac{0,625M_{WH}}{I_Z}y10^{-3}+C_{F\Omega}\sigma_{\Omega}\right)\right\rvert$
• Sagging **(1)**	$\sigma_{X1S} = \left\lvert\gamma_{S1}\frac{M_{SW,S}}{I_Y}(z-N)10^{-3}+\gamma_{W1}\left(C_{FV}\frac{0,625F_DM_{WV,S}}{I_Y}(z-N)10^{-3}+C_{FH}\frac{0,625M_{WH}}{I_Z}y10^{-3}+C_{F\Omega}\sigma_{\Omega}\right)\right\rvert$

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

3.4.2 Single span longitudinal and transverse ordinary stiffeners

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m w}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3 + \sigma_{X1}$$

$$\tau = 5\beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b , β_s : Coefficients defined in Tab 5.

Table 5 : Coefficients β_b and β_s

Brackets at ends	Bracket lengths	β_b	β_s
0	–	1	1
1	ℓ_b	$\left(1 - \frac{\ell_b}{2\ell}\right)^2$	$1 - \frac{\ell_b}{2\ell}$
2	ℓ_{b1} ; ℓ_{b2}	$\left(1 - \frac{\ell_{b1}}{2\ell} - \frac{\ell_{b2}}{2\ell}\right)^2$	$1 - \frac{\ell_{b1}}{2\ell} - \frac{\ell_{b2}}{2\ell}$

3.4.3 Single span vertical ordinary stiffeners

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \lambda_b \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m w}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$\tau = 5\lambda_s \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b , β_s : Coefficients defined in [3.4.2]

λ_b : Coefficient taken equal to the greater of the following values:

$$\lambda_b = 1 + 0{,}2\frac{\gamma_{S2}(p_{Sd} - p_{Su}) + \gamma_{W2}(p_{Wd} - p_{Wu})}{\gamma_{S2}(p_{Sd} + p_{Su}) + \gamma_{W2}(p_{Wd} + p_{Wu})}$$

$$\lambda_b = 1 - 0{,}2\frac{\gamma_{S2}(p_{Sd} - p_{Su}) + \gamma_{W2}(p_{Wd} - p_{Wu})}{\gamma_{S2}(p_{Sd} + p_{Su}) + \gamma_{W2}(p_{Wd} + p_{Wu})}$$

λ_s : Coefficient taken equal to the greater of the following values:

$$\lambda_s = 1 + 0{,}4\frac{\gamma_{S2}(p_{Sd} - p_{Su}) + \gamma_{W2}(p_{Wd} - p_{Wu})}{\gamma_{S2}(p_{Sd} + p_{Su}) + \gamma_{W2}(p_{Wd} + p_{Wu})}$$

$$\lambda_s = 1 - 0{,}4\frac{\gamma_{S2}(p_{Sd} - p_{Su}) + \gamma_{W2}(p_{Wd} - p_{Wu})}{\gamma_{S2}(p_{Sd} + p_{Su}) + \gamma_{W2}(p_{Wd} + p_{Wu})}$$

p_{Sd} : Still water pressure, in kN/m², at the lower end of the ordinary stiffener considered

p_{Su} : Still water pressure, in kN/m², at the upper end of the ordinary stiffener considered

p_{Wd} : Wave pressure, in kN/m², at the lower end of the ordinary stiffener considered

p_{Wu} : Wave pressure, in kN/m², at the upper end of the ordinary stiffener considered.

3.4.4 Multispan ordinary stiffeners

The maximum normal stress σ and shear stress τ in a multispan ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water and wave pressure and forces, to be determined on the basis of the criteria specified in Ch 5, Sec 5 and Ch 5, Sec 6
- 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.

3.5 Normal and shear stresses due to wheeled loads

3.5.1 General

Normal and shear stresses, induced by the wheeled loads, in ordinary stiffeners are to be obtained from the formulae in:

- [3.5.2] in the case of single span longitudinal and transverse stiffeners
- [3.5.3]in the case of multispan stiffeners.

3.5.2 Single span longitudinal and transverse ordinary stiffeners subjected to wheeled loads

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \alpha_W K_S \frac{P_0 \ell}{6w} 10^3 + \sigma_{X1,Wh}$$

$$\tau = \alpha_W K_T \frac{10 P_0}{A_{Sh}}$$

where:

P_0 : Wheeled force, in kN, taken equal to:

$P_0 = \gamma_{S2} F_S + \gamma_{W2} F_{W,Z}$

α_w : Coefficient taking account of the number of wheels per axle considered as acting on the stiffener, defined in Tab 6

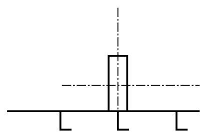
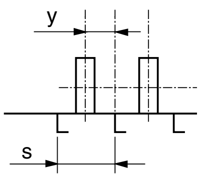
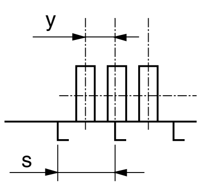
K_S , K_T : Coefficients taking account of the number of axles considered as acting on the stiffener, defined in Tab 7.

3.5.3 Multispan ordinary stiffeners subjected to wheeled loads

The maximum normal stress σ and shear stress τ in a multispan ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water forces and inertial forces applying on the stiffener, to be determined according to [3.3.6]
- the number and position of intermediate supports (girders, bulkheads, 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.

Table 6 : Wheeled loads - Coefficient α_W

Configuration		α_W
Single wheel		1
Double wheels		$2\left(1-\frac{y}{s}\right)$
Triple wheels		$3-2\frac{y}{s}$

Note 1:

y : Distance, in m, from the external wheel of a group of wheels to the stiffener under consideration, to be taken equal to the distance from the external wheel to the centre of the group of wheels.

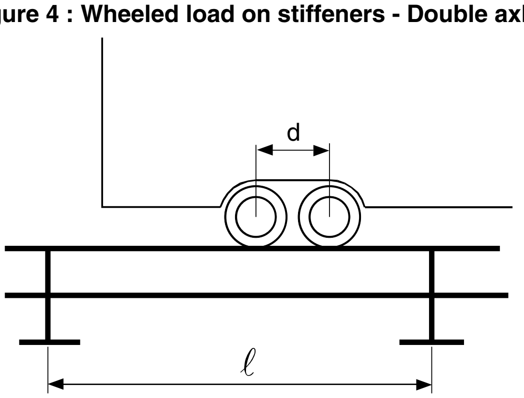
Table 7 : Wheeled loads - Coefficients K_S and K_T

Coefficient	Configuration	
	Single axle	Double axles
K_S	1	• if $d \le \ell/\sqrt{3}$ $\frac{172}{81}-\frac{4d}{3\ell}-\frac{d^2}{\ell^2}+\frac{d^4}{\ell^4}$ • if $d > \ell/\sqrt{3}$ $\frac{4}{3}-\frac{4d}{3\ell}+\frac{3d^2}{\ell^2}-\frac{8d^3}{3\ell^3}$
K_T	1	$2-\frac{d}{2\ell}-\frac{3d^2}{2\ell^2}+\frac{d^3}{\ell^3}$

Note 1:

d : Distance, in m, between two axles (see Fig 4).

Figure 4 : Wheeled load on stiffeners - Double axles



3.6 Checking criteria

3.6.1 General

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [3.4] and [3.5], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \ge \sigma$$

$$0,5\frac{R_y}{\gamma_R \gamma_m} \ge \tau$$

3.7 Net section modulus and net shear sectional area of ordinary stiffeners, complying with the checking criteria

3.7.1 General

The requirements in [3.7.3] and [3.7.4] provide the minimum net section modulus and net shear sectional area of single span ordinary stiffeners subjected to lateral pressure in intact conditions, complying with the checking criteria indicated in [3.6].

The requirements in [3.7.5] provide the minimum net section modulus and net shear sectional area of single span ordinary stiffeners subjected to wheeled loads, complying with the checking criteria indicated in [3.6].

The requirements in [3.7.6] provide the minimum net section modulus and net shear sectional area of multispan ordinary stiffeners subjected to lateral pressure in intact condition or to wheeled loads, complying with the checking criteria indicated in [3.6].

3.7.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.7.1] 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.

3.7.3 Single span longitudinal and transverse ordinary stiffeners subjected to lateral pressure

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of longitudinal or transverse ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})}\left(1-\frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}\left(1-\frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in [3.4.2].

3.7.4 Single span vertical ordinary stiffeners subjected to lateral pressure

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of vertical ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m R_y} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in [3.4.2]

λ_b, λ_s : Coefficients defined in [3.4.3].

3.7.5 Single span ordinary stiffeners subjected to wheeled loads

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of ordinary stiffeners subjected to wheeled loads are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \frac{\alpha_W K_S P_0 \ell}{6(R_y - \gamma_R \gamma_m \sigma_{X1,Wh})} 10^3$$

$$A_{Sh} = 20 \gamma_R \gamma_m \frac{\alpha_W K_T P_0}{R_y}$$

where:

P_0 : Wheeled force, in kN, defined in [3.5.2]

α_W, K_S, K_T: Coefficients defined in [3.5.2].

3.7.6 Multispan ordinary stiffeners

The minimum net section modulus and the net shear sectional area of multispan ordinary stiffeners are to be obtained from [3.4.4] or [3.5.3], as applicable, taking account of the checking criteria indicated in [3.6].

3.8 Net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in flooding conditions

3.8.1 General

The requirements in [3.8.3] to [3.8.5] provide the minimum net section modulus and net shear sectional area of ordinary stiffeners subject to flooding.

3.8.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.8.1] 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.

3.8.3 Single span longitudinal and transverse ordinary stiffeners

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of longitudinal or transverse ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b , β_s : Coefficients defined in [3.4.2].

3.8.4 Single span vertical ordinary stiffeners

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of vertical ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \lambda_b \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{m R_y} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b , β_s : Coefficients defined in [3.4.2]

λ_b : Coefficient taken equal to the greater of the following values:

$$\lambda_b = 1 + 0,2 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

$$\lambda_b = 1 - 0,2 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

λ_s : Coefficient taken equal to the greater of the following values:

$$\lambda_s = 1 + 0,4 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

$$\lambda_s = 1 - 0,4 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

p_{SFd} : Still water pressure, in kN/m^2, in flooding conditions, at the lower end of the ordinary stiffener considered

p_{SFu} : Still water pressure, in kN/m^2, in flooding conditions, at the upper end of the ordinary stiffener considered

p_{WFd} : Wave pressure, in kN/m^2, in flooding conditions, at the lower end of the ordinary stiffener considered

p_{WFu} : Wave pressure, in kN/m^2, in flooding conditions, at the upper end of the ordinary stiffener considered.

3.8.5 Multispan ordinary stiffeners

The minimum net section modulus and the net shear sectional area of multispan ordinary stiffeners are to be obtained from [3.4.4], considering the still water pressure p_{SF} and the wave pressure p_{WF} in flooding conditions, and taking account of the checking criteria indicated in [3.6].

3.9 Net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in testing conditions

3.9.1 General

The requirements in [3.9.3] to [3.9.5] provide the minimum net section modulus and net shear sectional area of ordinary stiffeners of compartments subject to testing conditions.

3.9.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.9.1] 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.

3.9.3 Single span longitudinal and transverse ordinary stiffeners

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of longitudinal or transverse ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_T}{m R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_T}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b , β_s : Coefficients defined in [3.4.2].

3.9.4 Single span vertical ordinary stiffeners

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of vertical ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_T}{m R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_T}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b , β_s : Coefficients defined in [3.4.2]

λ_b : Coefficient taken equal to the greater of the following values:

$$\lambda_b = 1 + 0{,}2 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

$$\lambda_b = 1 - 0{,}2 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

λ_s : Coefficient taken equal to the greater of the following values:

$$\lambda_s = 1 + 0{,}4 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

$$\lambda_s = 1 - 0{,}4 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

p_{Td} : Still water pressure, in kN/m^2, in testing conditions, at the lower end of the ordinary stiffener considered

p_{Tu} : Still water pressure, in kN/m^2, in testing conditions, at the upper end of the ordinary stiffener considered.

3.9.5 Multispan ordinary stiffeners

The minimum net section modulus and the net shear sectional area of multispan ordinary stiffeners are to be obtained from [3.4.4], considering the pressure in testing conditions and taking account of the checking criteria indicated in [3.6].

3.10 Net section modulus and net shear sectional area of ordinary stiffeners subject to impact loads

3.10.1 Single span longitudinal, transverse and vertical ordinary stiffeners

Unless otherwise specified, the net plastic section modulus Z_{pl} , in cm^3, as defined in Ch 4, Sec 3, [3.4.3] and the net web thickness t_w , in mm, of stiffeners subject to impact generated by fluids are to be not less than the values obtained from the following formulae:

$$Z_{pl} = \frac{P_I}{0,9(n+2)4R_{eH}} s \ell^2 10^3$$

$$t_w = \frac{\sqrt{3}}{2} \frac{P_I}{(h_w + t_p) R_{eH}} s \ell 10^3$$

where:

P_I : Any impact pressure defined in the Rules, including:

- bottom impact pressure, as defined in Ch 8, Sec 1, [3.2]
- bow impact pressure, as defined in Ch 8, Sec 1, [4.2]
- dynamic impact pressure, as defined in Ch 5, Sec 6, [2.5]
- stern impact pressure, as defined in Ch 8, Sec 2, [4.2]

n : Number of fixed ends of stiffener:

- n = 2 for continuous members or members with brackets fitted at both ends
- n = 1 for one end equivalent to built-in and the other end simply supported
- n = 0 for both ends with low end fixity

t_p : Attached plating net thickness, in mm.

If deemed necessary by the Society and depending on specific natures of loadings, different calculation methods may be applied, on a case-by-case basis.

4 Buckling check

4.1 Width of attached plating

4.1.1 The width of the attached plating to be considered for the buckling check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where no local buckling occurs on the attached plating (see Ch 7, Sec 1, [5.4.1]): $b_e = s$
- where local buckling occurs on the attached plating (see Ch 7, Sec 1, [5.4.1]):

  $$b_e = \left(\frac{2,25}{\beta_e} - \frac{1,25}{\beta_e^2}\right) s$$

  to be taken not greater than s

where:

$$\beta_e = \frac{s}{t_p}\sqrt{\frac{\sigma_b}{E}} 10^3$$

σ_b : Compression stress σ_X or σ_Y, in N/mm^2, acting on the plate panel, defined in Ch 7, Sec 1, [5.2.4], according to the direction x or y considered.

Table 8 : Hull girder normal compression stresses

Condition	σ_{S1} in N/mm² **(1)**	σ_{WV1} in N/mm²	σ_{WH1} in N/mm²
$z \geq N$	$\frac{M_{SW,S}}{I_Y}(z-N)10^{-3}$	$\frac{0,625F_D M_{WV,S}}{I_Y}(z-N)10^{-3}$	$-\left\lvert\frac{0,625M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$z < N$	$\frac{M_{SW,H}}{I_Y}(z-N)10^{-3}$	$\frac{0,625M_{WV,H}}{I_Y}(z-N)10^{-3}$	

(1) When the ship in still water is always in hogging condition, σ_{S1} for $z \geq N$ is to be obtained, in N/mm², from the following formula, unless σ_{X1} is evaluated by means of direct calculations (see [4.2.2]):

$$\sigma_{S1} = \frac{M_{SW,Hmin}}{I_Y}(z-N)10^{-3}$$

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

4.2 Load model

4.2.1 Sign convention for normal stresses

The sign convention for normal stresses is as follows:

- tension: positive
- compression: negative.

4.2.2 Hull girder compression normal stresses

The hull girder compression normal stresses to be considered for the buckling check of ordinary stiffeners contributing to the hull girder longitudinal strength are obtained, in N/mm², from the following formula:

$$\sigma_{X1} = \gamma_{S1}\,\sigma_{S1} + \gamma_{W1}\,(C_{FV}\,\sigma_{WV1} + C_{FH}\,\sigma_{WH1} + C_{F\Omega}\,\sigma_{\Omega})$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 8

σ_{Ω} : Compression warping stress, in N/mm², induced by the torque $0,625M_{WT}$ and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6]

C_{FV}, C_{FH}, $C_{F\Omega}$: Combination factors defined in Tab 2.

For longitudinal stiffeners, σ_{X1} is to be taken as the maximum compression stress on the stiffener considered.

When the ship in still water is always in hogging condition, σ_{X1} may be evaluated by means of direct calculations when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

Where deemed necessary, the buckling check is to be carried out in harbour conditions by considering a reduced wave bending moment equal to 0,1 M_{WV} given in Ch 5, Sec 2, [3.1].

4.3 Critical stress

4.3.1 General

The critical buckling stress is to be obtained, in N/mm², from the following formulae:

$$\sigma_c = \sigma_E \quad \text{for } \sigma_E \leq \frac{R_{eH,S}}{2}$$

$$\sigma_c = R_{eH,S}\left(1 - \frac{R_{eH,S}}{4\sigma_E}\right) \quad \text{for } \sigma_E > \frac{R_{eH,S}}{2}$$

where:

$\sigma_E = \text{Min}(\sigma_{E1}, \sigma_{E2}, \sigma_{E3})$

σ_{E1} : Euler column buckling stress, in N/mm², given in [4.3.2]

σ_{E2} : Euler torsional buckling stress, in N/mm², given in [4.3.3]

σ_{E3} : Euler web buckling stress, in N/mm², given in [4.3.4].

4.3.2 Column buckling of axially loaded stiffeners

The Euler column buckling stress is obtained, in N/mm², from the following formula:

$$\sigma_E = \pi^2 E \frac{I_e}{A_e \ell^2} 10^{-4}$$

4.3.3 Torsional buckling of axially loaded stiffeners

The Euler torsional buckling stresses is obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E I_w}{10^4 I_p \ell^2}\left(\frac{K_C}{m^2} + m^2\right) + 0,385E\frac{I_t}{I_p}$$

where:

I_w : Net sectorial moment of inertia, in cm⁶, of the stiffener about its connection to the attached plating:

- for flat bars:

$$I_w = \frac{h_w^3 t_w^3}{36} 10^{-6}$$

- for T-sections:

$$I_w = \frac{t_f b_f^3 h_w^2}{12} 10^{-6}$$

- for angles and bulb sections:

$$I_w = \frac{b_f^3 h_w^2}{12(b_f + h_w)^2}[t_f(b_f^2 + 2b_f h_w + 4h_w^2) + 3t_w b_f h_w]\,10^{-6}$$

I_p : Net polar moment of inertia, in cm⁴, of the stiffener about its connection to the attached plating:

- for flat bars:

$$I_p = \frac{h_w^3 t_w}{3} 10^{-4}$$

- for stiffeners with face plate:

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

I_t : St. Venant's net moment of inertia, in cm⁴, of the stiffener without attached plating:

- for flat bars:

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

- for stiffeners with face plate:

$$I_t = \frac{1}{3}\left[h_w t_w^3 + b_f t_f^3\left(1 - 0{,}63\frac{t_f}{b_f}\right)\right] 10^{-4}$$

m : Number of half waves, to be taken equal to the integer number such that (see also Tab 9):

$$m^2(m-1)^2 \le K_C < m^2(m+1)^2$$

$$K_C = \frac{C_0 \ell^4}{\pi^4 E I_w} 10^6$$

C_0 : Spring stiffness of the attached plating:

$$C_0 = \frac{E t_p^3}{2{,}73 s} 10^{-3}$$

Table 9 : Torsional buckling of axially loaded stiffeners - Number m of half waves

K_C	$0 \le K_C < 4$	$4 \le K_C < 36$	$36 \le K_C < 144$
m	1	2	3

4.3.4 Web buckling of axially loaded stiffeners

The Euler buckling stress of the stiffener web is obtained, in N/mm², from the following formulae:

- for flat bars:

$$\sigma_E = 16\left(\frac{t_W}{h_W}\right)^2 10^4$$

- for stiffeners with face plate:

$$\sigma_E = 78\left(\frac{t_W}{h_W}\right)^2 10^4$$

4.4 Checking criteria

4.4.1 Stiffeners parallel to the direction of compression

The critical buckling stress of the ordinary stiffener parallel to the direction of compression, as shown in Fig 5, is to comply with the following formula:

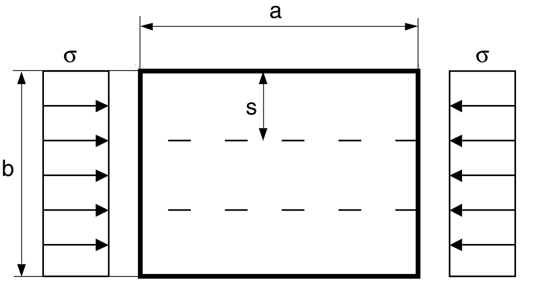
$$\frac{\sigma_c}{\gamma_R \gamma_m} \ge |\sigma_b|$$

where:

σ_c : Critical buckling stress, in N/mm², as calculated in [4.3.1]

σ_b : Compression stress σ_{xb} or σ_{yb}, in N/mm², in the stiffener, as calculated in [4.2.2].

Figure 5 : Buckling of stiffeners parallel to the direction of compression



5 Ultimate strength check of ordinary stiffeners contributing to the hull girder longitudinal strength

5.1 Application

5.1.1 The requirements of this Article apply to ships equal to or greater than 170 m in length. For such ships, the ultimate strength of stiffeners subjected to lateral pressure and to hull girder normal stresses is to be checked.

5.2 Width of attached plating

5.2.1 The width of the attached plating to be considered for the ultimate strength check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- if $\beta_U \le 1{,}25$:

  $b_U = s$

- if $\beta_U > 1{,}25$:

$$b_U = \left(\frac{2{,}25}{\beta_U} - \frac{1{,}25}{\beta_U^2}\right) s$$

where:

$$\beta_U = \frac{s}{t_p}\sqrt{\frac{\sigma_{X1E}}{E}} 10^3$$

σ_{X1E} : Stress defined in Tab 10.

5.3 Load model

5.3.1 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 ordinary stiffener under consideration and the type of compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases "a", "b", "c" and "d" in Ch 5, Sec 4.

5.3.2 Lateral pressure

Lateral pressure is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave induced pressure (p_W) includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case "a", "b", "c" and "d"
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case "a", "b", "c" and "d".

5.3.3 Hull girder compression normal stresses

The hull girder compression normal stresses σ_{X1} to be considered for the ultimate strength check of stiffeners contributing to the longitudinal strength are those given in [4.2.2], where the partial safety factors are those specified in Tab 1 for the ultimate strength check.

5.4 Ultimate strength stress

5.4.1 The ultimate strength stress σ_U is to be obtained, in N/mm², from the formulae in Tab 10, for resultant lateral pressure acting either on the side opposite to the ordinary stiffener, with respect to the plating, or on the same side as the ordinary stiffener.

5.5 Checking criteria

5.5.1 The ultimate strength stress of the ordinary stiffener is to comply with the following formula:

$$\frac{\sigma_U}{\gamma_R \gamma_m} \geq |\sigma_{X1}|$$

where:

σ_U : Ultimate strength stress, in N/mm², as calculated in [5.4.1]

σ_{X1} : Compression stress, in N/mm², as calculated in [5.3.3].

Table 10 : Ultimate strength stress

Symbol	Resultant load pressure acting on the side opposite to the ordinary stiffener, with respect to the plating, in N/mm²	Resultant load pressure acting on the same side as the ordinary stiffener, in N/mm²
σ_U	$f\frac{A_U}{A_S}\left(1-\frac{s}{10b_U}\right)R_{eH,P}$	$R_{eH,S}\,f$
f	$\frac{\zeta}{2}-\sqrt{\frac{\zeta^2}{4}-\frac{1-\mu}{(1+\eta_P)\lambda_U^2}}$	

Note 1:

$d_{P,U}$: Distance, in cm, between the neutral axis of the cross-section of the stiffener with attached plating of width b_U and the fibre at half-thickness of the plating

$d_{F,S}$: Distance, in cm, between the neutral axis of the cross-section of the stiffener with attached plating of width s and the fibre at half-thickness of the face plate of the stiffener

d_P : Distance, in cm, between the neutral axis of the ordinary stiffener without attached plating and the fibre at half-thickness of the attached plating

p : Lateral pressure acting on the stiffener, equal to: $p = \gamma_{S2}\,p_S + \gamma_{W2U}\,p_W$

δ_0 : Pre-deformation, in cm, of the ordinary stiffener, to be assumed, in the absence of more accurate evaluation: $\delta_0 = 0{,}2\,\ell$

E_T : Structural tangent modulus, equal to:

$$E_T = 4E\frac{\sigma_{X1E}}{R_{eH,P}}\left(1-\frac{\sigma_{X1E}}{R_{eH,P}}\right) \quad \text{for } \sigma_{X1E} > 0{,}5R_{eH,P}$$

$$E_T = E \quad \text{for } \sigma_{X1E} \leq 0{,}5R_{eH,P}$$

σ_{X1E} : Stress to be obtained, in N/mm², from the following formulae:

$$\sigma_{X1E} = \left\{\frac{-\frac{22{,}5st_P}{\alpha}+\sqrt{\left(\frac{22{,}5st_P}{\alpha}\right)^2+4A\left[(A+10st_P)|\sigma_{X1}|+\frac{12{,}5st_P}{\alpha^2}\right]}}{2A}\right\}^2 \quad \text{if } \alpha > \frac{1{,}25}{\sqrt{|\sigma_{X1}|}}$$

$$\sigma_{X1E} = |\sigma_{X1}| \quad \text{if } \alpha \leq \frac{1{,}25}{\sqrt{|\sigma_{X1}|}}$$

$$\alpha = 1000\frac{s}{t_P\sqrt{E}}$$

σ_{X1} : Compression stress, in N/mm², acting on the stiffener, as defined in [5.3.3].

Symbol	Resultant load pressure acting on the side opposite to the ordinary stiffener, with respect to the plating, in N/mm²	Resultant load pressure acting on the same side as the ordinary stiffener, in N/mm²
ζ	$\frac{1-\mu}{1+\eta_P}+\frac{1+\eta_P+\eta}{(1+\eta_P)\lambda_U^2}$	
μ	$\frac{125ps\ell^2 d_{P,U}}{R_{eH,P}I_U\left(1-\frac{s}{10b_U}\right)}$	$\frac{41,7ps\ell^2 d_{F,S}}{R_{eH,S}I_S}$
η	$\left(\delta_0+\frac{13ps\ell^4}{E_TI_S}10^4\right)\frac{d_{P,U}}{\rho_U^2}$	$\left(0,577\delta_0+\frac{1,5ps\ell^4}{E_TI_S}10^4\right)\frac{d_{F,S}}{\rho_S^2}$
η_P	$d_PA\left(\frac{1}{A_U}-\frac{1}{A_S}\right)\frac{d_{P,U}}{\rho_U^2}$	0
λ_U	$\frac{31,8\ell}{\rho_U}\sqrt{\frac{R_{eH,P}}{E_T}\left(1-\frac{s}{10b_U}\right)}$	$\frac{18,4\ell}{\rho_S}\sqrt{\frac{R_{eH,S}}{E_T}}$

Note 1:

$d_{P,U}$: Distance, in cm, between the neutral axis of the cross-section of the stiffener with attached plating of width b_U and the fibre at half-thickness of the plating

$d_{F,S}$: Distance, in cm, between the neutral axis of the cross-section of the stiffener with attached plating of width s and the fibre at half-thickness of the face plate of the stiffener

d_P : Distance, in cm, between the neutral axis of the ordinary stiffener without attached plating and the fibre at half-thickness of the attached plating

p : Lateral pressure acting on the stiffener, equal to: $p = \gamma_{S2}\, p_S + \gamma_{W2U}\, p_W$

δ_0 : Pre-deformation, in cm, of the ordinary stiffener, to be assumed, in the absence of more accurate evaluation: $\delta_0 = 0,2\ \ell$

E_T : Structural tangent modulus, equal to:

$$E_T = 4E\frac{\sigma_{X1E}}{R_{eH,P}}\left(1-\frac{\sigma_{X1E}}{R_{eH,P}}\right) \quad \text{for } \sigma_{X1E} > 0,5R_{eH,P}$$

$$E_T = E \quad \text{for } \sigma_{X1E} \le 0,5R_{eH,P}$$

σ_{X1E} : Stress to be obtained, in N/mm², from the following formulae:

$$\sigma_{X1E} = \left\{\frac{-\frac{22,5st_P}{\alpha}+\sqrt{\left(\frac{22,5st_P}{\alpha}\right)^2+4A\left[(A+10st_P)|\sigma_{X1}|+\frac{12,5st_P}{\alpha^2}\right]}}{2A}\right\}^2 \quad \text{if } \alpha > \frac{1,25}{\sqrt{|\sigma_{X1}|}}$$

$$\sigma_{X1E} = |\sigma_{X1}| \quad \text{if } \alpha \le \frac{1,25}{\sqrt{|\sigma_{X1}|}}$$

$$\alpha = 1000\frac{s}{t_P\sqrt{E}}$$

σ_{X1} : Compression stress, in N/mm², acting on the stiffener, as defined in [5.3.3].

SECTION 3 PRIMARY SUPPORTING MEMBERS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m², see [3.4.2] and [3.4.4]

p_W : Wave pressure, in kN/m², see [3.4.2] and [3.4.4]

p_{SF}, p_{WF} : Still water and wave pressures, in kN/m², in flooding conditions, defined in Ch 5, Sec 6, [9]

σ_{X1} : Hull girder normal stress, in N/mm², defined in [3.4.5]

s : Spacing, in m, of primary supporting members

ℓ : Span, in m, of primary supporting members, measured between the supporting elements, see Ch 4, Sec 3, [4.1]

b_p : Width, in m, of the plating attached to the primary supporting member, for the yielding check, defined in Ch 4, Sec 3, [4.2]

w : Net section modulus, in cm³, of the primary supporting member, with an attached plating of width b_p , to be calculated as specified in Ch 4, Sec 3, [4.3]

A_{Sh} : Net shear sectional area, in cm², of the primary supporting member, to be calculated as specified in Ch 4, Sec 3, [4.3]

m : Boundary coefficient, to be taken equal to:

- m = 10 in general
- m = 12 for bottom and side primary supporting members

I : Net moment of inertia, in cm⁴, of the primary supporting member without attached plating, about its neutral axis parallel to the plating.

1 General

1.1 Application

1.1.1 Analysis criteria

The requirements of this Section apply for the yielding and buckling checks of primary supporting members.

1.1.2 Structural models

Depending on the service notation and structural arrangement, primary structural models are to be modelled as specified in Tab 1.

Table 1 : Selection of structural models

Service notation	Ship length, in m	Calculation model
ro-ro cargo ship **PCT Carrier** **ro-ro passenger ship** **passenger ship** **general cargo ship** with large deck openings	$L \leq 120$	Isolated beam model, or three dimensional beam model for grillage or complex arrangement
	$120 < L \leq 170$	Three dimensional beam model
	$L > 170$	Complete ship model
Other ships	$L \leq 120$	Isolated beam model, or three dimensional beam model for grillage or complex arrangement
	$120 < L \leq 170$	Three dimensional beam model
	$L > 170$	Three dimensional finite element model

1.1.3 Yielding check

The yielding check is to be carried out according to:

- [3] for primary supporting members analysed through isolated beam models
- [4] for primary supporting members analysed through three dimensional beam or finite element models
- [5] for primary supporting members analysed through complete ship models.

1.1.4 Buckling check

The buckling check is to be carried out according to [7], on the basis of the stresses in primary supporting members calculated according to [3], [4] or [5], depending on the structural model adopted.

1.1.5 Minimum net thicknesses

In addition to the above, the scantlings of primary supporting members are to comply with the requirements in [2].

1.2 Analysis documentation

1.2.1 The following documents are to be submitted to the Society for review of the three dimensional beam or finite element structural analyses:

- reference to the calculation program used with identification of the version number and results of the validation text, if the results of the program have not been already submitted to the Society approval
- extent of the model, element types and properties, material properties and boundary conditions
- loads given in print-out or suitable electronic format. In particular, the method used to take into account the interaction between the overall, primary and local loadings is to be described. The direction and intensity of pressure loads, concentrated loads, inertia and weight loads are to be provided
- stresses given in print-out or suitable electronic format
- buckling checks as required in [7]
- fatigue checks of structural details, as required in Ch 7, Sec 4
- identification of the critical areas, where the results of the checkings exceed 97,5% of the permissible rule criteria in [4.4] or [5.3] and [7].

1.2.2 According to the results of the submitted calculations, the Society may request additional runs of the model with structural modifications or local mesh refinements in highly stressed areas.

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], 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 4, Sec 2.

1.4 Partial safety factors

1.4.1 The partial safety factors to be considered for checking primary supporting members are specified in:

- Tab 2 for analyses based on isolated beam models
- Tab 3 for analyses based on three dimensional models
- Tab 4 for analyses based on complete ship models.

Table 2 : Primary supporting members analysed through isolated beam models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check			Buckling check	
		General (see [3.4] to [3.7])	Flooding pressure **(1)** (see [3.8])	Testing check (see [3.9])	Plate panels (see [7.1])	Pillars (see [7.2] and [7.3])
Still water hull girder loads	γ_{S1}	1,00	1,00	NA	1,00	1,00
Wave hull girder loads	γ_{W1}	1,15	1,15	NA	1,15	1,15
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,05	NA	1,20	1,20
Material	γ_m	1,02	1,02	1,02	1,02	1,02
Resistance	γ_R	1,02 in general 1,15 for bottom and side girders	1,02 **(2)**	1,20	1,10	for [7.2]: see Tab 13 for [7.3]: 1,15

(1) Applies only to primary supporting members to be checked in flooding conditions
(2) For primary supporting members of the collision bulkhead, γ_R = 1,25

Table 3 : Primary supporting members analysed through three dimensional models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check (see [4])			Buckling check	
		General	Flooding pressure **(1)**	Testing check	Plate panels (see [7.1])	Pillars (see [7.2] and [7.3])
Still water hull girder loads	γ_{S1}	1,00	1,00	NA	1,00	1,00
Wave hull girder loads	γ_{W1}	1,05	1,05	NA	1,05	1,05
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10	NA	1,10	1,10
Material	γ_m	1,02	1,02	1,02	1,02	1,02
Resistance	γ_R	defined in Tab 5	defined in Tab 5	defined in Tab 5	1,02 **(2)**	for [7.2]: see Tab 13 for [7.3]: 1,15

(1) Applies only to primary supporting members to be checked in flooding conditions
(2) For corrugated bulkhead platings, γ_R = 1,10
Note 1: For primary supporting members of the collision bulkhead, γ_R = 1,25

Table 4 : Primary supporting members analysed through complete ship models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check (see [5])	Buckling check	
			Plate panels (see [7.1])	Pillars (see [7.2] and [7.3])
Still water hull girder loads	γ_{S1}	1,00	1,00	1,00
Wave hull girder loads	γ_{W1}	1,10	1,10	1,10
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10	1,10
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	defined in Tab 5	1,02 **(1)**	for [7.2]: see Tab 13 for [7.3]: 1,15
(1) For corrugated bulkhead platings, γ_R = 1,10				

Table 5 : Primary supporting members analysed through three dimensional or complete ship models Resistance partial safety factor

Type of three dimensional model (see Ch 7, App 1)	Resistance partial safety factor γ_R (see [4.4] and [5.3])		
	General	Flooding pressure	Testing check
Beam model	1,20	1,02	1,20
Coarse mesh finite element model	1,20	1,02	1,20
Standard mesh finite element model	1,05	1,02	1,05
Fine mesh finite element model	1,05	1,02	1,05

2 General requirements

2.1 Minimum thicknesses

2.1.1 General

The net thickness of plating which forms the webs of primary supporting members is to be not less than the value obtained, in mm, from the following formulae:

$t_{MIN} = 3,7 + 0,015\ L\ k^{1/2}$ for L < 120 m

$t_{MIN} = 3,7 + 1,8\ k^{1/2}$ for L ≥ 120 m

2.1.2 Double bottom

In addition to the requirements in [2.1], the net thickness of plating which forms the webs of primary supporting members of the double bottom is to be not less than the values given in Tab 6.

2.1.3 Single bottom

In addition to the requirements in [2.1], the net thickness of plating which forms the webs and the flanges of primary supporting members of the single bottom is to be not less than the values given in Tab 7.

Table 6 : Minimum net thicknesses of webs of double bottom primary supporting members

Primary supporting member	Minimum net thickness, in mm	
	Area within 0,4L amidships	Area outside 0,4L amidships
Centre girder	$2,0\ L^{1/3}\ k^{1/6}$	$1,7\ L^{1/3}\ k^{1/6}$
Side girders	$1,4\ L^{1/3}\ k^{1/6}$	$1,4\ L^{1/3}\ k^{1/6}$
Floors	$1,5\ L^{1/3}\ k^{1/6}$	$1,5\ L^{1/3}\ k^{1/6}$
Girder bounding a duct keel **(1)**	$1,5 + 0,8\ L^{1/2}\ k^{1/4}$	$1,5 + 0,8\ L^{1/2}\ k^{1/4}$
Margin plate	$L^{1/2}\ k^{1/4}$	$0,9\ L^{1/2}\ k^{1/4}$
(1) The minimum net thickness is to be taken not less than that required for the centre girder.		

Table 7 : Minimum net thicknesses of webs and flanges of single bottom primary supporting members

Primary supporting member	Minimum net thickness, in mm	
	Area within 0,4L amidships	Area outside 0,4L amidships
Centre girder	$6,0 + 0,05\ L_2\ k^{1/2}$	$4,5 + 0,05\ L_2\ k^{1/2}$
Floors and side girders	$5,0 + 0,05\ L_2\ k^{1/2}$	$3,5 + 0,05\ L_2\ k^{1/2}$

2.2 Deck primary members in way of launching appliances used for survival craft or rescue boat

2.2.1 The scantlings of deck primary supporting members are to be determined by direct calculations.

2.2.2 The loads exerted by launching appliance are to correspond to the SWL of the launching appliance.

2.2.3 The combined stress, in N/mm², is not to exceed the smaller of $R_{eH}/2,2$ and $R_m/4,5$ where R_m is the ultimate minimum tensile strength of the primary supporting member material, in N/mm².

3 Yielding check of primary supporting members analysed through an isolated beam structural model

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of primary supporting members subjected to lateral pressure or to wheeled loads and, for those contributing to the hull girder longitudinal strength, to hull girder normal stresses, which may be analysed through an isolated beam model, according to [1.1.2].

3.1.2 The yielding check is also to be carried out for primary supporting members subjected to specific loads, such as concentrated loads.

3.2 Bracket arrangement

3.2.1 The requirements of this Article apply to primary supporting members with brackets at both ends of length not greater than 0,2 ℓ.

In the case of a significantly different bracket arrangement, the determination of normal and shear stresses due to design loads and the required section modulus and shear sectional area are considered by the Society on a case by case basis.

3.3 Load point

3.3.1 Lateral pressure

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the primary supporting member considered.

3.3.2 Hull girder normal stresses

For longitudinal primary supporting members contributing to the hull girder longitudinal strength, the hull girder normal stresses are to be calculated in way of the neutral axis of the primary supporting member with attached plating.

3.4 Load model

3.4.1 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 primary supporting member under consideration and the type of compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

Primary supporting members located on platings below the deepest equilibrium waterline (excluding those on side shell platings) which constitute boundaries intended to stop vertical and horizontal flooding are to be subjected to lateral pressure in flooding conditions.

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases “a”, “b”, “c” and “d” in Ch 5, Sec 4.

3.4.2 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 still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case “a”, “b”, “c” and “d”
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case “a”, “b”, “c” and “d”.

3.4.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and the wave pressure p_{WF} defined in Ch 5, Sec 6, [9].

3.4.4 Wheeled loads

For primary supporting members subjected to wheeled loads, the yielding check may be carried out according to [3.5] to [3.7] considering uniform pressures equivalent to the distribution of vertical concentrated forces, when such forces are closely located.

For the determination of the equivalent uniform pressures, the most unfavourable case, i.e. where the maximum number of axles is located on the same primary supporting member according to Fig 1 to Fig 3, is to be considered.

The equivalent still water pressure and inertial pressure are indicated in Tab 8.

Table 8 : Wheeled loads
Equivalent uniform still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water condition		$p_S = p_{eq}$
Upright condition	“a”	No inertial pressure
	“b”	$p_W = \alpha\, p_{eq}\, a_{Z1} / g$
Inclined condition	“c”	The inertial pressure may be disregarded
	“d”	$p_W = \alpha\, p_{eq}\, a_{Z2} / g$

Note 1:

$$p_{eq} = 10\frac{n_V Q_A}{\ell s}\left(3 - \frac{X_1 + X_2}{s}\right)$$

- n_V : Maximum number of vehicles possible located on the primary supporting member
- Q_A : Maximum axle load, in t, defined in Ch 5, Sec 6, Tab 8
- X_1 : Minimum distance, in m, between two consecutive axles (see Fig 2 and Fig 3)
- X_2 : Minimum distance, in m, between axles of two consecutive vehicles (see Fig 3)
- α : Coefficient taken equal to:
  - 0,5 in general
  - 1,0 for landing gears of trailers

Figure 1 : Wheeled loads - Distribution of vehicles on a primary supporting member

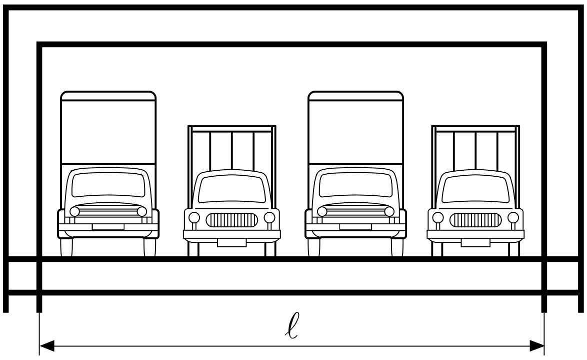


Figure 2 : Wheeled loads Distance between two consecutive axles

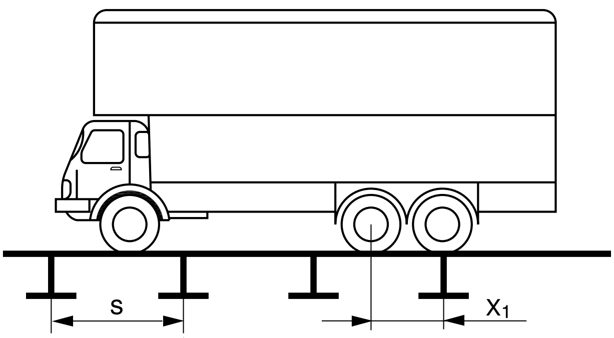
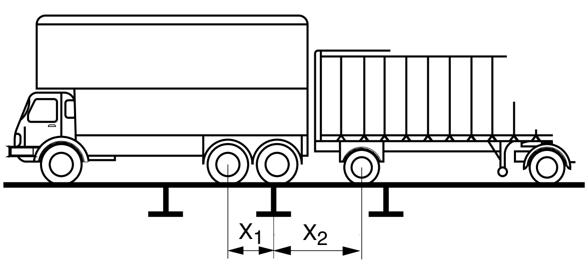


Figure 3 : Wheeled loads Distance between axles of two consecutive vehicles



For arrangements different from those shown in Fig 1 to Fig 3, the yielding check of primary supporting members is to be carried out by a direct calculation, taking into account the distribution of concentrated loads induced by vehicle wheels.

3.4.5 Hull girder normal stresses

The hull girder normal stresses to be considered for the yielding check of primary supporting members are obtained, in N/mm², from the following formulae:

- for longitudinal primary supporting members contributing to the hull girder longitudinal strength:

  $\sigma_{X1} = \gamma_{S1}\,\sigma_{S1} + \gamma_{W1}\,(C_{FV}\,\sigma_{WV1} + C_{FH}\,\sigma_{WH1} + C_{F\Omega}\,\sigma_{\Omega})$

- for longitudinal primary supporting members not contributing to the hull girder longitudinal strength:

  $\sigma_{X1} = 0$

- for transverse primary supporting members:

  $\sigma_{X1} = 0$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in:

- Tab 9 for primary supporting members subjected to lateral pressure
- Tab 10 for primary supporting members subjected to wheeled loads

σ_{Ω} : absolute value of the warping stress, in N/mm², induced by the torque 0,625 M_{WT} and obtained in accordance with Ch 6, Sec 1, [2.6]

C_{FV}, C_{FH}, $C_{F\Omega}$: Combination factors defined in Tab 11

3.5 Normal and shear stresses due to lateral pressure in intact conditions

3.5.1 General

Normal and shear stresses, induced by lateral pressures, in primary supporting members are to be determined from the formulae given in:

- [3.5.2] in the case of longitudinal and transverse stiffeners
- [3.5.3] in the case of vertical stiffeners.

Table 9 : Hull girder normal stresses - Primary supporting members subjected to lateral pressure

Condition		σ_{S1}, in N/mm² **(1)**	σ_{WV1}, in N/mm²	σ_{WH1}, in N/mm²
Lateral pressure applied on the side opposite to the primary supporting member, with respect to the plating:	$z \geq N$	$\left\lvert \dfrac{M_{SW,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \dfrac{0{,}625\,F_D\,M_{WV,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \dfrac{0{,}625\,M_{WH}}{I_Z}y \right\rvert 10^{-3}$
	$z < N$	$\left\lvert \dfrac{M_{SW,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \dfrac{0{,}625\,M_{WV,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	
Lateral pressure applied on the same side as the primary supporting member:	$z \geq N$	$\left\lvert \dfrac{M_{SW,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \dfrac{0{,}625\,M_{WV,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	
	$z < N$	$\left\lvert \dfrac{M_{SW,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \dfrac{0{,}625\,F_D\,M_{WV,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 10 : Hull girder normal stresses - Primary supporting members subjected to wheeled loads

Condition	σ_{S1} in N/mm² **(1)**	σ_{WV1} in N/mm²	σ_{WH1} in N/mm²
$z \geq N$	$\left\|\frac{M_{SW,H}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\frac{0{,}625 M_{WV,H}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\frac{0{,}625 M_{WH}}{I_Z}y\right\|10^{-3}$
$z < N$	$\left\|\frac{M_{SW,S}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\frac{0{,}625 F_D M_{WV,S}}{I_Y}(z-N)\right\|10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 11 : Combination factors C_{FV}, C_{FH} and $C_{F\Omega}$

Load case	C_{FV}	C_{FH}	$C_{F\Omega}$
"a"	1,0	0	0
"b"	1,0	0	0
"c"	0,4	1,0	1,0
"d"	0,4	1,0	0
Flooding	0,6	0	0

3.5.2 Longitudinal and transverse primary supporting members

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m w} s \ell^2 10^3 + \sigma_{X1}$$

$$\tau = 5\beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}} s \ell$$

where:

$$\beta_b = \left(1 - \frac{\ell_{b1}}{2\ell} - \frac{\ell_{b2}}{2\ell}\right)^2$$

$$\beta_s = 1 - \frac{\ell_{b1}}{2\ell} - \frac{\ell_{b2}}{2\ell}$$

ℓ_{b1}, ℓ_{b2} : Lengths of the brackets at ends, in m.

3.5.3 Vertical primary supporting members

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \lambda_b \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m w} s \ell^2 10^3 + \sigma_A$$

$$\tau = 5\lambda_s \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

λ_b : Coefficient taken equal to the greater of the following values:

$$\lambda_b = 1 + 0{,}2\frac{\gamma_{S2}(p_{Sd} - p_{Su}) + \gamma_{W2}(p_{Wd} - p_{Wu})}{\gamma_{S2}(p_{Sd} + p_{Su}) + \gamma_{W2}(p_{Wd} + p_{Wu})}$$

$$\lambda_b = 1 - 0{,}2\frac{\gamma_{S2}(p_{Sd} - p_{Su}) + \gamma_{W2}(p_{Wd} - p_{Wu})}{\gamma_{S2}(p_{Sd} + p_{Su}) + \gamma_{W2}(p_{Wd} + p_{Wu})}$$

λ_s : Coefficient taken equal to the greater of the following values:

$$\lambda_s = 1 + 0{,}4\frac{\gamma_{S2}(p_{Sd} - p_{Su}) + \gamma_{W2}(p_{Wd} - p_{Wu})}{\gamma_{S2}(p_{Sd} + p_{Su}) + \gamma_{W2}(p_{Wd} + p_{Wu})}$$

$$\lambda_s = 1 - 0{,}4\frac{\gamma_{S2}(p_{Sd} - p_{Su}) + \gamma_{W2}(p_{Wd} - p_{Wu})}{\gamma_{S2}(p_{Sd} + p_{Su}) + \gamma_{W2}(p_{Wd} + p_{Wu})}$$

p_{Sd} : Still water pressure, in kN/m², at the lower end of the primary supporting member considered

p_{Su} : Still water pressure, in kN/m², at the upper end of the primary supporting member considered

p_{Wd} : Wave pressure, in kN/m², at the lower end of the primary supporting member considered

p_{Wu} : Wave pressure, in kN/m², at the upper end of the primary supporting member considered

σ_A : Axial stress, to be obtained, in N/mm², from the following formula:

$$\sigma_A = 10\frac{F_A}{A}$$

F_A : Axial load (still water and wave) transmitted to the vertical primary supporting members by the structures above. For multideck ships, the criteria in [7.2.1] for pillars are to be adopted

A : Net sectional area, in cm², of the vertical primary supporting members with attached plating of width b_P.

3.6 Checking criteria

3.6.1 General

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [3.5], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0{,}5\frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

3.7 Net section modulus and net sectional shear area complying with the checking criteria

3.7.1 General

The requirements in [3.7.2] and [3.7.3] provide the minimum net section modulus and net shear sectional area of primary supporting members subjected to lateral pressure in intact conditions, complying with the checking criteria indicated in [3.6].

3.7.2 Longitudinal and transverse primary supporting members

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of longitudinal or transverse primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

where β_b and β_s are the coefficients defined in [3.5.2].

3.7.3 Vertical primary supporting members

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of vertical primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_A)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

λ_b, λ_s : Coefficients defined in [3.5.3]

σ_A : Defined in [3.5.3].

3.8 Net section modulus and net shear sectional area of primary supporting members subjected to lateral pressure in flooding conditions

3.8.1 General

The requirements in [3.8.2] to [3.8.3] provide the minimum net section modulus and net shear sectional area of primary supporting members subject to flooding.

3.8.2 Longitudinal and transverse primary supporting members

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of longitudinal or transverse primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{m(R_y - \gamma_m \sigma_{X1})} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2].

3.8.3 Vertical primary supporting members

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of vertical primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{m R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

λ_b : Coefficient taken equal to the greater of the following values:

$$\lambda_b = 1 + 0{,}2 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

$$\lambda_b = 1 - 0{,}2 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

λ_s : Coefficient taken equal to the greater of the following values:

$$\lambda_s = 1 + 0{,}4 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

$$\lambda_s = 1 - 0{,}4 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

p_{SFd} : Still water pressure, in kN/m², in flooding conditions, at the lower end of the primary supporting member considered

p_{SFu} : Still water pressure, in kN/m², in flooding conditions, at the upper end of the primary supporting member considered

p_{WFd} : Wave pressure, in kN/m², in flooding conditions, at the lower end of the primary supporting member considered

p_{WFu} : Wave pressure, in kN/m², in flooding conditions, at the upper end of the primary supporting member considered.

3.9 Net section modulus and net shear sectional area of primary supporting members subjected to lateral pressure in testing conditions

3.9.1 General

The requirements in [3.9.2] and [3.9.3] provide the minimum net section modulus and net shear sectional area of primary supporting members of compartments subject to testing conditions.

3.9.2 Longitudinal and transverse primary supporting members

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of longitudinal or transverse primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_T}{m R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_T}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2].

3.9.3 Vertical primary supporting members

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of vertical primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_T}{m R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_T}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

λ_b : Coefficient taken equal to the greater of the following values:

$$\lambda_b = 1 + 0,2 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

$$\lambda_b = 1 - 0,2 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

λ_s : Coefficient taken equal to the greater of the following values:

$$\lambda_s = 1 + 0,4 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

$$\lambda_s = 1 - 0,4 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

p_{Td} : Still water pressure, in kN/m^2, in testing conditions, at the lower end of the primary supporting member considered

p_{Tu} : Still water pressure, in kN/m^2, in testing conditions, at the upper end of the primary supporting member considered.

4 Yielding check of primary supporting members analysed through a three dimensional structural model

4.1 General

4.1.1 The requirements of this Article apply for the yielding check of primary supporting members subjected to lateral pressure or to wheeled loads and, for those contributing to the hull girder longitudinal strength, to hull girder normal stresses, which are to be analysed through a three dimensional structural model.

4.1.2 The yielding check is also to be carried out for primary supporting members subjected to specific loads, such as concentrated loads.

4.2 Analysis criteria

4.2.1 The analysis of primary supporting members based on three dimensional models is to be carried out according to:

- the requirements in Ch 7, App 1 for primary supporting members subjected to lateral pressure
- the requirements in Ch 7, App 2 for primary supporting members subjected to wheeled loads.

These requirements apply for:

- the structural modelling
- the load modelling
- the stress calculation.

4.3 Checking criteria for beam model analyses

4.3.1 General

For beam model analyses, according to Ch 7, App 1, [3.5], it is to be checked that the equivalent stress σ_{VM} calculated according to Ch 7, App 1, [5.2] is in compliance with the following formula:

$$\sigma_{VM} \le \frac{R_Y}{\gamma_R \gamma_m}$$

where the partial safety factors are to be taken as given in Tab 5 for beam models.

4.4 Checking criteria for finite element models analyses

4.4.1 Master allowable stress

The master allowable stress, σ_{MASTER}, in N/mm^2, is to be obtained from the following formula:

$$\sigma_{MASTER} = \frac{R_Y}{\gamma_R \gamma_m}$$

where the partial safety factors are to be taken as given in Tab 5.

4.4.2 General

For all types of finite element analyses, according to Ch 7, App 1, [3.4], it is to be checked that the equivalent stress σ_{VM} calculated according to Ch 7, App 1, [5.1] is in compliance with the following formula:

$$\sigma_{VM} \le \sigma_{MASTER}$$

4.4.3 Structural detail analysis based on fine mesh finite elements models

In a standard mesh model as defined in Ch 7, App 1, [3.4.3], high stress areas for which σ_{VM} exceeds 0,95 σ_{MASTER} are to be investigated through a fine mesh structural detail analysis according to Ch 7, App 1, [3.4.4], and both following criteria are to be checked:

a) The average Von Mises equivalent stress σ_{VM-av} as defined in [4.4.4] is to comply with the following formula:

$$\sigma_{VM-av} \le \sigma_{MASTER}$$

b) The equivalent stress σ_{VM} of each element is to comply with the following formulae:

- for elements not adjacent to the weld:

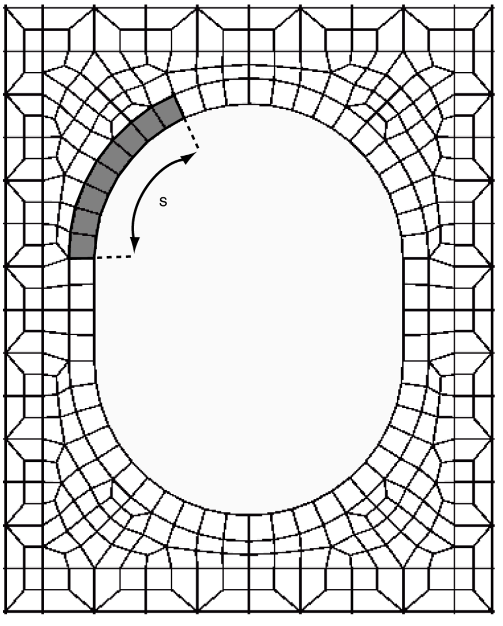
$$\sigma_{VM} \le 1,53 \sigma_{MASTER}$$

- for elements adjacent to the weld:

$$\sigma_{VM} \le 1,34 \sigma_{MASTER}$$

In case of mesh finer than (50 mm x 50 mm), the equivalent stress σ_{VM} is to be obtained by averaging over an equivalent area of (50 mm x 50 mm), based on the methodology given in [4.4.4].

Figure 4 : Example of stress averaging area at opening rounded edge



4.4.4 Stress averaging on fine mesh

The average Von Mises equivalent stress $\sigma_{VM\text{-}av}$, in N/mm², is to be obtained from the following formula:

$$\sigma_{VM-av} = \frac{\sum_{1}^{n} A_i \sigma_{VM-i}}{\sum_{1}^{n} A_i}$$

where:

$\sigma_{VM\text{-}i}$: Von Mises stress at the centre of the i-th element within the considered area, in N/mm²

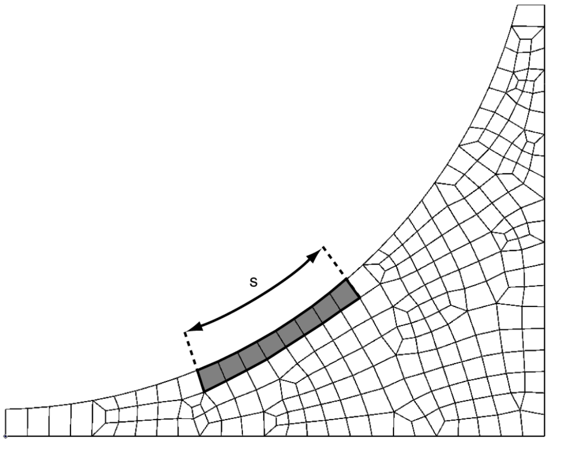
A_i : Area of the i-th element within the considered area, in mm²

n : Number of elements within the considered area.

Stress averaging is to be performed over an area defined as follows:

- the area considered for stress averaging is to have a size not above the relevant spacing of ordinary stiffeners (s x s)
- for fine mesh along rounded edges (openings, rounded brackets) the area considered for stress averaging is to be limited only to the first ring of border elements, over a length not greater than the lesser between 1.5 times the radius of the opening and the relevant spacing of ordinary stiffeners (see Fig 4 and Fig 5)
- the area considered for stress averaging is not to be defined across structural discontinuities, web stiffeners or other abutting structure
- for regions where several different stress averaging areas may be defined, the worst is to be considered for the calculation of average Von Mises equivalent stress.

Figure 5 : Example of stress averaging area at rounded bracket edge



4.4.5 Particular requirements

For fine mesh regions located on bracket webs in the vicinity of bracket toes, where an equivalent (s x s) area cannot be defined, the yielding check is to be based only on the criteria given in [4.4.3], item b).

Other structural details having shapes not allowing the stress averaging as required in [4.4.4] are to be specially considered by the Society, on a case by case basis.

5 Yielding check of primary supporting members analysed through a complete ship structural model

5.1 General

5.1.1 The requirements of this Article apply for the yielding check of primary supporting members which are to be analysed through a complete ship structural model.

5.1.2 A complete ship structural model is to be carried out, when deemed necessary by the Society, to analyse primary supporting members of ships with one or more of the following characteristics:

- ships having large deck openings
- ships having large space arrangements
- multideck ships having series of openings in side or longitudinal bulkheads, when the stresses due to the different contribution of each deck to the hull girder strength are to be taken into account.

5.1.3 Based on the criteria in [5.1.2], analyses based on complete ship models may be required, in general, for the following ship types:

- ships with the service notation **general cargo ship**, having large deck openings
- ships with the service notation **ro-ro cargo ship** or **PCT carrier**
- ships with the service notation **passenger ship**
- ships with the service notation **ro-ro passenger ship**.

5.2 Analysis criteria

5.2.1 The analysis of primary supporting members based on complete ship models is to be carried out according to Ch 7, App 3.

These requirements apply for:

- the structural modelling
- the load modelling
- the stress calculation.

5.3 Checking criteria

5.3.1 General

It is to be checked that the equivalent stress σ_{VM}, calculated according to Ch 7, App 3, [4] is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

5.3.2 Additional criteria for elements modelled with fine meshes

Fine meshes are defined with reference to Ch 7, App 3, [2.4].

For all the elements modelled with fine meshes, it is to be checked that the normal stresses σ_1 and σ_2 and the shear stress τ_{12}, calculated according to Ch 7, App 3, [4], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \max(\sigma_1, \sigma_2)$$

$$0{,}5 \frac{R_y}{\gamma_R \gamma_m} \geq \tau_{12}$$

6 Primary members subject to impact loads

6.1 General

6.1.1 The net section modulus w, in cm³, of primary supporting members and their net shear area A_{sh}, in cm², at any position along their span are not to be less than the values obtained from the following formulae:

$$w = \frac{f_{cb} P_I f_{pb} \ell^2 b_I}{m R_{eH}} 10^3$$

$$A_{sh} = 10 \frac{\sqrt{3} Q_I}{0,9 R_{eH}}$$

where:

f_{cb} : Correction factor for the bending moment at the ends and considering the patch load, taken as:

$$f_{cb} = 3 f_{pb}^3 - 8 f_{pb}^2 + 6 f_{pb}$$

P_I : Any impact pressure defined in the Rules, including:

- bottom impact pressure, as defined in Ch 8, Sec 1, [3.2]
- bow impact pressure, as defined in Ch 8, Sec 1, [4.2]
- dynamic impact pressure, as defined in Ch 5, Sec 6, [2.5]
- stern impact pressure, as defined in Ch 8, Sec 2, [4.2]

f_{pb} : Patch load modification factor for bending, taken as:

$$f_{pb} = \frac{\ell_I}{\ell}$$

Q_I : Shear force, in kN, taken as:

$Q_I = f_{cs} f_{dist} P_I \ell_I b_I$

ℓ_I : Extent of impact load area, in m, along the span:

$$\ell_I = \sqrt{A_I}$$

not to be taken greater than:

- 0,5 ℓ for the calculation of Q_I
- ℓ for the calculation of f_{pb}

f_{cs} : Correction factor for the proportion of patch load acting on a single primary supporting member, taken as:

$$f_{cs} = 0,5(f_{ps}^3 - 2 f_{ps}^2 + 2)$$

f_{dist} : Coefficient for shear force distribution along the span, as defined in Fig 6

f_{ps} : Patch load modification factor for shear, taken as:

$$f_{ps} = 0,5 \frac{b_I}{s}$$

b_I : Breadth of impact area supported by primary supporting member, in m, taken as:

$$b_I = \sqrt{A_I}$$

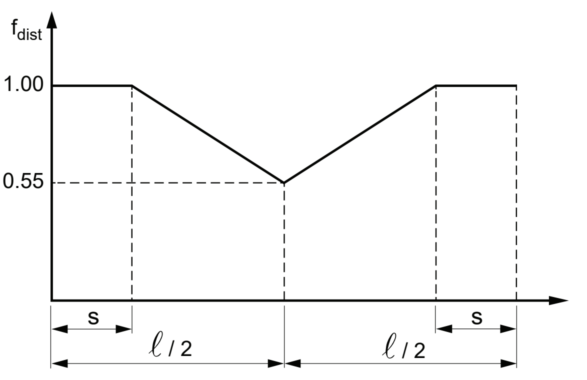
not to be taken greater than s

$A_I = 1{,}1\ L\ B\ C_B\ 10^{-3}$

For complex arrangements of primary supporting members, especially where grillage effect may not be ignored, or for primary supporting members having variable cross sections, direct calculation is to be performed.

It is to be checked that the maximum equivalent stress obtained by applying the load Q_I on a square area A_I to various locations on the model is not greater than 0,85 R_{eH}.

Figure 6 : Distribution of f_{dist} along the span of simple primary supporting members



s is the spacing, in m, of ordinary stiffeners

7 Buckling check

7.1 Local buckling of plate panels

7.1.1 A local buckling check is to be carried out, for plate panels which constitute primary supporting members and/or corrugated bulkheads, according to:

- Ch 7, App 1, [6] in case of buckling check based on a standard mesh element model
- Ch 7, Sec 1, [5] in other cases, calculating the stresses in the plate panels according to [3] or [5], depending on the structural model.

7.2 Buckling of pillars subjected to compression axial load

7.2.1 Compression axial load

Where pillars are in line, the compression axial load in a pillar is obtained, in kN, from the following formula:

$$F_A = A_D(\gamma_{S2} p_S + \gamma_{W2} p_W) + \sum_{i=1}^{N} r_i(\gamma_{S2} Q_{i,S} + \gamma_{W2} Q_{i,W})$$

where:

A_D : Area, in m², of the portion of the deck or platform supported by the pillar considered

r_i : Coefficient which depends on the relative position of each pillar above the one considered, to be taken equal to:

- $r_i = 0,9$ for the pillar immediately above that considered (i = 1)
- $r_i = 0,9^i$ for the i^th pillar of the line above the pillar considered, to be taken not less than 0,478

$Q_{i,S}$, $Q_{i,W}$: Still water and wave loads, respectively, in kN, from the i^th pillar of the line above the pillar considered.

7.2.2 Critical column buckling stress of pillars

The critical column buckling stress of pillars is to be obtained, in N/mm², from the following formulae:

$$\sigma_{cB} = \sigma_{E1} \quad \text{for} \quad \sigma_{E1} \le \frac{R_{eH}}{2}$$

$$\sigma_{cB} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eH}}{2}$$

where:

σ_{E1} : Euler column buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_{E1} = \pi^2 E \frac{I}{A(f\ell)^2} 10^{-4}$$

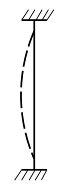
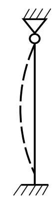
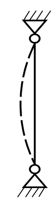
I : Minimum net moment of inertia, in cm⁴, of the pillar

A : Net cross-sectional area, in cm², of the pillar

ℓ : Span, in m, of the pillar

f : Coefficient, to be obtained from Tab 12.

Table 12 : Coefficient f

Boundary conditions of the pillar	f
Both ends fixed 	0,5
One end fixed, one end pinned 	$\frac{\sqrt{2}}{2}$
Both ends pinned 	1

7.2.3 Critical torsional buckling stress of built-up pillars

The critical torsional buckling stress of built-up pillars is to be obtained, in N/mm², from the following formulae:

$$\sigma_{cT} = \sigma_{E2} \quad \text{for} \quad \sigma_{E2} \le \frac{R_{eH}}{2}$$

$$\sigma_{cT} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E2}}\right) \quad \text{for} \quad \sigma_{E2} > \frac{R_{eH}}{2}$$

where:

σ_{E2} : Euler torsional buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_{E2} = \frac{\pi^2 f_{end} E I_w}{10^4 I_p \ell^2} + G\frac{I_t}{I_p}$$

I_w : Net sectorial moment of inertia of the pillar, to be obtained, in cm⁶, from the following formula:

$$I_w = \frac{t_f b_f^3 d_w^2}{24} 10^{-6}$$

d_W : Height of built-up section, in mm, taken equal to: $d_w = h_w + 0,5\,(t_p + t_f)$

h_W : Web height of built-up section, in mm

t_p : Net attached plating thickness of built-up section, in mm

t_f : Net face plate thickness of built-up section, in mm

t_W : Net web thickness of built-up section, in mm

b_F : Face plate width of built-up section, in mm

t_F : Net face plate thickness of built-up section, in mm

I_p : Net polar moment of inertia of the pillar, to be obtained, in cm^4, from the following formula:

$I_p = I_{XX} + I_{YY}$

I_{XX} : Net moment of inertia about the XX axis of the pillar section (see Fig 7)

I_{YY} : Net moment of inertia about the YY axis of the pillar section (see Fig 7)

I_t : St. Venant's net moment of inertia of the pillar, to be obtained, in cm^4, from the following formula:

$$I_t = \frac{1}{3}[d_w t_w^3 + 2 b_f t_f^3] 10^{-4}$$

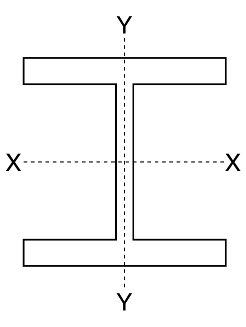
G : Shear modulus, to be obtained, in N/mm^2, from the following formula:

$$G = \frac{E}{2(1+\nu)}$$

f_{end} : End constraint factor, taken as:

- f_{end} = 1,0 where both ends are simply supported
- f_{end} = 2,0 where one end is simply supported and the other end is fixed
- f_{end} = 4,0 where both ends are fixed.

Figure 7 : Reference axes for the calculation of the moments of inertia of a built-up section



7.2.4 Critical local buckling stress of built-up pillars

The critical local buckling stress of built-up pillars is to be obtained, in N/mm^2, from the following formulae:

$$\sigma_{cL} = \sigma_{E3} \qquad \text{for} \quad \sigma_{E3} \le \frac{R_{eH}}{2}$$

$$\sigma_{cL} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E3}}\right) \quad \text{for} \quad \sigma_{E3} > \frac{R_{eH}}{2}$$

where:

σ_{E3} : Euler local buckling stress, to be taken equal to the lesser of the values obtained, in N/mm^2, from the following formulae:

- $\sigma_{E3} = 78\left(\frac{t_W}{h_W}\right)^2 10^4$
- $\sigma_{E3} = 32\left(\frac{t_F}{b_F}\right)^2 10^4$

t_W, h_W, t_F, b_F : Dimensions, in mm, of the built-up section, defined in [7.2.3].

7.2.5 Critical local buckling stress of pillars having hollow rectangular section

The critical local buckling stress of pillars having hollow rectangular section is to be obtained, in N/mm^2, from the following formulae:

$$\sigma_{cL} = \sigma_{E4} \qquad \text{for} \quad \sigma_{E4} \le \frac{R_{eH}}{2}$$

$$\sigma_{cL} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E4}}\right) \quad \text{for} \quad \sigma_{E4} > \frac{R_{eH}}{2}$$

where:

σ_{E4} : Euler local buckling stress, to be taken equal to the lesser of the values obtained, in N/mm^2, from the following formulae:

- $\sigma_{E4} = 78\left(\frac{t_2}{b}\right)^2 10^4$
- $\sigma_{E4} = 78\left(\frac{t_1}{h}\right)^2 10^4$

b : Length, in mm, of the shorter side of the section

t_2 : Net web thickness, in mm, of the shorter side of the section

h : Length, in mm, of the longer side of the section

t_1 : Net web thickness, in mm, of the longer side of the section.

7.2.6 Checking criteria

The net scantlings of the pillar loaded by the compression axial stress F_A defined in [7.2.1] are to comply with the formulae in Tab 13.

7.2.7 Contact pressure

At connexions between pillars and decks, it is to be checked that the contact pressure σ_C, in N/mm^2, is in compliance with the following formula:

$\sigma_C \le 0,8\ R_{eH}$

where:

$$\sigma_C = 10\frac{F_A}{A_C}$$

with:

F_A : Compression axial load in the pillar, in kN

A_C : Contact area between the pillar and the deck structural members, in cm^2

R_{eH} : Smallest of the assembled elements yield stress, in N/mm^2.

7.3 Buckling of pillars subjected to compression axial load and bending moments

7.3.1 Checking criteria

In addition to the requirements in [7.2], the net scantlings of the pillar loaded by the compression axial load and bending moments are to comply with the following formula:

$$10F\left(\frac{1}{A} + \frac{\Phi e}{w_P}\right) + \left(10^3\frac{M_{max}}{w_P}\right) \le \frac{R_{eH}}{\gamma_R \gamma_m}$$

where:

F : Compression load, in kN, acting on the pillar

A : Net cross-sectional area, in cm², of the pillar

e : Eccentricity, in cm, of the compression load with respect to the centre of gravity of the cross-section

$$\Phi = \frac{1}{1 - \frac{10F}{\sigma_{E1} A}}$$

σ_{E1} : Euler column buckling stress, in N/mm², defined in [7.2.2]

w_P : Minimum net section modulus, in cm³, of the cross-section of the pillar

M_{max} : Max (M_1, M_2, M_0)

M_1 : Bending moment, in kN.m, at the upper end of the pillar

M_2 : Bending moment, in kN.m, at the lower end of the pillar

$$M_0 = \frac{0,5(\sqrt{1+t^2})(M_1 + M_2)}{\cos(u)}$$

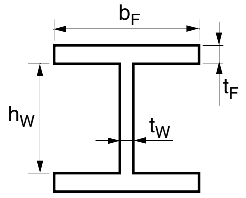
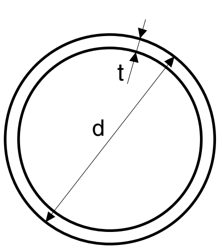
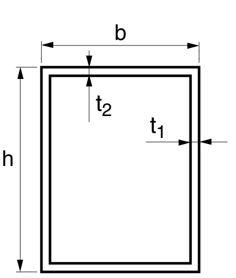
$$u = 0,5\pi \sqrt{\frac{10F}{\sigma_{E1} A}}$$

$$t = \frac{1}{\tan(u)}\left(\frac{M_2 - M_1}{M_2 + M_1}\right)$$

provided that:

$$-\tan^2 u \le \frac{M_2 - M_1}{M_2 + M_1} \le \tan^2 u$$

Table 13 : Buckling check of pillars subject to compression axial load

Pillar cross-section	Column buckling check	Torsional buckling check	Local buckling check	Geometric condition
Built-up 	$\frac{\sigma_{cB}}{\gamma_R \gamma_m} \ge 10\frac{F_A}{A}$	$\frac{\sigma_{cT}}{\gamma_R \gamma_m} \ge 10\frac{F_A}{A}$	$\frac{\sigma_{cL}}{\gamma_R \gamma_m} \ge 10\frac{F_A}{A}$	• $\frac{b_F}{t_F} \le 40$
Hollow tubular 	$\frac{\sigma_{cB}}{\gamma_R \gamma_m} \ge 10\frac{F_A}{A}$	Not required	Not required	• $\frac{d}{t} \le 55$ • $t \ge 5,5$ mm
Hollow rectangular 	$\frac{\sigma_{cB}}{\gamma_R \gamma_m} \ge 10\frac{F_A}{A}$	Not required	$\frac{\sigma_{cL}}{\gamma_R \gamma_m} \ge 10\frac{F_A}{A}$	• $\frac{b}{t_2} \le 55$ • $\frac{h}{t_1} \le 55$ • $t_1 \ge 5,5$ mm • $t_2 \ge 5,5$ mm

Note 1:

σ_{cB} : Critical column buckling stress, in N/mm², defined in [7.2.2]

σ_{cT} : Critical torsional buckling stress, in N/mm², defined in [7.2.3]

σ_{cL} : Critical local buckling stress, in N/mm², defined in [7.2.4] for built-up section or in [7.2.5] for hollow rectangular section

γ_R : Resistance partial safety factor, equal to:
- 1,15 for column buckling
- 1,05 for torsional and local buckling

F_A : Compression axial load in the pillar, in kN, defined in [7.2.1]

A : Net sectional area, in cm², of the pillar.

SECTION 4 FATIGUE CHECK OF STRUCTURAL DETAILS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m^2, see [2.2]

p_W : Wave pressure, in kN/m^2, see [2.2]

i : Index which denotes the load case "a", "b", "c" or "d"

j : Index which denotes the loading condition "Full load" or "Ballast"

K_h, K_ℓ : Stress concentration factors, defined in Ch 11, Sec 2 for the special structural details there specified

K_F : Fatigue notch factor, defined in [4.3.1]

K_m : Stress concentration factor, taking account of misalignment, defined in [4.3.1]

K_S : Coefficient taking account of the stiffener section geometry, defined in [6.2.2]

T_1 : Draught, in m, corresponding to the loading condition considered.

1 General

1.1 Application

1.1.1 General

The requirements of this Section apply to ships equal to or greater than 170 m in length.

1.1.2 Structural details to be checked

The requirements of this Section apply for the fatigue check of special structural details defined in Ch 11, Sec 2, depending on the ship type and on the hull area where the detail are located.

The Society may require other details to be checked, when deemed necessary on the basis of the detail geometry and stress level.

In case of a hot spot located in a plate edge without any welded joint, the SN curve to be used is to be considered on a case by case basis by the Society.

1.1.3 Categorisation of details

With respect to the method to be adopted to calculate the stresses acting on structural members, the details for which the fatigue check is to be carried out may be grouped as follows:

- details where the stresses are to be calculated through a three dimensional structural model (e.g. connections between primary supporting members)
- details located at ends of ordinary stiffeners, for which an isolated structural model can be adopted.

1.1.4 Details where the stresses are to be calculated through a three dimensional structural model

The requirements of Ch 7, App 1, [7] apply, in addition of those of [1] to [5] of this Section.

1.1.5 Details located at ends of ordinary stiffeners

The requirements of [1] to [6] of this Section apply.

1.1.6 Other details

In general, for details other than those in [1.1.3], the stresses are to be calculated through a method agreed by the Society on a case by case basis, using the load model defined in [2].

The checking criteria in [5] is generally to be applied.

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], 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 4, Sec 2.

1.3 Sign conventions

1.3.1 Bending moments

The sign conventions of bending moments at any ship transverse section are the following ones:

- the vertical bending moment is positive when it induces tensile stresses in the strength deck (hogging bending moment); it is negative in the opposite case (sagging bending moment)
- the horizontal bending moment is positive.

1.3.2 Stresses

The sign conventions of stresses are the following ones:

- tensile stresses are positive
- compressive stresses are negative.

1.4 Definitions

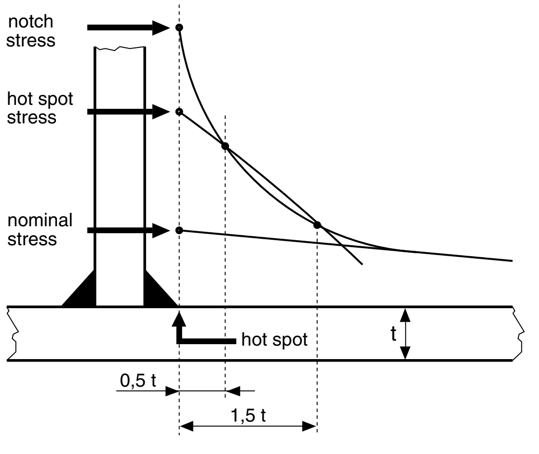
1.4.1 Hot spots

Hot spots are the locations where fatigue cracking may occur. They are indicated in the relevant figures of special structural details in Ch 11, Sec 2 (see [1.1.2]).

1.4.2 Nominal stress

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 (see Fig 1).

Figure 1 : Nominal, hot spot and notch stresses



1.4.3 Hot spot stress

Hot spot stress is a local stress at the hot spot taking into account the influence of structural discontinuities due to the geometry of the detail, but excluding the effects of welds (see Fig 1).

1.4.4 Notch stress

Notch stress is a peak stress in a notch such as the root of a weld or the edge of a cut-out. This peak stress takes into account the stress concentrations due to the presence of notches (see Fig 1).

1.4.5 Elementary stress range

Elementary stress range is the stress range determined for one of the load cases "a", "b", "c" or "d" (see Ch 5, Sec 4, [2]) and for either of the loading conditions (see Ch 5, Sec 1, [2.4] and Ch 5, Sec 1, [2.5]).

1.5 Partial safety factors

1.5.1 The partial safety factors to be considered for the fatigue check of structural details are specified in Tab 1.

Table 1 : Fatigue check - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Value	
		General	Details at ends of ordinary stiffeners
Still water hull girder loads	γ_{S1}	1,00	1,00
Wave hull girder loads	γ_{W1}	1,05	1,15
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,20
Resistance	γ_R	1,02	1,02

2 Load model

2.1 General

2.1.1 Load point

Unless otherwise specified, design loads are to be determined at points defined in:

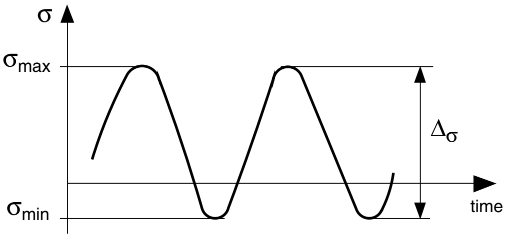
- Ch 7, Sec 2, [1.3] for ordinary stiffeners
- Ch 7, Sec 3, [1] for primary supporting members.

2.1.2 Local and hull girder loads

The fatigue check is based on the stress range induced at the hot spot by the time variation of the local pressures and hull girder loads in each load case "a", "b", "c" and "d" defined in [2.2] for the loading conditions defined in [2.1.4] and [2.1.3] (see Fig 2).

For the purpose of fatigue check, each load case "a", "b", "c" and "d" is divided in two cases "-max" and "-min" for which the local pressures and corresponding hull girder loads are defined in [2.2] and [2.3] respectively.

Figure 2 : Stress range



2.1.3 Loading conditions for details where the stresses are to be calculated through a three dimensional structural model

The most severe full load and ballast conditions for the detail concerned are to be considered in accordance with Ch 5, Sec 1, [2.5].

2.1.4 Loading conditions for details located at ends of ordinary stiffeners

The cargo and ballast distribution is to be considered in accordance with Ch 5, Sec 1, [2.4].

2.1.5 Spectral fatigue analysis

For ships with non-conventional shapes or with restricted navigation, the Society may require a spectral fatigue analysis to be carried out.

In this analysis, the loads and stresses are to be evaluated through long-term stochastic analysis taking into account the characteristics of the ship and the navigation notation.

The load calculations and fatigue analysis are to be submitted to the Society for approval.

2.2 Local lateral pressures

2.2.1 General

The still water and wave lateral pressures induced by the sea and various types of cargoes and ballast are to be considered.

Lateral pressure is constituted by still water pressure and wave pressure.

2.2.2 Load cases "a-max" and "a-min", in upright ship condition

The still water sea pressure (p_S) is defined in Ch 5, Sec 5, [1.1.1].

The wave pressure (p_W) is defined in Tab 2.

No internal inertial pressures are considered.

2.2.3 Load cases "b-max" and "b-min", in upright ship condition

Still water pressure (p_S) includes:

- the still water sea pressure defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Dynamic pressure (p_W) is constituted by internal inertial pressures defined in Tab 4.

No sea wave dynamic pressures are considered.

Table 2 : Wave pressure in load case a

Location	Wave pressure p_W, in kN/m²	
	a-max	a-min
Bottom and sides below the waterline ($z \le T_1$)	$\alpha^{1/4}\frac{\rho g h_1}{2}\left[\frac{T_1+z}{T_1}\right]$	$-\alpha^{1/4}\frac{\rho g h_1}{2}\left[\frac{T_1+z}{T_1}\right]$ without being taken less than $\frac{\gamma_S}{\gamma_W}\rho g(z-T_1)$
Sides above the waterline ($z > T_1$)	$\rho g(T_1+\alpha^{1/4}h_1-z)$	0,0

Note 1:
α : Coefficient equal to T_1/T, but not to be taken greater than 1.

Table 3 : Wave pressure in inclined ship conditions (load cases "c" and "d")

Location		Wave pressure p_W, in kN/m² **(1)**	
		c-max / d-max	c-min / d-min
Bottom and sides below the waterline ($z \le T_1$)	$y \ge 0$	$C_{F2}\alpha^{1/4}\rho g h_2\frac{\lvert y\rvert}{B_W}\left[\frac{T_1+z}{T_1}\right]$	$-C_{F2}\alpha^{1/4}\rho g h_2\frac{\lvert y\rvert}{B_W}\left[\frac{T_1+z}{T_1}\right]$ without being taken less than $\frac{\gamma_S}{\gamma_W}\rho g(z-T_1)$
	$y < 0$	$-C_{F2}\alpha^{1/4}\rho g h_2\frac{\lvert y\rvert}{B_W}\left[\frac{T_1+z}{T_1}\right]$ without being taken less than $\frac{\gamma_S}{\gamma_W}\rho g(z-T_1)$	$C_{F2}\alpha^{1/4}\rho g h_2\frac{\lvert y\rvert}{B_W}\left[\frac{T_1+z}{T_1}\right]$
Sides above the waterline ($z > T_1$)	$y \ge 0$	$\rho g\left[T_1+2C_{F2}\alpha^{1/4}\frac{\lvert y\rvert}{B_W}h_2-z\right]$	0,0
	$y < 0$	0,0	$\rho g\left[T_1+2C_{F2}\alpha^{1/4}\frac{\lvert y\rvert}{B_W}h_2-z\right]$

(1) In the formulae giving the wave pressure p_W, the ratio $|y| / B_W$ is not to be taken greater than 0,5.

Note 1:
α : Coefficient equal to T_1/T, but not to be taken greater than 1
C_{F2} : Combination factor, to be taken equal to:
- C_{F2} = 1,0 for load case "c"
- C_{F2} = 0,5 for load case "d"

B_W : Moulded breadth, in m, measured at the waterline at draught T_1, at the hull transverse section considered
h_2 : Reference value, in m, of the relative motion in the inclined ship condition, defined in Ch 5, Sec 3, [3.3.2] and not to be taken greater than the minimum of T_1 and (D – 0,9 T_1).

Table 4 : Inertial pressures

Cargo	Load case	Inertial pressures, in kN/m² **(1)**
Liquids	b-max	$p_W = \rho_L[-0,5a_{X1}\ell_B - a_{Z1}(z_{TOP}-z)]$
	b-min	$p_W = \rho_L[0,5a_{X1}\ell_B + a_{Z1}(z_{TOP}-z)]$
	c-max d-max	$p_W = \rho_L[0,7C_{FA}a_{Y2}(y-y_H) + (-0,7C_{FA}a_{Z2}-g)(z-z_H) + g(z-z_{TOP})]$
	c-min d-min	$p_W = \rho_L[-0,7C_{FA}a_{Y2}(y-y_H) + (0,7C_{FA}a_{Z2}-g)(z-z_H) + g(z-z_{TOP})]$
Dry bulk cargoes	b-max	$p_W = -\rho_B a_{Z1}(z_B-z)\left\{(\sin\alpha)^2\left[\tan\left(45^o-\frac{\varphi}{2}\right)\right]^2+(\cos\alpha)^2\right\}$
	b-min	$p_W = \rho_B a_{Z1}(z_B-z)\left\{(\sin\alpha)^2\left[\tan\left(45^o-\frac{\varphi}{2}\right)\right]^2+(\cos\alpha)^2\right\}$
	c-max and c-min d-max and d-min	The inertial pressure transmitted to the hull structures in inclined condition may generally be disregarded. Specific cases in which this simplification is not deemed permissible by the Society are considered individually.

(1) The symbols used in the formulae of inertial pressures are defined in Ch 5, Sec 6.

Note 1:

α : Angle, in degrees, between the horizontal plane and the surface of the hull structure to which the calculation point belongs

C_{FA} : Combination factor, to be taken equal to:
- $C_{FA} = 0,7$ for load case "c"
- $C_{FA} = 1,0$ for load case "d".

2.2.4 Load cases "c-max" and "c-min", in inclined ship condition

Still water pressure (p_S) includes:
- the still water sea pressure defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:
- the wave pressure obtained from Tab 3
- the inertial pressure obtained from Tab 4 for the various types of cargoes and ballast.

2.2.5 Load cases "d-max" and "d-min", in inclined ship condition

Still water pressure (p_S) includes:
- the still water sea pressure defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:
- the wave pressure obtained from Tab 3
- the inertial pressure obtained from Tab 4 for the various types of cargoes and ballast.

2.3 Nominal hull girder normal stresses

2.3.1 The nominal hull girder normal stresses are obtained, in N/mm², from the following formulae:
- for members contributing to the hull girder longitudinal strength:

$$\sigma_h = \gamma_{S1}\sigma_{SW} + \gamma_{W1}(C_{FV}\sigma_{WV} + C_{FH}\sigma_{WH} + C_{F\Omega}\sigma_\Omega)$$

- for members not contributing to the hull girder longitudinal strength:

$$\sigma_h = 0$$

where:

σ_{SW} : Still water hull girder normal stresses, in N/mm², taken equal to:

$$\sigma_{SW} = \frac{M_{SW}}{I_Y}(z-N)10^{-3}$$

M_{SW} : Still water bending moment for the loading condition considered

σ_{WV}, σ_{WV}, σ_{WH}: Hull girder normal stresses, in N/mm², defined in Tab 5

Table 5 : Nominal hull girder normal stresses

Load case	σ_{WV}, in N/mm²	σ_{WH}, in N/mm²
a-max	$\frac{0,625M_{WV,H}}{I_Y}(z-N)10^{-3}$	0
a-min	$\frac{0,625F_DM_{WV,S}}{I_Y}(z-N)10^{-3}$	0
b-max b-min	0	0
c-max d-max	0	$-\frac{0,625M_{WH}}{I_Z}y10^{-3}$
c-min d-min	0	$\frac{0,625M_{WH}}{I_Z}y10^{-3}$

Note 1: F_D is defined in Ch 5, Sec 2, [4].

σ_Ω : Warping stresses, in N/mm², induced by the torque $0,625 M_{WT}$ and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6]

C_{FV}, C_{FH}, $C_{F\Omega}$: Combination factors defined in Tab 6.

Table 6 : Combination factors C_{FV}, C_{FH} and $C_{F\Omega}$

Load case	C_{FV}	C_{FH}	$C_{F\Omega}$
"a"	1,0	0	0
"b"	1,0	0	0
"c"	0,4	1,0	1,0
"d"	0,4	1,0	0

3 Fatigue damage ratio

3.1 General

3.1.1 Elementary fatigue damage ratio

The elementary fatigue damage ratio is to be obtained from the following formula:

$$D_{ij} = \frac{N_t}{K_P} \frac{(\Delta\sigma_{N,ij})^3}{(-\ln p_R)^{3/\xi}} \mu_{ij} \Gamma_C\left[\frac{3}{\xi}+1\right]$$

where:

$\Delta\sigma_{N,ij}$: Elementary notch stress range, in N/mm², defined in [4.3.1]

$$\mu_{ij} = 1 - \frac{\Gamma_N\left[\frac{3}{\xi}+1, \nu_{ij}\right] - \Gamma_N\left[\frac{5}{\xi}+1, \nu_{ij}\right]\nu_{ij}^{-2/\xi}}{\Gamma_C\left[\frac{3}{\xi}+1\right]}$$

$$\xi = \xi_0\left(1,04 - 0,14\frac{|z - T_1|}{D - T_1}\right) \text{ without being less than } 0,9\ \xi_0$$

$$\xi_0 = \frac{73 - 0,07L}{60} \quad \text{without being less than } 0,85$$

T_1 : Draught, in m, corresponding to the loading condition "Full load" or "Ballast"

$$\nu_{ij} = -\left(\frac{S_q}{\Delta\sigma_{N,ij}}\right)^{\xi} \ln p_R$$

$$S_q = (K_p 10^{-7})^{1/3}$$

$$K_p = 5,802\left(\frac{22}{t}\right)^{0,9} 10^{12}$$

t : Net thickness, in mm, of the element under consideration not being taken less than 22 mm

N_t : Number of cycles, to be taken equal to:

$$N_t = \frac{31,55\alpha_0 T_{FL}}{T_A} 10^6$$

α_0 : Sailing factor, taken equal to 0,85

T_A : Average period, in seconds, to be taken equal to:

$T_A = 4 \log L$

T_{FL} : Design fatigue life, in years, taken equal to:

- when the notation **FAT** is assigned:

  $T_{FL} = 20$

- when the notation **FAT xx years** is assigned:

  $T_{FL} = xx$

  with xx having a value between 25 and 40.

Note 1: Details for the assignment of notations **FAT** and **FAT xx years** are defined in Pt A, Ch 1, Sec 2, [6.2.2] and Pt A, Ch 1, Sec 2, [6.2.3].

$p_R = 10^{-5}$

$\Gamma_N[X+1, \nu_{ij}]$: Incomplete Gamma function, calculated for $X = 3/\xi$ or $X = 5/\xi$ and equal to:

$$\Gamma_N[X+1, \nu_{ij}] = \int_0^{\nu_{ij}} t^X e^{-t} dt$$

Values of $\Gamma_N[X+1, \nu_{ij}]$ are also indicated in Tab 7. For intermediate values of X and ν_{ij}, Γ_N may be obtained by linear interpolation

$\Gamma_C[X+1]$: Complete Gamma function, calculated for $X = 3/\xi$, equal to:

$$\Gamma_C[X+1] = \int_0^{\infty} t^X e^{-t} dt$$

Values of $\Gamma_C[X+1]$ are also indicated in Tab 8. For intermediate values of X, Γ_C may be obtained by linear interpolation.

3.1.2 Cumulative damage ratio

The cumulative damage ratio is to be obtained from the following formula:

$$D = \frac{K_{cor}}{\beta_{IF}}[\alpha D_F + (1-\alpha) D_B]$$

where:

α : Part of the ship's life in full load condition, given in Tab 9 for various ship types

β_{IF} : Fatigue life improvement factor for improvement technique, if any, as defined in:

- [3.1.3] in case of grinding
- [3.1.4] for improvement techniques other than grinding

D_F : Cumulative damage ratio for ship in "Full load" condition, taken equal to:

$$D_F = \frac{1}{6}D_{aF} + \frac{1}{6}D_{bF} + \frac{1}{3}D_{cF} + \frac{1}{3}D_{dF}$$

D_B : Cumulative damage ratio for ship in "Ballast" condition, taken equal to:

$$D_B = \frac{1}{3}D_{aB} + \frac{1}{3}D_{bB} + \frac{1}{3}D_{cB}$$

Table 7 : Function Γ_N [X+1, ν_{ij}]

X	Value of ν_{ij}													
	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5	6,0	6,5	7,0	7,5	8,0
2,5	0,38	0,73	1,13	1,53	1,90	2,22	2,48	2,70	2,86	2,99	3,08	3,15	3,20	3,24
2,6	0,38	0,75	1,19	1,63	2,04	2,41	2,71	2,96	3,16	3,31	3,42	3,51	3,57	3,61
2,7	0,39	0,78	1,25	1,73	2,20	2,62	2,97	3,26	3,49	3,67	3,81	3,91	3,99	4,04
2,8	0,39	0,80	1,31	1,85	2,38	2,85	3,26	3,60	3,87	4,09	4,25	4,37	4,46	4,53
2,9	0,39	0,83	1,38	1,98	2,57	3,11	3,58	3,98	4,30	4,56	4,75	4,90	5,01	5,10
3,0	0,39	0,86	1,45	2,12	2,78	3,40	3,95	4,41	4,79	5,09	5,33	5,51	5,65	5,75
3,1	0,40	0,89	1,54	2,27	3,01	3,72	4,35	4,89	5,34	5,70	5,99	6,21	6,37	6,49
3,2	0,40	0,92	1,62	2,43	3,27	4,08	4,81	5,44	5,97	6,40	6,74	7,01	7,21	7,36
3,3	0,41	0,95	1,72	2,61	3,56	4,48	5,32	6,06	6,68	7,20	7,61	7,93	8,17	8,36
3,4	0,41	0,99	1,82	2,81	3,87	4,92	5,90	6,76	7,50	8,11	8,60	8,99	9,29	9,51
3,5	0,42	1,03	1,93	3,03	4,22	5,42	6,55	7,55	8,42	9,15	9,74	10,21	10,57	10,85
3,6	0,42	1,07	2,04	3,26	4,60	5,97	7,27	8,45	9,48	10,34	11,05	11,62	12,06	12,41
3,7	0,43	1,12	2,17	3,52	5,03	6,59	8,09	9,47	10,68	11,71	12,56	13,25	13,79	14,21
3,8	0,43	1,16	2,31	3,80	5,50	7,28	9,02	10,63	12,06	13,28	14,30	15,13	15,80	16,31
3,9	0,44	1,21	2,45	4,10	6,02	8,05	10,06	11,94	13,63	15,09	16,31	17,32	18,12	18,76
4,0	0,45	1,26	2,61	4,43	6,59	8,91	11,23	13,43	15,42	17,16	18,63	19,85	20,83	21,61
4,1	0,45	1,32	2,78	4,80	7,22	9,87	12,55	15,12	17,47	19,54	21,31	22,78	22,98	24,94
4,2	0,46	1,38	2,96	5,20	7,93	10,95	14,05	17,05	19,82	22,29	24,41	26,19	27,65	28,83
4,3	0,47	1,44	3,16	5,63	8,70	12,15	15,73	19,24	22,51	25,45	28,00	30,16	31,93	33,38
4,4	0,48	1,51	3,37	6,11	9,56	13,50	17,64	21,74	25,60	29,10	32,16	34,77	36,94	38,71
4,5	0,49	1,57	3,60	6,63	10,52	15,01	19,79	24,58	29,14	33,31	36,99	40,15	42,79	44,96
4,6	0,49	1,65	3,85	7,20	11,57	16,70	22,23	27,82	33,20	38,17	42,59	46,41	49,63	52,29
4,7	0,50	1,73	4,12	7,82	12,75	18,59	24,98	31,53	37,88	43,79	49,10	53,72	57,65	60,91
4,8	0,52	1,81	4,40	8,50	14,04	20,72	28,11	35,75	43,25	50,29	56,66	62,26	67,05	71,05
4,9	0,52	1,90	4,71	9,25	15,49	23,11	31,64	40,57	49,42	57,81	65,47	72,24	78,08	82,98
5,0	0,53	1,99	5,04	10,07	17,09	25,78	35,65	46,08	56,53	66,52	75,72	83,92	91,03	97,05
5,1	0,55	2,09	5,40	10,97	18,86	28,79	40,19	52,39	64,71	76,61	87,66	97,58	106,3	113,6
5,2	0,56	2,19	5,79	11,95	20,84	32,17	45,34	59,60	74,15	88,32	101,6	113,6	124,2	133,2
5,3	0,57	2,30	6,21	13,03	23,03	35,96	51,19	67,85	85,02	101,9	117,8	132,4	145,3	156,4
5,4	0,58	2,41	6,66	14,21	25,46	40,23	57,83	77,29	97,56	117,7	136,8	154,4	170,1	183,8
5,5	0,59	2,54	7,14	15,50	28,17	45,03	65,37	88,11	112,0	136,0	159,0	180,3	199,4	216,2
5,6	0,61	2,67	7,67	16,92	31,18	50,42	73,93	100,5	128,8	157,3	184,9	210,7	234,0	254,6
5,7	0,62	2,80	8,23	18,48	34,53	56,49	83,66	114,7	148,1	182,0	215,2	246,4	274,8	300,1
5,8	0,64	2,95	8,84	20,19	38,25	63,33	94,73	131,0	170,4	210,9	250,7	288,4	323,1	354,1
5,9	0,65	3,10	9,50	22,07	42,39	71,02	107,3	149,8	196,2	244,4	292,2	337,9	380,2	418,2
6,0	0,67	3,26	10,21	24,13	47,00	79,69	121,6	171,2	226,1	283,5	340,9	396,2	447,7	494,4
6,1	0,68	3,44	10,98	26,39	52,14	89,45	138,0	195,9	260,6	329,0	398,0	464,9	527,7	585,0
6,2	0,70	3,62	11,82	28,87	57,86	100,5	156,5	224,2	300,6	382,1	464,9	546,0	622,5	692,8
6,3	0,72	3,81	12,71	31,60	64,24	112,9	177,7	256,8	347,0	444,0	543,5	641,6	734,9	821,1
6,4	0,73	4,02	13,68	34,60	71,34	126,9	201,7	294,3	400,7	516,3	635,8	754,5	868,3	974,0
6,5	0,75	4,23	14,73	37,90	79,25	142,6	229,2	337,3	463,0	600,6	744,2	887,9	1026,6	1156,3
6,6	0,77	4,46	15,87	41,52	88,07	160,4	260,5	386,9	535,2	699,2	871,6	1045,5	1214,6	1373,8

Table 8 : Function Γ_C [X+1]

X	Γ_C [X+1]	X	Γ_C [X+1]
2,5	3,323	3,3	8,855
2,6	3,717	3,4	10,136
2,7	4,171	3,5	11,632
2,8	4,694	3,6	13,381
2,9	5,299	3,7	15,431
3,0	6,000	3,8	17,838
3,1	6,813	3,9	20,667
3,2	7,757	4,0	24,000

Table 9 : Part of the ship's life in full load condition

Service notation	Coefficient α
oil tanker ESP **chemical tanker ESP** **liquefied gas carrier** **LNG bunkering ship** **tanker** **bulk carrier ESP** **self-unloading bulk carrier ESP** **ore carrier ESP** **combination carrier ESP**	0,60
Others	0,75

D_{aF}, D_{bF}, D_{cF}, D_{dF}: Elementary damage ratios for load cases "a", "b", "c" and "d", respectively, in "Full load" condition, defined in [3.1.1]

D_{aB}, D_{bB}, D_{cB}: Elementary damage ratios for load cases "a", "b", and "c", respectively, in "Ballast" condition, defined in [3.1.1]

K_{cor} : Corrosion factor, taken equal to:

- K_{cor} = 1,5 for cargo oil tanks
- K_{cor} = 1,1 for ballast tanks having an effective coating protection
- K_{cor} = 1,0 otherwise.

3.1.3 Grinding of welds

In principle, grinding technique for improving fatigue life is applicable only to full penetration welds; applicability is indicated in Tab 11 depending on the weld configuration. For welds other than full penetration welds, grinding may be considered on a case by case basis.

When applicable, grinding of welds is to be regarded as an exceptional measure considered case by case, and only when the design fatigue life cannot be achieved by the design (such as improvement of the shape of cut-outs, softening of bracket toes and local increase in thickness) and geometry of the structural detail.

In such a case:

- the information "grinding of welds", with indication of the toe to be ground, is to be specified by the designer on drawings
- the relevant grinding procedure, according to Ch 11, Sec 2, [3], is to be submitted to the Society by the designer for review
- the fatigue life improvement factor for grinding β_{IF} may, generally, be taken equal to 2,2 provided that a permanent protective coating is applied on the ground weld. Otherwise, the value of β_{IF} may be considered by the Society on a case by case basis.

3.1.4 Improvement techniques other than grinding of welds

Improving fatigue life by using improvement techniques other than grinding is to be regarded as an exceptional measure. Such improvement techniques may be considered by the Society on a case by case basis. In such a case, the fatigue life improvement factor β_{IF} is to be duly justified by the designer.

4 Stress range

4.1 General

4.1.1 Calculation point

Unless otherwise specified, stresses are to be determined at the hot spots indicated, for each detail, in the relevant figures in Ch 11, Sec 2.

4.1.2 Stress components

For the details in [1.1.3], the stresses to be used in the fatigue check are the normal stresses in the directions indicated, for each detail, in the relevant figures in Ch 11, Sec 2.

Where the fatigue check is required for details other than those in [1.1.3], the stresses to be used are the principal stresses at the hot spots which form the smallest angle with the crack rising surface.

4.2 Hot spot stress range

4.2.1 Elementary hot spot stress range

The elementary hot spot stress range $\Delta\sigma_{G,ij}$ is to be obtained, in N/mm², in accordance with:

- Ch 7, App 1, [7] for details where the stresses are to be calculated through a three dimensional structural models
- [6.2] for details located at ends of ordinary stiffeners.

4.3 Notch stress range

4.3.1 Elementary notch stress range

The elementary notch stress range is to be obtained, in N/mm², from the following formula:

$\Delta\sigma_{N,ij} = K_{C,ij}\,\Delta\sigma_{N0,ij}$

with:

$\Delta\sigma_{N0,ij} = 0,7\,K_F\,K_m\,\Delta\sigma_{G,ij}$

where:

K_F : Fatigue notch factor, equal to:

$$K_F = \lambda \sqrt{\frac{\theta}{30}}$$

for flame-cut edges, K_F may be taken equal to the values defined in Tab 12, depending on the cutting quality, post treatment and control quality

λ : Coefficient depending on the weld configuration, and given in Tab 11

θ : Mean weld toe angle, in degrees, without being taken less than 30°. Unless otherwise specified, θ may be taken equal to:

- 30° for butt joints
- 45° for T joints or cruciform joints

K_m : Stress concentration factor, taking account of misalignment, defined in Tab 10, and to be taken not less than 1,0

$\Delta\sigma_{G,ij}$: Elementary hot spot stress range, defined in [4.2.1]

$$K_{C,ij} = \frac{0,4 R_{eH}}{\Delta\sigma_{N0,ij}} + 0,6 \quad \text{with} \quad 0,8 \le K_{C,ij} \le 1$$

Table 10 : Stress concentration factor K_m for misalignment

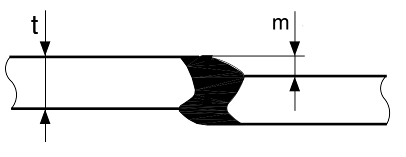
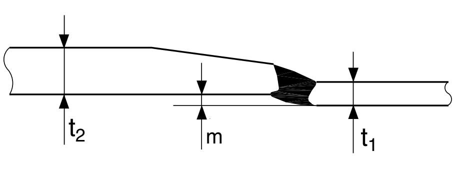
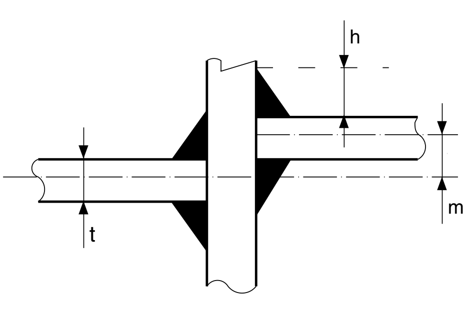
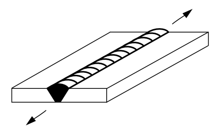
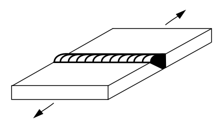
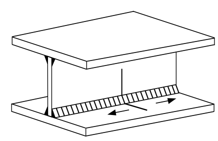
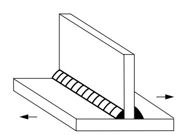
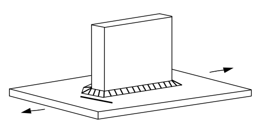
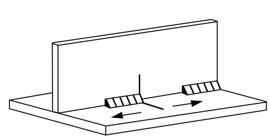
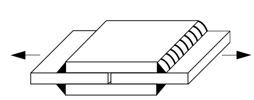
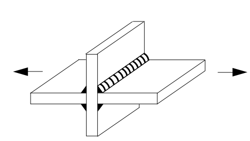
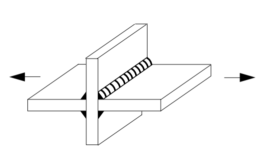
Geometry	K_m **(1)**
Axial misalignment between flat plates 	$1 + \frac{3(m - m_0)}{t}$
Axial misalignment between flat plates of different thicknesses 	$1 + \frac{6(m - m_0)}{t_1} \frac{t_1^{3/2}}{t_1^{3/2} + t_2^{3/2}}$
Axial misalignment in fillet welded cruciform joints 	$1 + \frac{m - m_0}{t + h}$
(1) When the actual misalignment m is lower than the permissible misalignment m_0, K_m is to be taken equal to 1. **Note 1:** m : Actual misalignment between two abutting members m_0 : Permissible misalignment for the detail considered, given in Ch 11, Sec 2.	

Table 11 : Weld coefficient λ

Weld configuration				Coefficient λ	Grinding applicable
Type	Description	Stress direction	Figure		
Butt weld		Parallel to the weld		2,10	yes
		Perpendicular to the weld		2,40	yes
Fillet weld	Continuous	Parallel to the weld		1,80	yes
		Perpendicular to the weld **(1)**		2,15	yes
	Well contoured end	Perpendicular to the weld		2,15	yes
	Not continuous	Parallel to the weld		2,90	yes
	Lap weld (root cracking)	Axial loading out of plane and perpendicular to the weld		4,50	no
Cruciform joint	Full penetration	Perpendicular to the weld		2,10	yes
	Partial penetration	Perpendicular to the weld		Toe cracking: 2,10	yes
				Root cracking: 4,50	no

(1) This case includes the hot spots indicated in the sheets of special structural details in Ch 11, Sec 2 relevant to the connections of longitudinal ordinary stiffeners with transverse primary supporting members.

Table 12 : K_F values

Flame-cut edge description	K_F
Machine gas cut edges, with subsequent machining, dressing or grinding	1,4
Machine thermally cut edges, corners removed, no crack by inspection	1,6
Manually thermally cut edges, free from cracks and severe notches	2,0
Manually thermally cut edges, uncontrolled, no notch deeper than 0,5 mm	2,5

5 Checking criteria

5.1 Damage ratio

5.1.1 The cumulative damage ratio D calculated according to [3.1.2], is to comply with the following formula:

$$D \le \frac{1}{\gamma_R}$$

6 Structural details located at ends of ordinary stiffeners

6.1 General

6.1.1 For the fatigue check of connections located at ends of ordinary stiffeners, the elementary hot spot stress range $\Delta\sigma_{G,ij}$ may be calculated as indicated in [6.2].

6.2 Determination of elementary hot spot stress range

6.2.1 Nominal local stress

For each load case "a", "b", "c" and "d", "-max" and "-min", the nominal local stress σ_ℓ applied to the ordinary stiffener, is to be obtained, in N/mm², from the following formula:

$$\sigma_\ell = \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{12 w}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

where:

- w : Net section modulus, in cm³, of the stiffener, with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [3.4]
- s : Spacing, in m, of ordinary stiffeners
- ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 4, Sec 3, [3.2].

6.2.2 Elementary hot spot stress range

For each load case "a", "b", "c" and "d", the elementary hot spot stress range $\Delta\sigma_{G,ij}$ is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{G,ij} = |\sigma_{G(i\text{-}max)} - \sigma_{G(i\text{-}min)}| + K_\ell \Delta\sigma_{DEF,ij}$$

where:

$$\sigma_{G(i\text{-}max)} = K_N(K_h\sigma_h + K_\ell K_S \sigma_\ell)_{(i\text{-}max)}$$

$$\sigma_{G(i\text{-}min)} = K_N(K_h\sigma_h + K_\ell K_S \sigma_\ell)_{(i\text{-}min)}$$

- $\Delta\sigma_{DEF,ij}$: Nominal stress range due to the local deflection of the ordinary stiffener to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{DEF,ij} = \frac{4(\Delta\delta)EI}{w\ell^2} 10^{-5}$$

- σ_h : Nominal hull girder stress for the load case "i-max" or "i-min" considered, to be determined as indicated in [2.3.1]
- σ_ℓ : Nominal local stress for the load case "i-max" or "i-min" considered, to be determined as indicated in [6.2.1]
- K_N : Coefficient taking account of North Atlantic navigation, taken equal to 1,0
- K_S : Coefficient taking account of the stiffener section geometry, equal to:

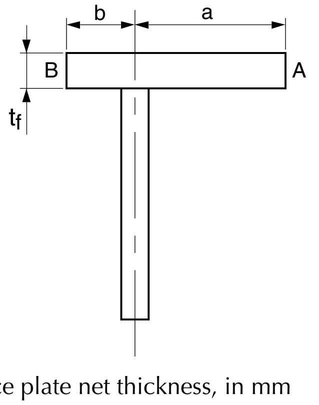
$$K_S = 1 + \left[\frac{t_f(a^2 - b^2)}{2 w_B}\right]\left[1 - \frac{b}{a+b}\left(1 + \frac{w_B}{w_A}\right)\right] 10^{-3}$$

without being taken less than 1,0

- a, b : Eccentricities of the stiffener, in mm, defined in Fig 3

  Bulb sections are to be taken as equivalent to an angle profile, as defined in Ch 4, Sec 3, [3.1.2] with a = 0,75 b_f and b = 0,25 b_f

Figure 3 : Geometry of a stiffener section



- t_f : Face plate net thickness, in mm
- b_f : Face plate width, in mm
- w_A, w_B : Net section moduli of the stiffener without attached plating, in cm³, respectively in A and B (see Fig 3), about its neutral axis parallel to the stiffener web
- $\Delta\delta$: Local range of deflection, in mm, of the ordinary stiffener
- I : Net moment of inertia, in cm⁴, of the ordinary stiffener with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [3.4].

APPENDIX 1 ANALYSES BASED ON THREE DIMENSIONAL MODELS

Symbols

For symbols not defined in this Appendix, refer to the list at the beginning of this Chapter.

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

g : Gravity acceleration, in m/s^2:

$g = 9,81$ m/s^2

h_1 : Reference values of the ship relative motions in the upright ship condition, defined in Ch 5, Sec 3, [3.3]

h_2 : Reference values of the ship relative motions in the inclined ship conditions, defined in Ch 5, Sec 3, [3.3]

α : Coefficient equal to T_1/T, but not to be taken greater than 1

T_1 : Draught, in m, corresponding to the loading condition considered

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

M_{WV} : Vertical wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1], having the same sign as M_{SW}

Q_{SW} : 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, defined in Ch 5, Sec 2, [3.4], having sign:

- where M_{WV} is positive (hogging condition):
  positive for $x < 0,5$ L
  negative for $x \geq 0,5$ L
- where M_{WV} is negative (sagging condition):
  negative for $x < 0,5$ L
  positive for $x \geq 0,5$ L

γ_{S1}, γ_{W1} : Partial safety factors, defined in Ch 7, Sec 3.

φ_1 : Coefficient for pressure on exposed decks, as defined in Tab 5

φ_2 : Coefficient taken equal to:

- $\varphi_2 = 1$ for $L \geq 120$ m
- $\varphi_2 = L/120$ for $L < 120$ m

1 General

1.1 Application

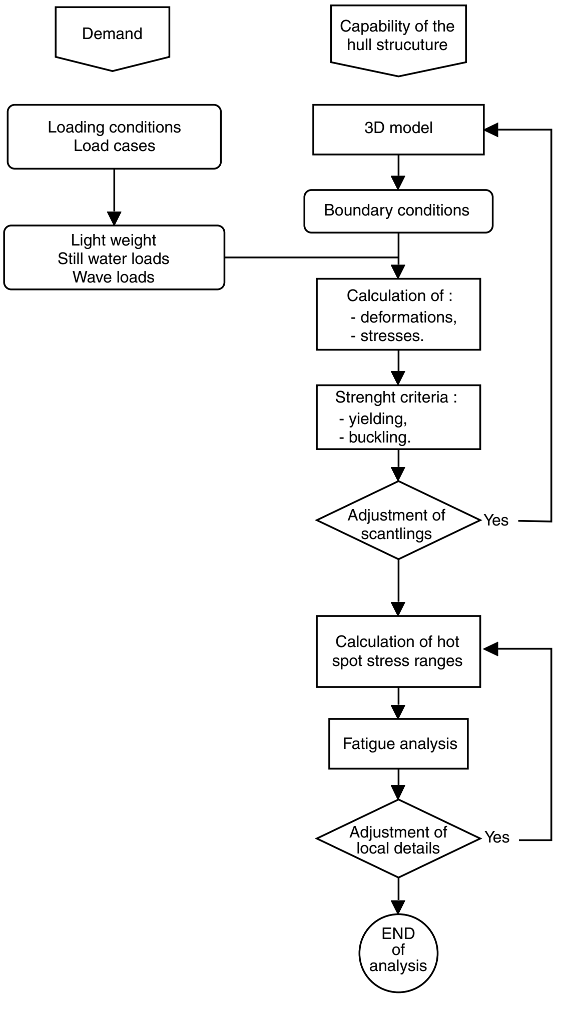
1.1.1 The requirements of this Appendix apply for the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members which are to be analysed through three dimensional structural models, according to Ch 7, Sec 3.

The analysis application procedure is shown graphically in Fig 1.

1.1.2 This Appendix deals with that part of the structural analysis which aims at:

- calculating the stresses in the primary supporting members in the midship area and, when necessary, in other areas, which are to be used in the yielding and buckling checks
- calculating the hot spot stress ranges in the structural details which are to be used in the fatigue check.

Figure 1 : Application procedure of the analyses based on three dimensional models



1.1.3 The yielding and buckling checks of primary supporting members are to be carried out according to Ch 7, Sec 3.

The fatigue check of structural details is to be carried out according to Ch 7, Sec 4.

2 Analysis criteria

2.1 General

2.1.1 All primary supporting members in the midship regions are normally to be included in the three dimensional model, with the purpose of calculating their stress level and verifying their scantlings.

When the primary supporting member arrangement is such that the Society can accept that the results obtained for the midship region are extrapolated to other regions, no additional analyses are required. Otherwise, analyses of the other regions are to be carried out.

2.2 Finite element model analyses

2.2.1 The analysis of primary supporting members is to be carried out on standard mesh models, as defined in [3.4.3].

2.2.2 Areas which appear, from the primary supporting member analysis, to be highly stressed may be required to be further analysed through appropriately meshed structural models, as defined in [3.4.4].

2.3 Beam model analyses

2.3.1 Beam models may be adopted in cases specified in Ch 7, Sec 3, [1.1.2], provided that:

- primary supporting members are not so stout that the beam theory is deemed inapplicable by the Society
- their behaviour is not substantially influenced by the transmission of shear stresses through the shell plating.

In any case, finite element models are to be adopted when deemed necessary by the Society on the basis of the ship's structural arrangement.

2.4 Structural detail analysis

2.4.1 Structural details in Ch 7, Sec 4, [1.1.4], for which a fatigue analysis is to be carried out, are to be modelled as specified in [7].

3 Primary supporting members structural modelling

3.1 Model construction

3.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected.

Ordinary stiffeners are also to be represented in the model in order to reproduce the stiffness and inertia of the actual hull girder structure. The way ordinary stiffeners are represented in the model depends on the type of model (beam or finite element), as specified in [3.4] and [3.5].

3.1.2 Net scantlings

All the elements in [3.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2. Therefore, also the hull girder stiffness and inertia to be reproduced by the model are those obtained by considering the net scantlings of the hull structures.

3.2 Model extension

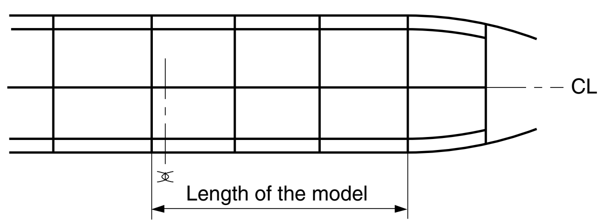
3.2.1 The longitudinal extension of the structural model is to be such that:

- the hull girder stresses in the area to be analysed are properly taken into account in the structural analysis
- the results in the areas to be analysed are not influenced by the unavoidable inaccuracy in the modelling of the boundary conditions.

3.2.2 In general, for multitank / hold ships more than 170 m in length, the conditions in [3.2.1] are considered as being satisfied when the model is extended over at least three cargo tank/hold lengths.

For the analysis of the midship area, this model is to be such that its aft end corresponds to the first transverse bulkhead aft of the midship, as shown in Fig 2. The structure of the fore and aft transverse bulkheads located within the model, including the bulkhead plating, is to be modelled.

Figure 2 : Model longitudinal extension Ships more than 170 m in length

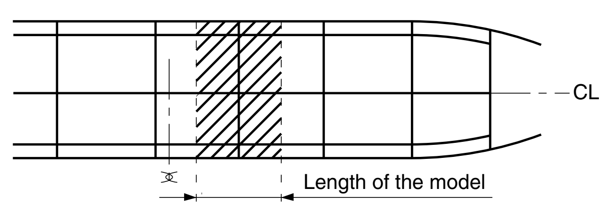


3.2.3 For ships less than 170 m in length, the model may be limited to one cargo tank/hold length (one half cargo tank/hold length on either side of the transverse bulkhead; see Fig 3).

However, larger models may need to be adopted when deemed necessary by the Society on the basis of the ship's structural arrangement.

3.2.4 In the case of structural symmetry with respect to the ship's centreline longitudinal plane, the hull structures may be modelled over half the ship's breadth.

Figure 3 : Model longitudinal extension Ships less than 170 m in length



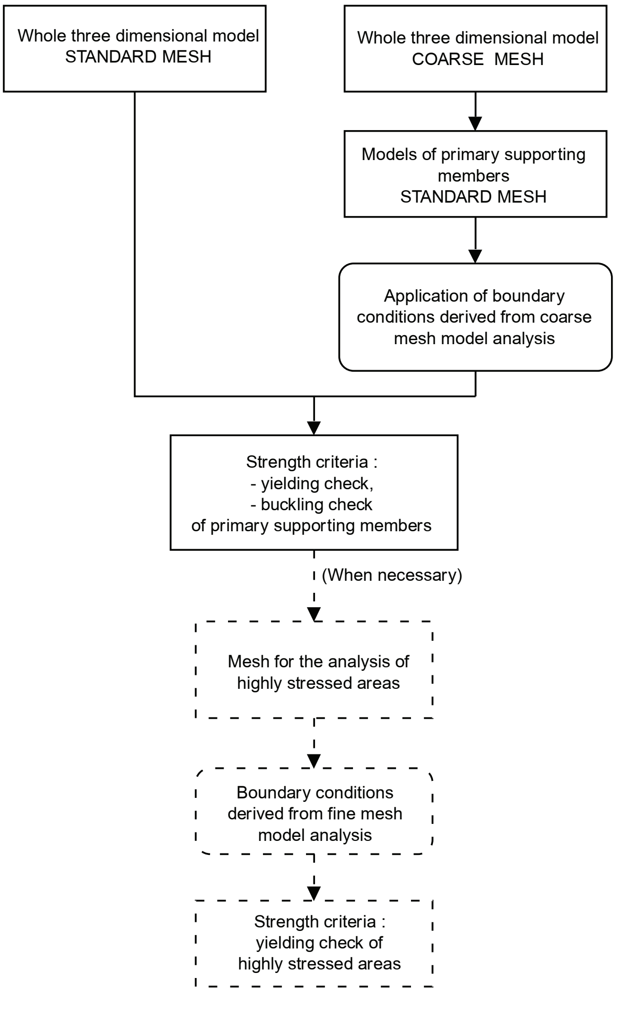
3.3 Finite element modelling criteria

3.3.1 Modelling of primary supporting members

The analysis of primary supporting members based on standard mesh models, as defined in [3.4.3], is to be carried out by applying one of the following procedures (see Fig 4), depending on the computer resources:

- an analysis of the whole three dimensional model based on a standard mesh
- an analysis of the whole three dimensional model based on a coarse mesh, as defined in [3.4.2], from which the nodal displacements or forces are obtained to be used as boundary conditions for analyses based on fine mesh models of primary supporting members, e.g.:
  - transverse rings
  - double bottom girders
  - side girders
  - deck girders
  - primary supporting members of transverse bulkheads
  - primary supporting members which appear from the analysis of the whole model to be highly stressed.

Figure 4 : Finite element modelling criteria



3.3.2 Modelling of the most highly stressed areas

The areas which appear from the analyses based on standard mesh models to be highly stressed may be required to be further analysed, using the mesh accuracy specified in [3.4.4].

3.4 Finite element models

3.4.1 General

Finite element models are generally to be based on linear assumptions. The mesh is to be executed using membrane or shell elements, with or without mid-side nodes.

Meshing is to be carried out following uniformity criteria among the different elements.

Most of quadrilateral elements are to be such that the ratio between the longer side length and the shorter side length does not exceed 2. Some of them may have a ratio not exceeding 4. Their angles are to be greater than 60° and less than 120°. The triangular element angles are to be greater than 30° and less than 120°.

Further modelling criteria depend on the accuracy level of the mesh, as specified in [3.4.2] to [3.4.4].

3.4.2 Coarse mesh

The number of nodes and elements is to be such that the stiffness and inertia of the model properly represent those of the actual hull girder structure, and the distribution of loads among the various load carrying members is correctly taken into account.

To this end, the structural model is to be built on the basis of the following criteria:

- ordinary stiffeners contributing to the hull girder longitudinal strength and which are not individually represented in the model are to be modelled by rod elements and grouped at regular intervals
- webs of primary supporting members may be modelled with only one element on their height
- face plates may be simulated with bars having the same cross-section
- the plating between two primary supporting members may be modelled with one element strip
- holes for the passage of ordinary stiffeners or small pipes may be disregarded
- manholes (and similar discontinuities) in the webs of primary supporting members may be disregarded, but the element thickness is to be reduced in proportion to the hole height and the web height ratio.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

3.4.3 Standard mesh

The ship's structure may be considered as finely meshed when each longitudinal ordinary stiffener is modelled; as a consequence, the standard size of finite elements used is based on the spacing of ordinary stiffeners.

The structural model is to be built on the basis of the following criteria:

- webs of primary members are to be modelled with at least three elements on their height
- the plating between two primary supporting members is to be modelled with at least two element strips
- the ratio between the longer side and the shorter side of elements is to be less than 3 in the areas expected to be highly stressed
- holes for the passage of ordinary stiffeners may be disregarded.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

3.4.4 Fine mesh for the analysis of structural details

In order to obtain an accurate representation of stresses in the area of interest, the structural model is to be built on the basis of the following criteria:

- the mesh dimensions are to be such as to enable a faithful representation of the stress gradients
- the size of elements in the area of interest is not to be greater than 50 mm x 50 mm
- the extent of the refined area is to be at least of 10 elements in any direction around its centre
- the use of membrane elements is only allowed when significant bending effects are not present; in the other cases, elements with general behaviour are to be used
- the use of linear triangular elements is to be avoided as much as possible in high stress area; quadrilateral elements are to have 90° angles as much as possible, or angles between 60° and 120°; the aspect ratio is to be close to 1; when the use of a linear triangular element cannot be avoided, its edges are to have the same length
- the local fine mesh can either be included directly into the global model or belong to a separate sub-model; the gradient of mesh size must be reasonably low.

3.5 Beam models

3.5.1 Beams representing primary supporting members

Primary supporting members are to be modelled by beam elements with shear strain, positioned on their neutral axes, whose inertia characteristics are to be calculated as specified in Ch 4, Sec 3, [4].

3.5.2 Torsional moments of inertia

Whenever the torsional effects of the modelling beams are to be taken into account (e.g. for modelling the double bottom, hopper tanks and lower stools), their net torsional moments of inertia are obtained, in cm^4, from the following formulae:

- for open section beams (see Fig 5):

$$I_T = \frac{1}{3}\sum_i (t_i^3 \ell_i) 10^{-4}$$

- for box-type section beams, e.g. those with which hopper tanks and lower stools are modelled (see Fig 6):

$$I_T = \frac{4\Omega^2}{\sum_i \frac{\ell_i}{t_i}} 10^{-4}$$

- for beams of double skin structures (see Fig 7):

$$I_T = \frac{t_1 t_2 (b_1 + b_2) H_D^2}{2(t_1 + t_2)} 10^{-4}$$

where:

Σ_i : Sum of all the profile segments that constitute the beam section

t_i , ℓ_i : Net thickness and length, respectively, in mm, of the i-th profile segment of the beam section (see Fig 5 and Fig 6)

Ω : Area, in mm^2, of the section enclosed by the beam box profile (see Fig 6)

t_1 , t_2 : Net thickness, in mm, of the inner and outer plating, respectively, (see Fig 7)

b_1 , b_2 : Distances, in mm, from the beam considered to the two adjacent beams (see Fig 7)

H_D : Height, in mm, of the double skin (see Fig 7).

Figure 5 : Open section beams

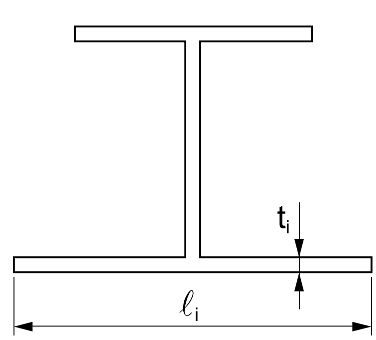


Figure 6 : Box-type section beams

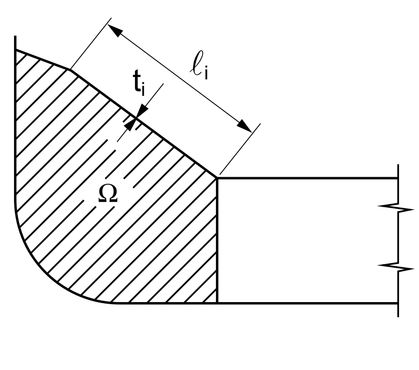
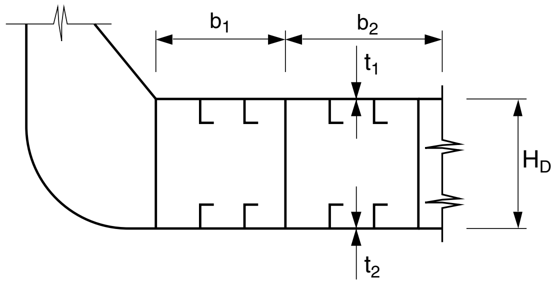


Figure 7 : Beams of double skin structures



3.5.3 Variable cross-section primary supporting members

In the case of variable cross-section primary supporting members, the inertia characteristics of the modelling beams may be assumed as a constant and equal to their average value along the length of the elements themselves.

3.5.4 Modelling of primary supporting members ends

The presence of end brackets may be disregarded; in such case their presence is also to be neglected for the evaluation of the beam inertia characteristics.

Rigid end beams are generally to be used to connect ends of the various primary supporting members, such as:

- floors and side vertical primary supporting members
- bottom girders and vertical primary supporting members of transverse bulkheads
- cross ties and side/longitudinal bulkhead primary supporting members.

3.5.5 Beams representing hull girder characteristics

The stiffness and inertia of the hull girder are to be taken into account by longitudinal beams positioned as follows:

- on deck and bottom in way of side shell and longitudinal bulkheads, if any, for modelling the hull girder bending strength
- on deck, side shell, longitudinal bulkheads, if any, and bottom for modelling the hull girder shear strength.

3.6 Boundary conditions of the whole three dimensional model

3.6.1 Structural model extended over at least three cargo tank/hold lengths

The whole three dimensional model is assumed to be fixed at one end, while shear forces and bending moments are applied at the other end to ensure equilibrium (see [4]).

At the free end section, rigid constraint conditions are to be applied to all nodes located on longitudinal members, in such a way that the transverse section remains plane after deformation.

When the hull structure is modelled over half the ship's breadth (see [3.2.4]), in way of the ship's centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Tab 1 are to be applied, depending on the loads applied to the model (symmetrical or anti-symmetrical, respectively).

Table 1 : Symmetry and anti-symmetry conditions in way of the ship's centreline longitudinal plane

Boundary conditions	DISPLACEMENTS in directions **(1)**		
	X	Y	Z
Symmetry	free	fixed	free
Anti-symmetry	fixed	free	fixed

Boundary conditions	ROTATION around axes **(1)**		
	X	Y	Z
Symmetry	fixed	free	fixed
Anti-symmetry	free	fixed	free

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [4].

3.6.2 Structural models extended over one cargo tank/hold length

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 2.

Table 2 : Symmetry conditions at the model fore and aft ends

DISPLACEMENTS in directions **(1)**:			ROTATION around axes **(1)**:		
X	Y	Z	X	Y	Z
fixed	free	free	free	fixed	fixed

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [4].

When the hull structure is modelled over half the ship's breadth (see [3.2.4]), in way of the ship's centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Tab 1 are to be applied, depending on the loads applied to the model (symmetrical or anti-symmetrical, respectively).

Vertical supports are to be fitted at the nodes positioned in way of the connection of the transverse bulkheads with longitudinal bulkheads, if any, or with sides.

4 Primary supporting members load model

4.1 General

4.1.1 Loading conditions and load cases in intact conditions

The still water and wave loads are to be calculated for the most severe loading conditions as given in the loading manual, with a view to maximising the stresses in the longitudinal structure and primary supporting members.

The following loading conditions are generally to be considered:

- homogeneous loading conditions at draught T
- non-homogeneous loading conditions at draught T, when applicable
- partial loading conditions at the relevant draught
- ballast conditions at the relevant draught.

The wave local and hull girder loads are to be calculated in the mutually exclusive load cases "a", "b", "c" and "d" in Ch 5, Sec 4.

4.1.2 Loading conditions and load cases in flooding conditions

When applicable, the pressures in flooding conditions are to be calculated according to Ch 5, Sec 6, [9].

4.1.3 Lightweight

The structure weight of the modelled portion of the hull is to be included in the static loads. In order to obtain the actual longitudinal distribution of the still water bending moment, the lightweight is to be uniformly distributed over the length of the model.

4.1.4 Models extended over half ship's breadth

When the ship is symmetrical with respect to her centreline longitudinal plane and the hull structure is modelled over half the ship's breadth, non-symmetrical loads are to be broken down into symmetrical and anti-symmetrical loads and applied separately to the model with symmetry and anti-symmetry boundary conditions in way of the ship's centreline longitudinal plane (see [3.6]).

4.2 Local loads

4.2.1 General

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave loads include:

- the wave pressure, defined in [4.2.2] for each load case "a", "b", "c" and "d"
- the inertial loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case "a", "b", "c" and "d".

4.2.2 Wave loads

The wave pressure at any point of the model is obtained from the formulae in Tab 3 for upright ship conditions (load cases "a" and "b") and in Tab 4 for inclined ship conditions (load cases "c" and "d").

4.2.3 Distributed loads

Distributed loads are to be applied to the plating panels.

In the analyses carried out on the basis of membrane finite element models or beam models, the loads distributed perpendicularly to the plating panels are to be applied on the ordinary stiffeners proportionally to their areas of influence. When ordinary stiffeners are not modelled or are modelled with rod elements (see [3.4]), the distributed loads are to be applied to the primary supporting members actually supporting the ordinary stiffeners.

4.2.4 Concentrated loads

When the elements directly supporting the concentrated loads are not represented in the structural model, the loads are to be distributed on the adjacent structures according to the actual stiffness of the structures which transmit them.

In the analyses carried out on the basis of coarse mesh finite element models or beam models, concentrated loads applied in five or more points almost equally spaced inside the same span may be applied as equivalent linearly distributed loads.

4.2.5 Cargo in sacks, bales and similar packages

The vertical loads are comparable to distributed loads. The loads on vertical walls may be disregarded.

4.2.6 Other cargoes

The modelling of cargoes other than those mentioned under [4.2.3] to [4.2.5] will be considered by the Society on a case by case basis.

Table 3 : Wave pressure in upright ship conditions (load cases "a" and "b")

Location	Wave pressure p_W, in kN/m²	
	crest	trough **(1)**
Bottom and sides below the waterline ($z \le T_1$)	$C_{F1}\alpha^{1/4}\rho g h_1 e^{\frac{-2\pi(T_1-z)}{\alpha L}}$	$-C_{F1}\alpha^{1/4}\rho g h_1 e^{\frac{-2\pi(T_1-z)}{\alpha L}}$ without being taken less than $\rho\, g\,(z - T_1)$
Sides above the waterline ($z > T_1$)	$\rho g(T_1 + C_{F1}\alpha^{1/4}h_1 - z)$ without being taken, for case "a" only, less than $0{,}15\,\varphi_1\,\varphi_2\,L$	0,0

(1) The wave pressure for load case "b, trough" is to be used only for the fatigue check of structural details (see Ch 7, Sec 4).
Note 1:
C_{F1} : Combination factor, to be taken equal to:
- C_{F1} = 1,0 for load case "a"
- C_{F1} = 0,5 for load case "b".

Table 4 : Wave pressure in inclined ship conditions (load cases "c" and "d")

Location	Wave pressure p_W, in kN/m² (negative roll angle) **(1)**	
	$y \geq 0$	$y < 0$
Bottom and sides below the waterline ($z \leq T_1$)	$\beta C_{F2}\alpha^{1/4}\rho g\left[\frac{y}{B_W}h_1 e^{\frac{-2\pi(T_1-z)}{\alpha L}} + A_R y e^{\frac{-\pi(T_1-z)}{\alpha L}}\right]$	$\beta C_{F2}\alpha^{1/4}\rho g\left[\frac{y}{B_W}h_1 e^{\frac{-2\pi(T_1-z)}{\alpha L}} + A_R y e^{\frac{-\pi(T_1-z)}{\alpha L}}\right]$ without being taken less than $\rho g (z - T_1)$
Sides above the waterline ($z > T_1$)	$\rho g\left[T_1 + \beta C_{F2}\alpha^{1/4}\left(\frac{y}{B_W}h_1 + A_R y\right) - z\right]$ without being taken, for case "c" only, less than 0,15 φ_1 φ_2 L	0,0

(1) In the formulae giving the wave pressure p_W, the ratio (y / B_W) is not to be taken greater than 0,5.

Note 1:

C_{F2} : Combination factor, to be taken equal to:
- C_{F2} = 1,0 for load case "c"
- C_{F2} = 0,5 for load case "d"

β : coefficient, to be taken as the minimum of:
- 1
- $T_1/\left(0{,}5h_1 + A_R\frac{B_W}{2}\right)$
- $(D - 0.9T)/\left(0{,}5h_1 + A_R\frac{B_W}{2}\right)$

B_W : Moulded breadth, in m, measured at the waterline at draught T_1, at the hull transverse section considered

A_R : Roll amplitude, defined in Ch 5, Sec 3, [2.4.1].

Table 5 : Coefficient φ_1

Exposed deck location	φ_1
Freeboard deck and below	1,00
Top of lowest tier	0,75
Top of second tier	0,56
Top of third tier	0,42
Top of fourth tier	0,32
Top of fifth tier	0,25
Top of sixth tier	0,20
Top of seventh tier	0,15
Top of eighth tier and above	0,10

4.3 Hull girder loads

4.3.1 Structural model extended over at least three cargo tank/hold lengths

The hull girder loads are constituted by:

- the still water and wave vertical bending moments
- the horizontal wave bending moment
- the still water and wave vertical shear forces,

and are to be applied at the model free end section. The shear forces are to be distributed on the plating according to the theory of bidimensional flow of shear stresses.

These loads are to be applied for the following two conditions:

- maximal bending moments at the middle of the central tank/hold within 0,4 L amidships: the hull girder loads applied at the free end section are to be such that the values of the hull girder loads in Tab 6 are obtained
- maximal shear forces in way of the aft or forward transverse bulkhead of the central tank/hold: the hull girder loads applied at the free end section are to be such that the values of the hull girder loads in Tab 7 are obtained.

When the assessment of the foremost or aftmost cargo tank/hold is required, the following two conditions are to be considered:

- maximal bending moment for a given studied region along the length of the foremost / aftmost cargo tank / hold: the hull girder loads applied at the free end section are to be such that the values of the hull girder loads in Tab 8 are obtained.
- maximal shear force for a given studied region along the length of foremost/aftmost cargo tank/hold: the hull girder loads applied at the free end section are to be such that the values of the hull girder loads in Tab 9 are obtained.

4.3.2 Structural model extended over one cargo tank/hold length

The normal and shear stresses induced by the hull girder loads in Tab 10 are to be added to the stresses induced in the primary supporting members by local loads.

Table 6 : Hull girder loads - Maximal bending moments at the middle of the central tank/hold

Ship condition	Load case	Vertical bending moments at the middle of the central tank/hold		Horizontal wave bending moment at the middle of the central tank/hold	Vertical shear forces at the middle of the central tank/hold	
		Still water	Wave		Still water	Wave
Upright	"a" crest	γ_{S1} M_{SW}	0,625 γ_{W1} $M_{WV,H}$	0	0	0
	"a" trough	γ_{S1} M_{SW}	0,625 γ_{W1} $M_{WV,S}$	0	0	0
	"b"	γ_{S1} M_{SW}	0,625 γ_{W1} $M_{WV,S}$	0	0	0
Inclined	"c"	γ_{S1} M_{SW}	0,250 γ_{W1} M_{WV}	0,625 γ_{W1} M_{WH}	0	0
	"d"	γ_{S1} M_{SW}	0,250 γ_{W1} M_{WV}	0,625 γ_{W1} M_{WH}	0	0

Note 1: Hull girder loads are to be calculated at the middle of the central tank/hold.

Table 7 : Hull girder loads - Maximal shear forces in way of the aft or forward bulkhead of the central tank/hold

Ship condition	Load case	Vertical bending moments in way of one bulkhead of the central tank/hold		Vertical shear forces in way of one bulkhead of the central tank/hold	
		Still water	Wave	Still water	Wave
Upright	"a" crest	γ_{S1} M_{SW}	0,40 γ_{W1} M_{WV}	γ_{S1} Q_{SW}	0,625 γ_{W1} Q_{WV}
	"a" trough	γ_{S1} M_{SW}	0,40 γ_{W1} M_{WV}	γ_{S1} Q_{SW}	0,625 γ_{W1} Q_{WV}
	"b"	γ_{S1} M_{SW}	0,40 γ_{W1} M_{WV}	γ_{S1} Q_{SW}	0,625 γ_{W1} Q_{WV}
Inclined	"c"	γ_{S1} M_{SW}	0,25 γ_{W1} M_{WV}	γ_{S1} Q_{SW}	0,250 γ_{W1} Q_{WV}
	"d"	γ_{S1} M_{SW}	0,25 γ_{W1} M_{WV}	γ_{S1} Q_{SW}	0,250 γ_{W1} Q_{WV}

Note 1: Hull girder loads are to be calculated in way of the aft bulkhead of the central tank/hold.

Table 8 : Hull girder loads - Maximal bending moments for the foremost or aftmost tank/hold

Ship condition	Load case	Vertical bending moments		Horizontal wave bending moment	Vertical shear forces	
		Still water	Wave		Still water	Wave
Upright	"a" crest	γ_{S1} M_{SW}	0,625 γ_{W1} $M_{WV,H}$	0	γ_{S1} Q_{SW} **(3)**	0,625 γ_{W1} Q_{WV}
	"a" trough	γ_{S1} M_{SW}	0,625 γ_{W1} $M_{WV,S}$	0	γ_{S1} Q_{SW} **(3)**	0,625 γ_{W1} Q_{WV}
	"b"	γ_{S1} M_{SW}	0,625 γ_{W1} $M_{WV,S}$	0	γ_{S1} Q_{SW} **(3)**	0,625 γ_{W1} Q_{WV}
Inclined	"c"	γ_{S1} M_{SW} **(1)**	0,250 γ_{W1} M_{WV} **(2)**	0,625 γ_{W1} M_{WH}	γ_{S1} Q_{SW} **(3)**	0,250 γ_{W1} Q_{WV}
	"d"	γ_{S1} M_{SW} **(1)**	0,250 γ_{W1} M_{WV} **(2)**	0,625 γ_{W1} M_{WH}	γ_{S1} Q_{SW} **(3)**	0,250 γ_{W1} Q_{WV}

Note 1: Hull girder loads are to be calculated at the middle of studied region. Several studied regions may be necessary in order to obtain the target hull girder loads over the length of the fore/aft model.

(1) M_{SW} is to be taken equal to $M_{SW,H}$ or to $M_{SW,S}$ depending on the loading condition.

(2) M_{WV} is to be taken equal to $M_{WV,H}$ or to $M_{WV,S}$ depending on the loading condition.

(3) Q_{SW} may be taken from the loading manual among the relevant loading conditions in order to maximize the bending moments.

Table 9 : Hull girder loads - Maximal shear forces for the foremost or aftmost tank/hold

Ship condition	Load case	Vertical bending moments		Horizontal wave bending moment	Vertical shear forces	
		Still water	Wave		Still water	Wave
Upright	"a" crest	γ_{S1} M_{SW} **(3)**	0,625 γ_{W1} $M_{WV,H}$	0	γ_{S1} Q_{SW}	0,625 γ_{W1} Q_{WV}
	"a" trough	γ_{S1} M_{SW} **(3)**	0,625 γ_{W1} $M_{WV,S}$	0	γ_{S1} Q_{SW}	0,625 γ_{W1} Q_{WV}
	"b"	γ_{S1} M_{SW} **(3)**	0,625 γ_{W1} $M_{WV,S}$	0	γ_{S1} Q_{SW}	0,625 γ_{W1} Q_{WV}
Inclined	"c"	γ_{S1} M_{SW} **(1) (3)**	0,250 γ_{W1} M_{WV} **(2)**	0,625 γ_{W1} M_{WH}	γ_{S1} Q_{SW}	0,250 γ_{W1} Q_{WV}
	"d"	γ_{S1} M_{SW} **(1) (3)**	0,250 γ_{W1} M_{WV} **(2)**	0,625 γ_{W1} M_{WH}	γ_{S1} Q_{SW}	0,250 γ_{W1} Q_{WV}

Note 1: Hull girder loads are to be calculated at the middle of studied region. Several studied regions may be necessary in order to obtain the target hull girder loads over the length of the fore/aft model.

(1) M_{SW} is to be taken equal to $M_{SW,H}$ or to $M_{SW,S}$ depending on the loading condition.

(2) M_{WV} is to be taken equal to $M_{WV,H}$ or to $M_{WV,S}$ depending on the loading condition.

(3) M_{SW} may be taken from the loading manual among the relevant loading conditions in order to maximize the bending moments.

Table 10 : Hull girder loads for a structural model extended over one cargo tank/hold length

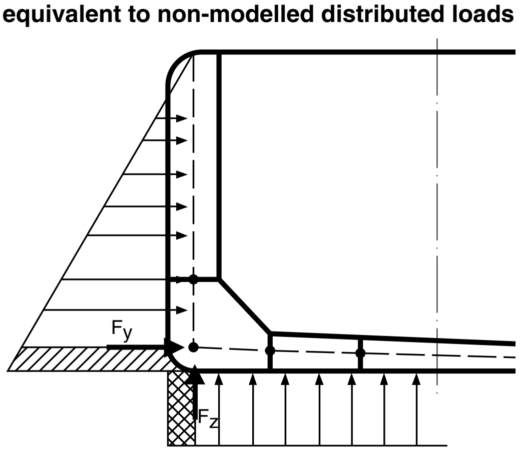
Ship condition	Load case	Vertical bending moments at the middle of the model		Horizontal wave bending moment at the middle of the model	Vertical shear forces at the middle of the model	
		Still water	Wave		Still water	Wave
Upright	"a" crest	$\gamma_{S1} M_{SW}$	$0{,}625\ \gamma_{W1} M_{WV,H}$	0	$\gamma_{S1} Q_{SW}$	$0{,}625\ \gamma_{W1} Q_{WV}$
	"a" trough	$\gamma_{S1} M_{SW}$	$0{,}625\ \gamma_{W1} F_D M_{WV,S}$	0	$\gamma_{S1} Q_{SW}$	$0{,}625\ \gamma_{W1} Q_{WV}$
	"b"	$\gamma_{S1} M_{SW}$	$0{,}625\ \gamma_{W1} F_D M_{WV,S}$	0	$\gamma_{S1} Q_{SW}$	$0{,}625\ \gamma_{W1} Q_{WV}$
Inclined	"c"	$\gamma_{S1} M_{SW}$	$0{,}250\ \gamma_{W1} M_{WV}$	$0{,}625\ \gamma_{W1} M_{WH}$	$\gamma_{S1} Q_{SW}$	$0{,}250\ \gamma_{W1} Q_{WV}$
	"d"	$\gamma_{S1} M_{SW}$	$0{,}250\ \gamma_{W1} M_{WV}$	$0{,}625\ \gamma_{W1} M_{WH}$	$\gamma_{S1} Q_{SW}$	$0{,}250\ \gamma_{W1} Q_{WV}$
Note 1: Hull girder loads are to be calculated at the middle of the model.						

4.4 Additional requirements for the load assignment to beam models

4.4.1 Vertical and transverse concentrated loads are to be applied to the model, as shown in Fig 8, to compensate the portion of distributed loads which, due to the positioning of beams on their neutral axes, are not modelled.

In this figure, F_Y and F_Z represent concentrated loads equivalent to the dashed portion of the distributed loads which is not directly modelled.

Figure 8 : Concentrated loads equivalent to non-modelled distributed loads



5 Stress calculation

5.1 Analyses based on finite element models

5.1.1 Stresses induced by local and hull girder loads

When finite element models extend over at least three cargo tank/hold lengths, both local and hull girder loads are to be directly applied to the model, as specified in [4.3.1]. In this case, the stresses calculated by the finite element program include the contribution of both local and hull girder loads.

When finite element models extend over one cargo tank/hold length, only local loads are directly applied to the structural model, as specified in [4.3.2]. In this case, the stresses calculated by the finite element program include the contribution of local loads only. Hull girder stresses are to be calculated separately and added to the stresses induced by local loads.

5.1.2 Stress components

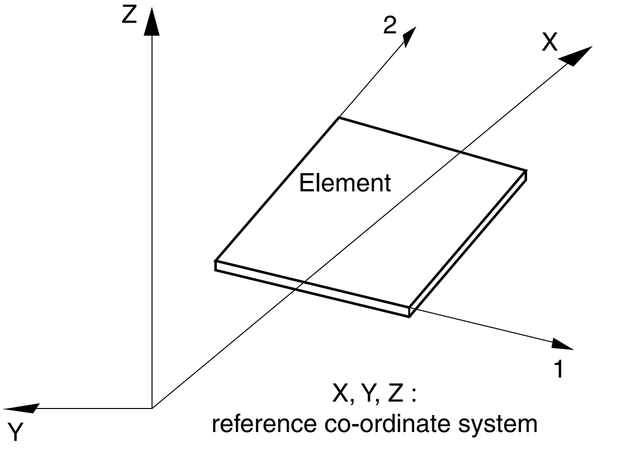
Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 9. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [4].

The following stress components are to be calculated at the centroid of the mid-plane layer of each element:

- the normal stresses σ_1 and σ_2 in the directions of the element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^{\,2} + \sigma_2^{\,2} - \sigma_1\sigma_2 + 3\tau_{12}^{\,2}}$$

Figure 9 : Reference and element co-ordinate systems



5.1.3 Stress calculation points

Stresses are generally calculated by the computer programs for each element. The values of these stresses are to be used for carrying out the checks required.

5.2 Analyses based on beam models

5.2.1 Stresses induced by local and hull girder loads

Since beam models generally extend over one cargo tank/hold length (see [2.3.1] and [3.2.3]), only local loads are directly applied to the structural model, as specified in [4.3.2]. Therefore, the stresses calculated by the beam program include the contribution of local loads only. Hull girder stresses are to be calculated separately and added to the stresses induced by local loads.

5.2.2 Stress components

The following stress components are to be calculated:

- the normal stress σ_1 in the direction of the beam axis
- the shear stress τ_{12} in the direction of the local loads applied to the beam
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^{\ 2} + 3\tau_{12}^{\ 2}}$$

5.2.3 Stress calculation points

Stresses are to be calculated at least in the following points of each primary supporting member:

- in the primary supporting member span where the maximum bending moment occurs
- at the connection of the primary supporting member with other structures, assuming as resistant section that formed by the member, the bracket (if any and if represented in the model) and the attached plating
- at the toe of the bracket (if any and if represented in the model) assuming as resistant section that formed by the member and the attached plating.

The values of the stresses are to be used for carrying out the checks required.

6 Buckling assessment based on standard mesh element model

6.1 Buckling panel properties

6.1.1 Yield stress

The buckling panel yield stress R_{eH} is taken as the minimum value of the elements yield stresses.

6.1.2 Thickness

In order to carry out the critical stresses according to Ch 7, Sec 1, [5.3], the net thickness of the buckling panel is to be obtained by deducting t_C from the gross thickness.

Where the thickness is not constant across a buckling panel defined by a number of finite plate elements, an equivalent average thickness is calculated according to the following formula:

$$t_{avr} = \frac{\sum_1^n A_i t_i}{\sum_1^n A_i}$$

where:

t_i : Thickness, in mm, of the element i

A_i : Area, in mm², of the element i.

6.2 Reference stresses

6.2.1 Where the buckling panel is meshed by several finite plate elements, the stresses of the buckling panel are obtained by the following methodology:

- For each finite element, the stresses ($\sigma_{x\ e}^*$, $\sigma_{y\ e}^*$, τ_e^*) expressed in the element co-ordinate system are projected in the co-ordinate system of the buckling panel to obtained the stresses ($\sigma_{x\,e}$, $\sigma_{y\,e}$, τ_e) (see Fig 10).
- For the buckling panel, the stresses are calculated according to the following formulae:

$$\sigma_x = \frac{\sum_i^n A_i \sigma_{x\,e_i}}{\sum_i^n A_i} \ge 0 \qquad \sigma_y = \frac{\sum_i^n A_i \sigma_{y\,e_i}}{\sum_i^n A_i} \ge 0$$

$$\tau = \frac{\sum_i^n A_i \tau_{e_i}}{\sum_i^n A_i} \ge 0$$

where:

$\sigma_{x\,ei}$, $\sigma_{y\,ei}$: Stresses, in N/mm², of the element i, taken equal to 0 in case of tensile stress

τ_{ei} : Shear stress, in N/mm², of the element i

A_i : Area, in mm², of the element i.

6.2.2 The edge stress ratio for the stresses (σ_x, σ_y) is equal to 1.

6.3 Checking criteria

6.3.1 The buckling check is to be carried out for four type of solicitations (see Fig 11 and Fig 12):

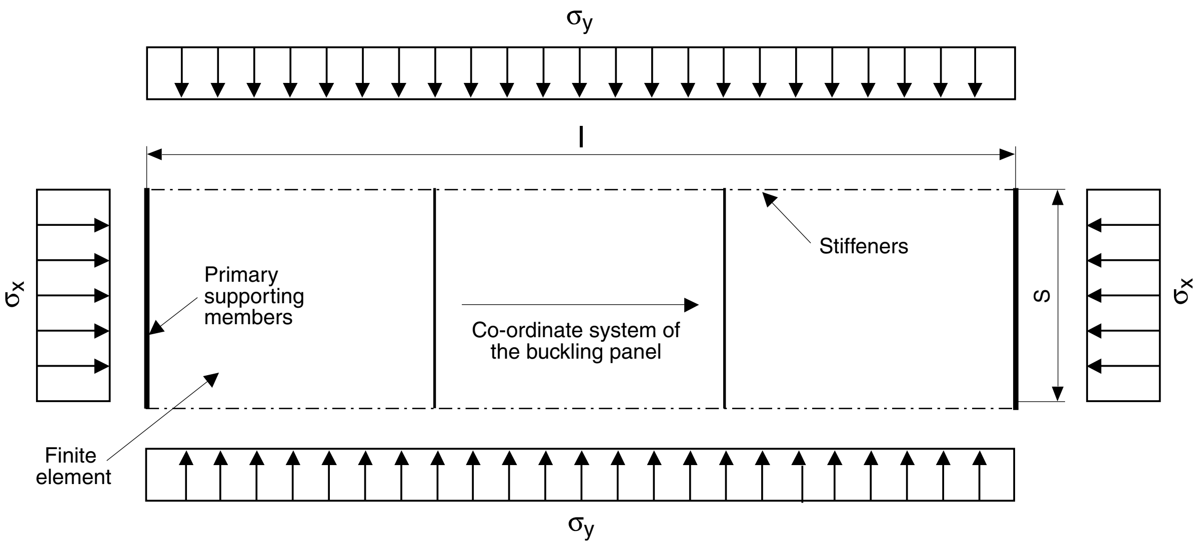
a) compression according to Ch 7, Sec 1, [5.4.2]

b) shear according to Ch 7, Sec 1, [5.4.3]

c) compression and shear according to Ch 7, Sec 1, [5.4.4]

d) bi-axial compression taking into account of shear stress according to Ch 7, Sec 1, [5.4.5].

Figure 10 : Definition of the buckling panel



7 Fatigue analysis

7.1 Elementary hot spot stress range calculation

7.1.1 General

The requirements of this Article apply for calculating the elementary hot spot stress range for the fatigue check of structural details at the connections of primary supporting members analysed through a three dimensional structural model. The fatigue check of these details is to be carried out in accordance with the general requirements of Ch 7, Sec 4, [1] to Ch 7, Sec 4, [5].

The definitions in Ch 7, Sec 4, [1.4] apply.

7.1.2 Net scantlings

The three dimensional structural model is to be built considering all the structures with their net scantlings according to Ch 4, Sec 2.

7.1.3 Hot spot stresses directly obtained through finite element analyses

Where the structural detail is analysed through a finite element analysis based on a fine mesh, the elementary hot spot stress range may be obtained as the difference between the maximum and minimum stresses induced by the wave loads in the hot spot considered.

The requirements for:

- the finite element modelling, and
- the calculation of the hot spot stresses and the hot spot stress range

are specified in [7.2].

7.1.4 Hot spot stresses directly obtained through the calculation of nominal stresses

Where the structural detail is analysed through a finite element analysis based on a mesh less fine than that in [7.1.3], the elementary hot spot stress range may be obtained by multiplying the nominal stress range, obtained as the difference between the maximum and minimum nominal stresses induced by the wave loads in the vicinity of the hot spot considered, by the appropriate stress concentration factors.

The requirements for:

- the finite element modelling
- the calculation of the nominal stresses and the nominal stress range
- the stress concentration factors
- the calculation of the hot spot stresses and the hot spot stress range

are specified in [7.3].

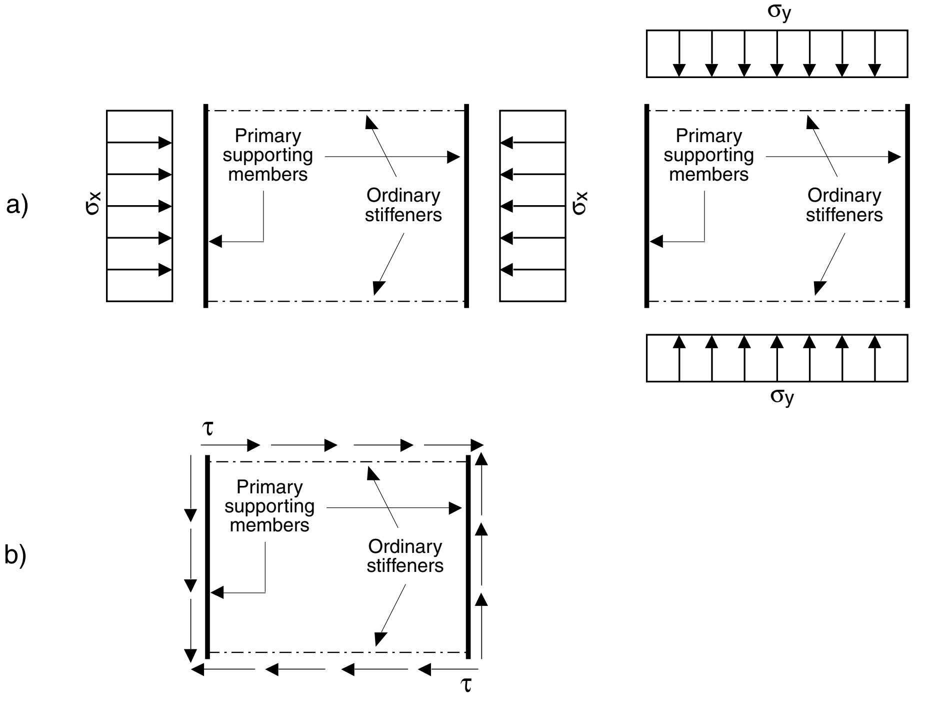
7.2 Hot spot stresses directly obtained through finite element analyses

7.2.1 Finite element model

In general, the determination of hot spot stresses necessitates carrying out a fine mesh finite element analysis, further to a coarser mesh finite element analysis. The boundary nodal displacements or forces obtained from the coarser mesh model are applied to the fine mesh model as boundary conditions.

The model extension is to be such as to enable a faithful representation of the stress gradient in the vicinity of the hot spot and to avoid it being incorrectly affected by the application of the boundary conditions.

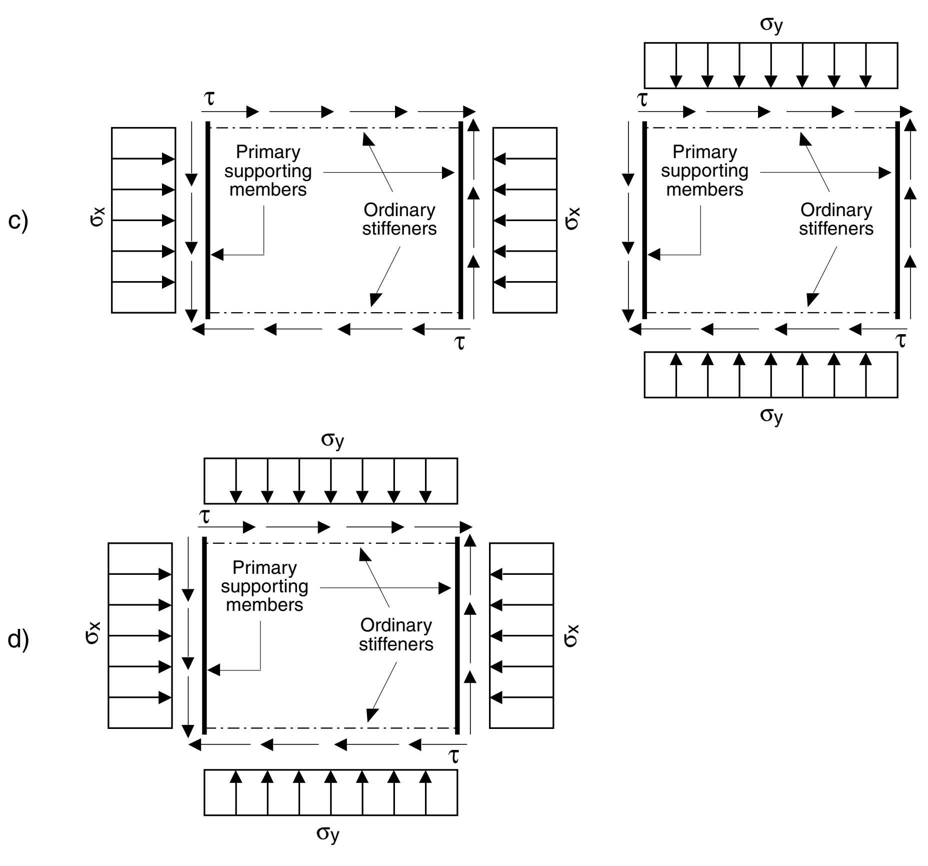
Figure 11 : Buckling check criteria: types a) and b)



Type a) : Compression according to Ch 7, Sec 1, [5.4.2]

Type b) : Shear according to Ch 7, Sec 1, [5.4.3]

Figure 12 : Buckling check criteria: types c) and d)



Type c): Compression and shear according to Ch 7, Sec 1, [5.4.4]

Type d): Bi-axial compression taking into account of shear stress according to Ch 7, Sec 1, [5.4.5]

7.2.2 Finite element modelling criteria

The finite element model is to be built according to the following requirements:

- the detail may be considered as being realised with no misalignment
- the size of finite elements located in the vicinity of the hot spot is to be about once to twice the thickness of the structural member. Where the details is the connection between two or more members of different thickness, the thickness to be considered is that of the thinnest member
- the centre of the first element adjacent to a weld toe is to be located between the weld toe and 0,4 times the thickness of the thinnest structural member connected by the weld
- plating, webs and face plates of primary and secondary members are to be modelled by 4-node thin shell or 8-node solid elements. In the case of a steep stress gradient, 8-node thin shell elements or 20-node solid elements are recommended
- when thin shell elements are used, the structure is to be modelled at mid-face of the plates
- the aspect ratio of elements is to be not greater than 2.

7.2.3 Calculation of hot spot stresses

When the detail is located at a structural discontinuity where a large stress gradient is expected the hot spot stresses are normally obtained by linear extrapolation. The stress components must be evaluated at a distance of 0,5 and 1,5 times the thickness of the plating from the weld toe and linearly extrapolated to the weld toe. The two evaluation points must be located in two different finite elements.

In other cases or when extrapolation can not be used the hot spot stresses are to be calculated at the centroid of the first element adjacent to the hot spot. The size of this element has to be determined according to the requirements in [7.2.2].

Where the detail is the free edge of an opening (e.g. a cut-out for the passage of an ordinary stiffener through a primary supporting member), the hot spot stresses have to be calculated at the free edge. The stresses can be obtained by linear extrapolation or using fictitious truss elements with minimal stiffness fitted along the edge.

The stress components to be considered are those specified in Ch 7, Sec 4, [4.1.2]. They are to be calculated at the surface of the plate in order to take into account the plate bending moment, where relevant.

7.2.4 Calculation of the elementary hot spot stress range

The elementary hot spot stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{S,ij} = |\sigma_{S,ij,max} - \sigma_{S,ij,min}|$$

where:

$\sigma_{S,ij,max}$, $\sigma_{S,ij,min}$: Maximum and minimum values of the hot spot stress, induced by the maximum and minimum loads, defined in Ch 7, Sec 4, [2.2] and Ch 7, Sec 4, [2.3]

i : Denotes the load case

j : Denotes the loading condition.

7.3 Hot spot stresses obtained through the calculation of nominal stresses

7.3.1 Finite element model

A finite element is to be adopted, to be built according to the requirements in [3.3] and [3.4]. The areas in the vicinity of the structural details are to be modelled with standard mesh models, as defined in [3.4.3].

7.3.2 Calculation of the elementary nominal stress range

The elementary nominal stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{n,ij} = |\sigma_{n,ij,max} - \sigma_{n,ij,min}|$$

where:

$\sigma_{n,ij,max}$, $\sigma_{n,ij,min}$: Maximum and minimum values of the nominal stress, induced by the maximum and minimum loads, defined in Ch 7, Sec 4, [2.2] and Ch 7, Sec 4, [2.3]

i : Denotes the load case

j : Denotes the loading condition.

7.3.3 Calculation of the elementary hot spot stress range

The elementary hot spot stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{S,ij} = K_S\, \Delta\sigma_{n,ij}$$

where:

K_S : Stress concentration factor, defined in Ch 11, Sec 2, [2], for the relevant detail configuration

$\Delta\sigma_{n,ij}$: Elementary nominal stress range, defined in [7.3.2].

APPENDIX 2 ANALYSES OF PRIMARY SUPPORTING MEMBERS SUBJECTED TO WHEELED LOADS

1 General

1.1 Scope

1.1.1 The requirements of this Appendix apply to the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members subjected to wheeled loads which are to be analysed through three dimensional structural models, according to Ch 7, Sec 3.

1.1.2 The purpose of these structural analyses is to determine:

- the distribution of the forces induced by the vertical acceleration acting on wheeled cargoes, among the various primary supporting members of decks, sides and possible bulkheads
- the behaviour of the above primary supporting members under the racking effects due to the transverse forces induced by the transverse acceleration acting on wheeled cargoes, when the number or location of transverse bulkheads are not sufficient to avoid such effects,

and to calculate the stresses in primary supporting members.

The above calculated stresses are to be used in the yielding and buckling checks.

In addition, the results of these analyses may be used, where deemed necessary by the Society, to determine the boundary conditions for finer mesh analyses of the most highly stressed areas.

1.1.3 When the behaviour of primary supporting members under the racking effects, due to the transverse forces induced by the transverse acceleration, is not to be determined, the stresses in deck primary supporting members may be calculated according to the simplified analysis in [6], provided that the conditions for its application are fulfilled (see [6.1]).

1.1.4 The yielding and buckling checks of primary supporting members are to be carried out according to Ch 7, Sec 3, [4.4].

1.2 Application

1.2.1 The requirements of this Appendix apply to ships whose structural arrangement is such that the following assumptions may be considered as being applicable:

- primary supporting members of side and possible bulkheads may be considered fixed in way of the double bottom (this is generally the case when the stiffness of floors is at least three times that of the side primary supporting members)
- under transverse inertial forces, decks behave as beams loaded in their plane and supported at the ship ends; their effect on the ship transverse rings (side primary supporting members and deck beams) may therefore be simulated by means of elastic supports in the transverse direction or transverse displacements assigned at the central point of each deck beam.

1.2.2 When the assumptions in [1.2.1] are considered by the Society as not being applicable, the analysis criteria are defined on a case by case basis, taking into account the ship's structural arrangement and loading conditions. In such cases, the analysis is generally to be carried out on the basis of a finite element model of the whole ship, built according to the requirements in Ch 7, App 1, as far as applicable.

1.3 Information required

1.3.1 To perform these structural analyses, the following characteristics of vehicles loaded are necessary:

- load per axle
- arrangement of wheels on axles
- tyre dimensions.

1.4 Lashing of vehicles

1.4.1 The presence of lashing for vehicles is generally to be disregarded, but may be given consideration by the Society, on a case by case basis, at the request of the interested parties.

2 Analysis criteria

2.1 Finite element model analyses

2.1.1 For ships greater than 170 m in length, finite element models, built according to Ch 7, App 1, [3.4] or Ch 7, App 3, [2], are to be adopted in accordance with Ch 7, Sec 3, Tab 1.

The analysis of primary supporting members is to be carried out on standard mesh models, as defined in Ch 7, App 1, [3.4.3].

2.1.2 Areas which appear, from the primary supporting member analysis, to be highly stressed may be required to be further analysed through appropriately meshed structural models, as defined in Ch 7, App 1, [3.4.4].

2.2 Beam model analyses

2.2.1 For ships less than 170 m in length, beam models, built according to Ch 7, App 1, [3.5], may be adopted in lieu of the finite element models in [2.1], provided that:

- primary supporting members are not so stout that the beam theory is deemed inapplicable by the Society
- their behaviour is not substantially influenced by the transmission of shear stresses through the shell plating.

2.2.2 In any case, finite element models may need to be adopted when deemed necessary by the Society on the basis of the ship's structural arrangement.

3 Primary supporting members structural modelling

3.1 Model construction

3.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected. In particular, the following primary supporting members are to be included in the model:

- deck beams
- side primary supporting members
- primary supporting members of longitudinal and transverse bulkheads, if any
- pillars
- deck beams, deck girders and pillars supporting ramps and deck openings, if any.

3.1.2 Net scantlings

All the elements in [3.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2, [1].

3.2 Model extension

3.2.1 The structural model is to represent a hull portion which includes the zone under examination and which is repeated along the hull. The non-modelled hull parts are to be considered through boundary conditions as specified in [3.3].

In addition, the longitudinal extension of the structural model is to be such that the results in the areas to be analysed are not influenced by the unavoidable inaccuracy in the modelling of the boundary conditions.

3.2.2 Double bottom structures are not required to be included in the model, based on the assumptions in [1.2.1].

3.3 Boundary conditions of the three dimensional model

3.3.1 Boundary conditions at the lower ends of the model

The lower ends of the model (i.e. the lower ends of primary supporting members of side and possible bulkheads) are to be considered as being clamped in way of the inner bottom.

3.3.2 Boundary conditions at the fore and aft ends of the model

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 1.

Table 1 : Symmetry conditions at the model fore and aft ends

DISPLACEMENTS in directions (1):			ROTATION around axes (1):		
X	Y	Z	X	Y	Z
fixed	free	free	free	fixed	fixed
(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [4].					

3.3.3 Additional boundary conditions at the fore and aft ends of models subjected to transverse loads

When the model is subjected to transverse loads, i.e. when the loads in inclined ship conditions (as defined in Ch 5, Sec 4) are applied to the model, the transverse displacements of the deck beams are to be obtained by means of a racking analysis and applied at the fore and aft ends of the model, in way of each deck beam.

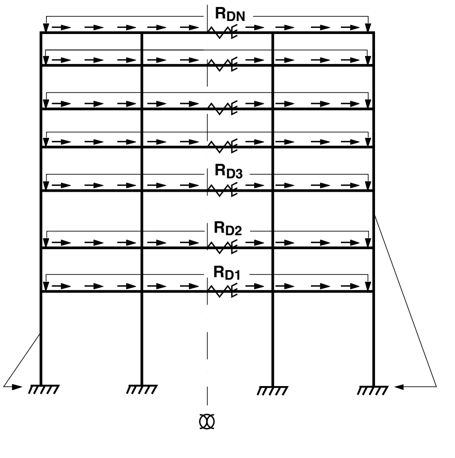
For ships with a traditional arrangement of fore and aft parts, a simplified approximation may be adopted, when deemed acceptable by the Society, defining the boundary conditions without taking into account the racking calculation and introducing springs, acting in the transverse direction, at the fore and aft ends of the model, in way of each deck beam (see Fig 1). Each spring, which simulates the effects of the deck in way of which it is modelled, has a stiffness obtained, in kN/m, from the following formula:

$$R_D = \frac{24EJ_Ds_a10^3}{2x^4 - 4L_Dx^3 + L_D^2\left(x^2 + 15{,}6\frac{J_D}{A_D}\right) + L_D^3x}$$

where:

J_D : Net moment of inertia, in m^4, of the average cross-section of the deck, with the attached side shell plating

Figure 1 : Springs at the fore and aft ends of models subjected to transverse loads



A_D : Net area, in m², of the average cross-section of deck plating

s_a : Spacing of side vertical primary supporting members, in m

x : Longitudinal distance, in m, measured from the transverse section at mid-length of the model to any deck end

L_D : Length of the deck, in m, to be taken equal to the ship's length. Special cases in which such value may be reduced will be considered by the Society on a case by case basis.

4 Load model

4.1 General

4.1.1 Hull girder and local loads

Only local loads are to be directly applied to the structural model.

The stresses induced by hull girder loads are to be calculated separately and added to the stresses induced by local loads.

4.1.2 Loading conditions and load cases: wheeled cargoes

The still water and wave loads are to be calculated for the most severe loading conditions as given in the loading manual, with a view to maximising the stresses in primary supporting members.

The loads transmitted by vehicles are to be applied taking into account the most severe axle positions for the ship structures.

The wave local loads and hull girder loads are to be calculated in the mutually exclusive load cases "b" and "d" in Ch 5, Sec 4. Load cases "a" and "c" may be disregarded for the purposes of the structural analyses dealt with in this Appendix.

4.1.3 Loading conditions and load cases: dry uniform cargoes

When the ship's decks are also designed to carry dry uniform cargoes, the loading conditions which envisage the transportation of such cargoes are also to be considered. The still water and wave loads induced by these cargoes are to be calculated for the most severe loading conditions, with a view to maximising the stresses in primary supporting members.

The wave local loads and hull girder loads are to be calculated in the mutually exclusive load cases "b" and "d" in Ch 5, Sec 4. Load cases "a" and "c" may be disregarded for the purposes of the structural analyses dealt with in this Appendix.

4.2 Local loads

4.2.1 General

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water forces induced by wheeled cargoes, defined in Ch 5, Sec 6, Tab 8.

Wave induced loads include:

- the wave pressure, defined in Ch 5, Sec 5, [2] for load cases "b" and "d"
- the inertial forces defined in Ch 5, Sec 6, Tab 8 for load cases "b" and "d".

When the ship's decks are also designed to carry dry uniform cargoes, local loads also include the still water and inertial pressures defined in Ch 5, Sec 6, [4]. Inertial pressures are to be calculated for load cases "b" and "d".

4.2.2 Tyred vehicles

For the purpose of primary supporting members analyses, the forces transmitted through the tyres may be considered as concentrated loads in the tyre print centre.

The forces acting on primary supporting members are to be determined taking into account the area of influence of each member and the way ordinary stiffeners transfer the forces transmitted through the tyres.

4.2.3 Non-tyred vehicles

The requirements in [4.2.2] also apply to tracked vehicles. In this case, the print to be considered is that below each wheel or wheelwork.

For vehicles on rails, the loads transmitted are to be applied as concentrated loads.

4.2.4 Distributed loads

In the analyses carried out on the basis of beam models or membrane finite element models, the loads distributed perpendicularly to the plating panels are to be applied on the primary supporting members proportionally to their areas of influence.

4.3 Hull girder loads

4.3.1 The normal stresses induced by the hull girder loads in Tab 2 are to be added to the stresses induced in the primary supporting members by local loads.

Table 2 : Hull girder loads

Ship condition	Load case	Vertical bending moments at the middle of the model		Horizontal wave bending moment at the middle of the model
		Still water	Wave	
Upright	"b"	M_{SW}	0,625 F_D $M_{WV,S}$	0
Inclined	"d"	M_{SW}	0,25 M_{WV}	0,625 M_{WH}

Note 1:

M_{SW} : Still water bending moment at the middle of the model, for the loading condition considered

$M_{WV,S}$: Sagging wave bending moments at the middle of the model, defined in Ch 5, Sec 2

M_{WV} : Wave bending moment at the middle of the model, defined in Ch 5, Sec 2, having the same sign as M_{SW}

M_{WH} : Horizontal wave bending moment at the middle of the model, defined in Ch 5, Sec 2.

5 Stress calculation

5.1 Stresses induced by local and hull girder loads

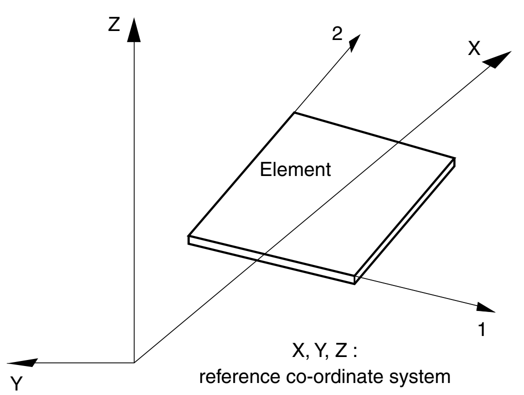
5.1.1 Only local loads are directly applied to the structural model, as specified in [4.1.1]. Therefore, the stresses calculated by the program include the contribution of local loads only. Hull girder stresses are to be calculated separately and added to the stresses induced by local loads.

5.2 Analyses based on finite element models

5.2.1 Stress components

Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 2. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [4].

Figure 2 : Reference and element co-ordinate systems



The following stress components are to be calculated at the centroid of each element:

- the normal stresses σ_1 and σ_2 in the directions of element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

5.2.2 Stress calculation points

Stresses are generally calculated by the computer programs for each element. The values of these stresses are to be used for carrying out the checks required.

5.3 Analyses based on beam models

5.3.1 Stress components

The following stress components are to be calculated:

- the normal stress σ_1 in the direction of the beam axis
- the shear stress τ_{12} in the direction of the local loads applied to the beam
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + 3\tau_{12}^2}$$

5.3.2 Stress calculation points

Stresses are to be calculated at least in the following points of each primary supporting member:

- in the primary supporting member span where the maximum bending moment occurs
- at the connection of the primary supporting member with other structures, assuming as resistant section that formed by the member, the bracket (if any and if represented in the model) and the attached plating
- at the toe of the bracket (if any and if represented in the model) assuming as resistant section that formed by the member and the attached plating.

The values of the stresses calculated in the above points are to be used for carrying out the checks required.

6 Grillage analysis of primary supporting members of decks

6.1 Application

6.1.1 For the sole purpose of calculating the stresses in deck primary supporting members, due to the forces induced by the vertical accelerations acting on wheeled cargoes, these members may be subjected to the simplified two dimensional analysis described in [6.2].

This analysis is generally considered as being acceptable for usual structural typology, where there are neither pillar lines, nor longitudinal bulkheads.

6.2 Analysis criteria

6.2.1 Structural model

The structural model used to represent the deck primary supporting members is a beam grillage model.

6.2.2 Model extension

The structural model is to represent a hull portion which includes the zone under examination and which is repeated along the hull. The non-modelled hull parts are to be considered through boundary conditions as specified in [3.3].

6.3 Boundary conditions

6.3.1 Boundary conditions at the fore and aft ends of the model

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 1.

6.3.2 Boundary conditions at the connections of deck beams with side vertical primary supporting members

Vertical supports are to be fitted at the nodes positioned in way of the connection of deck beams with side primary supporting members.

The contribution of flexural stiffness supplied by the side primary supporting members to the deck beams is to be simulated by springs, applied at their connections, having rotational stiffness, in the plane of the deck beam webs, obtained, in kN.m/rad, from the following formulae:

- for intermediate decks:

$$R_F = \frac{3E(J_1 + J_2)(\ell_1 + \ell_2)}{\ell_1^2 + \ell_2^2 - \ell_1 \ell_2} 10^{-5}$$

- for the uppermost deck:

$$R_F = \frac{6EJ_1}{\ell_1} 10^{-5}$$

where:

ℓ_1, ℓ_2 : Height, in m, of the 'tweendecks, respectively below and above the deck under examination (see Fig 3)

J_1, J_2 : Net moments of inertia, in cm^4, of side primary supporting members with attached shell plating, relevant to the 'tweendecks, respectively below and above the deck under examination.

6.4 Load model

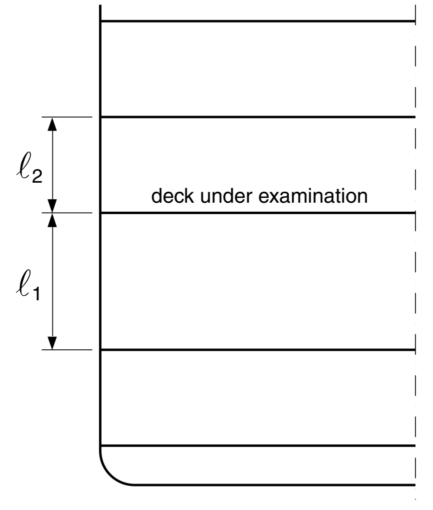
6.4.1 Hull girder and local loads are to be calculated and applied to the model according to [4].

Wave loads are to be calculated considering load case "b" only.

6.5 Stress calculation

6.5.1 Stress components are to be calculated according to [5.1] and [5.3].

Figure 3 : Heights of 'tweendecks for grillage analysis of deck primary supporting members



APPENDIX 3 ANALYSES BASED ON COMPLETE SHIP MODELS

Symbols

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

Δ : Moulded displacement in seawater, in t

B : Moulded breadth, in m

L : Rule length, in m

T_R : Roll period, in s, defined in Ch 5, Sec 3, [2.4.1]

F : Froude's number, defined in Part B, Chapter 5, calculated at the maximum service speed

γ_{S1}, γ_{W1}, γ_{S2}, γ_{W2} : Partial safety factors defined in Ch 7, Sec 3

λ : Wave length, in m.

1 General

1.1 Application

1.1.1 The requirements of this Appendix apply for the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members which are to be analysed through a complete ship model, according to Ch 7, Sec 3.

1.1.2 This Appendix deals with that part of the structural analysis which aims at calculating the stresses in the primary supporting members and also in the hull plating, to be used for yielding and buckling checks.

1.1.3 The yielding and buckling checks of primary supporting members are to be carried out according to Ch 7, Sec 3.

2 Structural modelling

2.1 Model construction

2.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected.

Ordinary stiffeners are also to be represented in the model in order to reproduce the stiffness and the inertia of the actual hull girder structure.

2.1.2 Net scantlings

All the elements in [2.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2. Therefore, also the hull girder stiffness and inertia to be reproduced by the model are those obtained by considering the net scantlings of the hull structures.

2.2 Model extension

2.2.1 The complete ship is to be modelled so that the coupling between torsion and horizontal bending is properly taken into account in the structural analysis.

Superstructures are to be modelled in order to reproduce the correct lightweight distribution.

Long superstructures of ships with one of the service notations **passenger ship** or **ro-ro passenger ship** are to be modelled in order to also reproduce the correct hull global strength, in particular the contribution of each superstructure deck to the hull girder longitudinal strength.

2.2.2 In the case of structural symmetry with respect to the ship's centreline longitudinal plane, the hull structures may be modelled over half the ship's breadth.

2.3 Finite element modelling criteria

2.3.1 Modelling of primary supporting members

The analyses of primary supporting members are to be based on standard mesh models, as defined in Ch 7, App 1, [3.4.3].

Such analyses may be carried out deriving the nodal displacements or forces, to be used as boundary conditions, from analyses of the complete ship based on coarse meshes, as defined in Ch 7, App 1, [3.4.2].

The areas for which analyses based on standard mesh models are to be carried out are listed in Tab 1 for various types of ships.

Other areas may be required to be analysed through standard mesh models, where deemed necessary by the Society, depending on the ship's structural arrangement and loading conditions as well as the results of the coarse mesh analysis.

2.3.2 Modelling of the most highly stressed areas

The areas which appear from the analyses based on standard mesh models to be highly stressed may be required to be further analysed, using the mesh accuracy specified in Ch 7, App 1, [3.4.4].

Table 1 : Areas to be analysed through standard mesh models

Service notation	Areas
ro-ro cargo ship PCT Carrier	• typical reinforced transverse rings • typical deck girders • areas of structural discontinuity (e.g. ramp areas).
passenger ship	• areas in way of typical side and deck openings • areas of significant discontinuity in primary supporting member arrangements (e.g. in way of lounges, large public spaces, theatres).
ro-ro passenger ship	• typical reinforced transverse rings • typical deck girders • areas of structural discontinuity (e.g. ramp areas) • areas in way of typical side and deck openings • areas of significant discontinuity in primary supporting member arrangements (e.g. in way of lounges, large public spaces).

2.4 Finite element models

2.4.1 General

Finite element models are generally to be based on linear assumptions. The mesh is to be executed using membrane or shell elements, with or without mid-side nodes.

Meshing is to be carried out following uniformity criteria among the different elements.

In general, for some of the most common elements, the quadrilateral elements are to be such that the ratio between the longer side length and the shorter side length does not exceed 4 and, in any case, is less than 2 for most elements. Their angles are to be greater than 60° and less than 120°. The triangular element angles are to be greater than 30° and less than 120°.

Further modelling criteria depend on the accuracy level of the mesh, as specified in [2.4.2] to [2.4.4].

2.4.2 Coarse mesh

The number of nodes and elements is to be such that the stiffness and the inertia of the model represent properly those of the actual hull girder structure, and the distribution of loads among the various load carrying members is correctly taken into account.

To this end, the structural model is to be built on the basis of the following criteria:

- ordinary stiffeners contributing to the hull girder longitudinal strength and which are not individually represented in the model are to be modelled by rod elements and grouped at regular intervals
- webs of primary supporting members may be modelled with only one element on their height
- face plates may be simulated with bars having the same cross-section
- the plating between two primary supporting members may be modelled with one element stripe
- holes for the passage of ordinary stiffeners or small pipes may be disregarded
- manholes (and similar discontinuities) in the webs of primary supporting members may be disregarded, but the element thickness is to be reduced in proportion to the hole height and the web height ratio.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

2.4.3 Standard mesh

The standard mesh for the ship’s structure corresponds to a model where each longitudinal secondary stiffener is modelled; as a consequence, the standard size of finite elements used is based on the spacing of ordinary stiffeners.

The structural model is to be built on the basis of the following criteria:

- webs of primary members are to be modelled with at least three elements on their height
- the plating between two primary supporting members is to be modelled with at least two element stripes
- the ratio between the longer side and the shorter side of elements is to be less than 3 in the areas expected to be highly stressed
- holes for the passage of ordinary stiffeners may be disregarded.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

2.4.4 Mesh for the analysis of structural details

The structural modelling is to be accurate; the mesh dimensions are to be such as to enable a faithful representation of the stress gradients. The use of membrane elements is only allowed when significant bending effects are not present; in other cases, elements with bending behaviour are to be used.

2.5 Boundary conditions of the model

2.5.1 In order to prevent rigid body motions of the overall model, the constraints specified in Tab 2 are to be applied.

2.5.2 When the hull structure is modelled over half the ship's breadth (see [2.2.2]), in way of the ship’s centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Tab 3 are to be applied, depending on the loads applied to the model (respectively symmetrical or anti-symmetrical).

Table 2 : Boundary conditions to prevent rigid body motion of the model

Boundary conditions	DISPLACEMENTS in directions (1)		
	X	Y	Z
One node on the fore end of the ship	free	fixed	fixed
One node on the port side shell at aft end of the ship (2)	fixed	free	fixed
One node on the starboard side shell at aft end of the ship (2)	free	fixed	fixed

Boundary conditions	ROTATION around axes (1)		
	X	Y	Z
One node on the fore end of the ship	free	free	free
One node on the port side shell at aft end of the ship (2)	free	free	free
One node on the starboard side shell at aft end of the ship (2)	free	free	free

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [4].
(2) The nodes on the port side shell and that on the starboard side shell are to be symmetrical with respect to the ship's longitudinal plane of symmetry.

Table 3 : Symmetry and anti-symmetry conditions in way of the ship's centreline longitudinal plane

Boundary conditions	DISPLACEMENTS in directions (1)		
	X	Y	Z
Symmetry	free	fixed	free
Anti-symmetry	fixed	free	fixed

Boundary conditions	ROTATION around axes (1)		
	X	Y	Z
Symmetry	fixed	free	fixed
Anti-symmetry	free	fixed	free

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [4].

3 Load model

3.1 General

3.1.1 Design wave method

The various load components which occur simultaneously may be combined by setting the characteristics of regular waves that maximise the dominant load parameters given in Part B, Chapter 5.

Any other method may be used provided that relevant documentation is submitted to the Society for review.

A recommended procedure to compute the characteristics of the design wave is provided in [3.2].

3.1.2 Loads

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave loads, determined by mean of hydrodynamic calculations according to [3.2], include:

- the wave pressure
- the inertial loads.

3.1.3 Lightweight

The lightweight of the ship is to be distributed over the model length, in order to obtain the actual longitudinal distribution of the still water bending moment.

3.1.4 Models extended over half ship's breadth

When the ship is symmetrical with respect to her centreline longitudinal plane and the hull structure is modelled over half the ship's breadth, non-symmetrical loads are to be broken down into symmetrical and anti-symmetrical loads and applied separately to the model with symmetry and anti-symmetry boundary conditions in way of the ship's centreline longitudinal plane (see [2.5.2]).

3.2 Procedure for the selection of design waves

3.2.1 Summary of the loading procedure

Applicable cargo loading conditions given in Part D or Part E are analysed through:

- the computation of the characteristics of the finite element model under still water loads (see [3.3.1])
- the selection of the load cases critical for the strength of the resistant structural members (see [3.3.2]).

The determination of the design wave characteristics for each load case includes the following steps:

- computation of the response operators (amplitude and phase) of the dominant load effect
- selection of the wave length and heading according to the guidelines in [3.3]
- determination of the wave phase such that the dominant load effect reaches its maximum
- computation of the wave amplitude corresponding to the design value of the dominant load effect.

3.2.2 Dominant load effects

Each critical load case maximises the value of one of the nine following load effects having a dominant influence on the strength of some parts of the structure:

- vertical wave bending moment in hogging condition at midship section
- vertical wave bending moment in sagging condition at midship section
- vertical wave shear force on transverse bulkheads
- horizontal wave bending moment at midship section
- wave torque within cargo area of ships with large deck openings
- vertical acceleration in midship and fore body sections

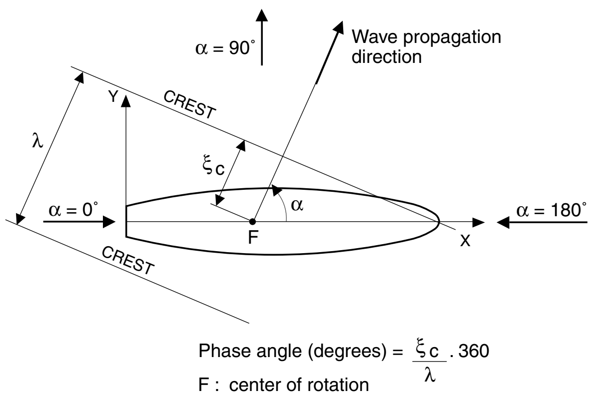
- transverse acceleration at deck at sides at midship section
- wave pressure at bottom at centreline in upright ship condition, at midship section
- wave pressure at bottom at side in inclined ship condition, at midship section.

3.2.3 Response Amplitude Operators

The Response Amplitude Operators (RAO's) and associated phase characteristics are to be computed for wave periods between 4 and 22 seconds, using a seakeeping program, for the following motions and load effects:

- heave, sway, pitch, roll and yaw motions
- vertical wave bending moment at 0,50L or at the longitudinal position where the bending moment RAO is maximum
- vertical wave shear force at 0,25L and 0,50L
- horizontal wave bending moment at 0,50L
- wave torque at 0,25L, 0,50L and 0,75L (for ships with large deck openings).

Figure 1 : Wave heading



The response amplitude operators are to be calculated for wave headings ranging from following seas (0 degree) to head seas (180 degrees) by increment of 15 degrees, using a ship speed of 60% of the maximum service speed.

The amplitude and phase of other dominant load effects may be computed at relevant wave period, using the RAO's listed above.

3.2.4 Design waves

For each load case, the ship is considered to encounter a regular wave, defined by its parameters:

- wave length λ or period T
- heading angle α (see Fig 1)
- wave height (double amplitude)
- wave phase (see Fig 1).

The wave length λ and the wave period T are linked by the following relation:

$\lambda = g\,T^2/\,2\,\pi$

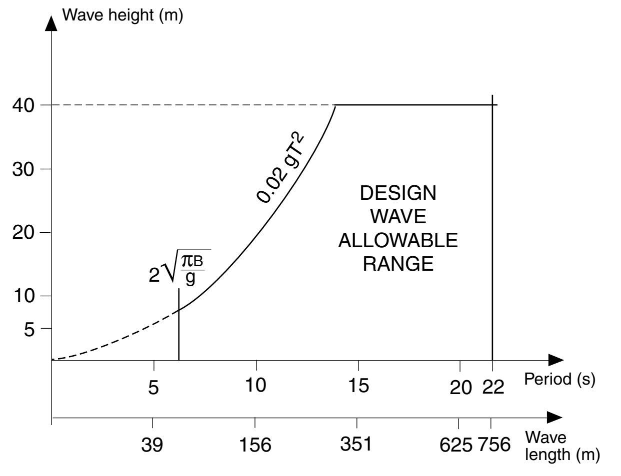
The range of variation of design wave period is between T1 and 22 seconds, where T1 is equal to:

$$T1 = 2\sqrt{\frac{\pi B}{g}}$$

The possible wave height H, in m, is limited by the maximum wave steepness according to the relation (see Fig 2):

$H = 0{,}02\ g\ T^2$

Figure 2 : Allowable range of design waves



3.2.5 Design wave amplitude

The amplitude of the design wave is obtained by dividing the design value of the dominant load effect by the value of the response amplitude operator of this effect computed for the relevant heading and wave length.

The design values of load effect, heading and wave length are given for each load case in [3.3.2].

When positioning the finite element model of the ship on the design wave, the amplitude of the wave is to be corrected to obtain the design value of the dominant load effect in order to take into account the non linear effects due to the hull shape and to the pressure distribution above the mean water line given in [3.2.7].

The design wave phase is the phase of the dominant load effect.

3.2.6 Combined load cases

For the wave characteristics and crest position selected according to [3.2.5], the value of the wave-induced motions, accelerations and other load effects is obtained by the following formula:

$E_i = RAO_i\ a\cos(\varphi_d - \varphi_i)$

where:

E_i	:	Value of amplitude of the load component i
RAO_i	:	Response amplitude operator of the load component i computed for the design heading and wave length
a	:	Design wave amplitude
φ_d	:	Phase of the dominant load effect
φ_i	:	Phase of the load component i.

As a rule, the amplitude of the load components computed above are not to exceed their rule reference value by a factor C_{max} given in Tab 4.

Table 4 : Values of factor C_{max}

Load component	C_{max}
Wave bending moments and wave torque (see Ch 5, Sec 2, [3])	1,10
Wave shear forces (see Ch 5, Sec 2, [3])	1,40
Roll angle, vertical and horizontal accelerations (see Ch 5, Sec 3, [2])	1,10
Wave pressure (see Ch 7, App 1, [4.2.2])	1,20

3.2.7 Finite element model loading

The loads are applied to the finite element model according to the following indications:

a) for fatigue analysis of structural members located in the vicinity of the mean waterline, the sum of the wave and hydrostatic parts of the pressure is zero above the deformed wave profile and varies linearly between the mean waterline and the wave crest levels

b) the fluid pressure in tanks is affected by the change of direction of the total acceleration vector defined in Ch 5, Sec 6, [1.1.3]

c) for dry unit cargoes, the inertial forces are computed at the centre of mass, taking into account the mass moment of inertia

d) inertial loads for structure weight and dry uniform cargo are computed using local accelerations calculated at their location.

3.2.8 Equilibrium check

The finite element model is to be in equilibrium condition with all the still water and wave loads applied.

The unbalanced forces in the three axes are not to exceed 2% of the displacement.

The unbalanced moments are not to exceed 2% of Δ.B around y and z axes and 0,2% of Δ.B around x axis.

3.3 Load cases

3.3.1 Hydrostatic calculation

For each cargo loading condition given in the relevant chapter of Part E, the longitudinal distribution of still water shear force and bending moment is to be computed and checked by reference to the approved loading manual (see Ch 10, Sec 2).

The convergence of the displacement, trim and vertical bending moment is deemed satisfactory if within the following tolerances:

- 2% of the displacement
- 0,1 degrees of the trim angle
- 10% of the still water bending moment.

3.3.2 Value of load effects

The wave length and heading which maximise each dominant load effect are specified in Tab 5. Where two values of heading angle are indicated in the table, the angle which corresponds to the highest peak value of the load effect's RAO is to be considered. The wave length and heading may have to be adjusted in order to fulfil the requirements given in [3.3.2].

The design value of dominant load effects is specified in Tab 6.

4 Stress calculation

4.1 Stress components

4.1.1 Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 3. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [4].

The following stress components are to be calculated at the centroid of each element:

- the normal stresses σ_1 and σ_2 in the directions of element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \sigma_2 + 3\tau_{12}^2}$$

Figure 3 : Reference and element co-ordinate systems

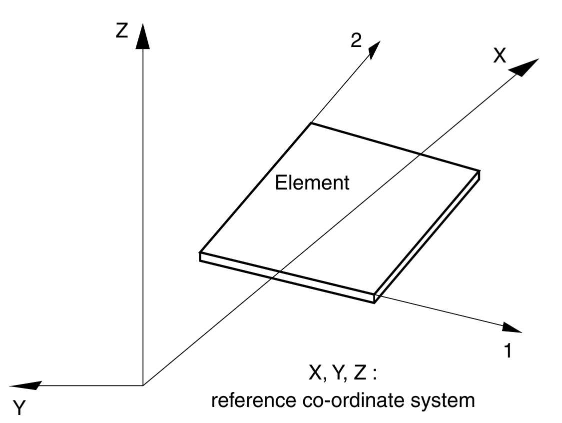


Table 5 : Load cases and load effect values

Load case	Dominant load effect	Wave parameters (1) λ	Wave parameters (1) Heading angle	Location(s)	Notes
1	Vertical wave bending moment in hogging condition	peak value of vertical wave bending moment RAO without being less than 0,9L	180°	Midship section	
2	Vertical wave bending moment in sagging condition	same as load case 1	180°	Midship section	
3	Vertical wave shear force	peak value of vertical wave shear force RAO: at 0,5L for 0,35L < x < 0,65L at 0,25L elsewhere	0° or 180°	Each transverse bulkhead	
4	Horizontal wave bending moment	peak value of horizontal wave bending moment RAO or 0,5L	120° or 135°	Midship section	Select the heading such that the value of C_{max} for vertical wave bending moment is not exceeded
5	Wave torque	peak value of wave torque RAO or 0,5L	60° or 75°	Vicinity of 0,25 L Midship section	Select the heading such that the value of C_{max} for vertical wave bending moment is not exceeded
6	Wave torque	peak value of wave torque RAO within the allowable range	90°	Midship section	Wave amplitude may have to be limited such that the value of C_{max} for transverse acceleration and vertical relative motion at sides are not exceeded
7	Wave torque	same as load case 5	105° or 120 °	Vicinity of 0,75 L Midship section	Select the heading such that the value of C_{max} for vertical wave bending moment is not exceeded
8	Vertical acceleration in inclined ship condition	$\lambda = \frac{12,3 C_\beta \Delta}{B L C_W}$ where: C_β = 1,0 for 90° heading 1,15 for 105° heading C_W : Waterplane coefficient at load waterline	90° or 105°	Midship section	
9	Vertical acceleration in upright ship condition	$\lambda = 1,6\ L\ (0,575 + 0,8\ F)^2$	180°	From forward end of cargo area to F.P.	
10	Transverse acceleration	$\lambda = 1,35\ g\ T_R^2 / (2\pi)$ without being taken greater than 756 m	90°	Midship section	
11	Wave pressure at bottom at centreline in upright ship condition	0,7 L	180° or 0°	Midship section	λ may have to be increased to keep the wave steepness below wave breaking limit
12	Wave pressure at bottom at side in inclined ship condition	$\lambda = 0,35\ g\ T_R^2 / (2\pi)$ without being taken less than 2,0B	90°	Midship section	

(1) The forward ship speed is to be taken equal to 0,6 V.

Table 6 : Dominant load effect values

Dominant load effect	Design value	Combined load components	References
Vertical wave bending moment in hogging condition	0,625 γ_{W1} $M_{WV,H}$	–	$M_{WV,H}$ defined in Ch 5, Sec 2, [3.1.1]
Vertical wave bending moment in sagging condition	0,625 γ_{W1} F_D $M_{WV,S}$		$M_{WV,S}$ defined in Ch 5, Sec 2, [3.1.1] F_D defined in Ch 5, Sec 2, [4.2.1]
Vertical wave shear force	0,625 γ_{W1} Q_{WV}	–	Q_{WV} defined in Ch 5, Sec 2, [3.4]
Horizontal wave bending moment	0,625 γ_{W1} M_{WH}	–	M_{WH} defined in Ch 5, Sec 2, [3.2.1]
Wave torque **(1)**	0,625 γ_{W1} M_{WT}	Horizontal wave bending moment	M_T defined in Ch 5, Sec 2, [3.3]
Vertical acceleration at centreline in upright ship condition	γ_{W2} a_{Z1}	Vertical relative motion at sides at F.E.	a_{Z1} defined in Ch 5, Sec 3, [3.4.1]
Vertical acceleration at deck at sides in inclined ship condition	γ_{W2} a_{Z2}	–	a_{Z2} defined in Ch 5, Sec 3, [3.4.1]
Transverse acceleration at deck at sides	γ_{W2} a_{Y2}	Roll angle	a_{Y2} defined in Ch 5, Sec 3, [3.4.1]
Wave pressure at bottom at centreline in upright ship condition	γ_{W2} p_W	Vertical wave bending moment at midship	p_W defined in Ch 7, App 1, Tab 3 for case “a”
Wave pressure at bottom at side in inclined ship condition	γ_{W2} p_W	–	p_W defined in Ch 7, App 1, Tab 4 for case “c”

(1) This load effect is to be considered for ships with large deck openings only.

Part B
Hull and Stability

Chapter 8
OTHER STRUCTURES

Symbols used in this Chapter

L_1, L_2 : Lengths, in m, defined in Pt B, Ch 1, Sec 2, [2.1.1]

n : Navigation coefficient, defined in Pt B, Ch 5, Sec 1, [2.6]

h_1 : Reference value of the ship relative motion, defined in Pt B, Ch 5, Sec 3, [3.3]

a_{Z1} : Reference value of the vertical acceleration, defined in Pt B, Ch 5, Sec 3, [3.4]

ρ : Sea water density, in t/m^3

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

g : Gravity acceleration, in m/s^2:

$g = 9,81\ m/s^2$

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [4]

k : Material factor, defined in:
- Pt B, Ch 4, Sec 1, [2.3], for steel
- Pt B, Ch 4, Sec 1, [4.4], for aluminium alloys

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

R_{eH} : Minimum yield stress, in N/mm^2, of the material, defined in Pt B, Ch 4, Sec 1, [2]

R_m : Minimum ultimate tensile strength, in N/mm^2, of the material, defined in Pt B, Ch 4, Sec 1, [2].

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

  $E = 2,06.10^5\ N/mm^2$
- for stainless steels:

  $E = 1,95.10^5\ N/mm^2$
- for aluminium alloys:

  $E = 7,0.10^4\ N/mm^2$

SECTION 1 FORE PART

Symbols

p_S, p_W : Still water pressure and wave pressure defined in [2.3]

p_{BI} : Bottom impact pressure, defined in [3.2]

p_{FI} : Bow impact pressure, defined in [4.2]

s : Spacing, in m, of ordinary stiffeners or primary supporting members, as applicable

ℓ : Span, in m, of ordinary stiffeners or primary supporting members, as applicable

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:

$c_r = 1 - 0{,}5\ s / r$

to be taken not less than 0,5

r : Radius of curvature, in m

β_b, β_s : Coefficients defined in Ch 7, Sec 2, [3.4.2]

λ_b, λ_s : Coefficients defined in Ch 7, Sec 2, [3.4.3]

c_E : Coefficient to be taken equal to:

$c_E = 1$ for $L \le 65$ m

$c_E = 3 - L / 32{,}5$ for $65\text{ m} < L < 90$ m

$c_E = 0$ for $L \ge 90$ m

c_F : Coefficient to be taken equal to:

$c_F = 0{,}9$ for forecastle sides

$c_F = 1{,}0$ in other cases

m : Boundary coefficient, to be taken equal to:

- m = 12 in general, for stiffeners considered as clamped
- m = 8 for stiffeners considered as simply supported
- other values of m may be considered, on a case by case basis, for other boundary conditions.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantling of structures located forward of the collision bulkhead, i.e.:

- fore peak structures
- stems.

In addition, it includes:

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

1.1.2 Fore peak structures which form vertical watertight boundary between two compartments 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 Part B, Chapter 7.

1.2 Connections of the fore part with structures located aft of the collision bulkhead

1.2.1 Tapering

Adequate tapering is to be ensured between the scantlings in the fore part and those aft of the collision bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

1.2.2 Supports of fore peak structures

Aft of the collision bulkhead, side girders are to be fitted as specified in Ch 4, Sec 5, [3.2] or Ch 4, Sec 5, [5.3], as applicable.

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section, with the exception of those indicated in [5], are net, i.e. they do not include any margin for corrosion.

Gross scantlings are obtained as specified in Ch 4, Sec 2.

2 Fore peak

2.1 Partial safety factors

2.1.1 The partial safety factors to be considered for checking fore peak structures are specified in Tab 1.

Table 1 : Fore peak structures - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors			
	Symbol	Plating	Ordinary stiffeners	Primary supporting members **(1)**
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave induced pressure	γ_{W2}	1,20	1,20	1,20
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	1,20	1,40	1,60

(1) For primary supporting members analysed through complete ship models, the partials safety factors defined in Ch 7, Sec 3, [1.4] are to be considered.

2.1.2 The partial safety factors to be considered for testing of fore peak structures are specified in Tab 2.

Table 2 : Fore peak structures Partial safety factors for testing

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbols	Plating	Ordinary stiffeners
Still water pressure	γ_{S2}	1,00	1,00
Wave induced pressure	γ_{W2}	N.A.	N.A.
Material	γ_m	1,02	1,02
Resistance	γ_R	1,05	1,20

2.2 Load point

2.2.1 Unless otherwise specified, lateral pressure is to be calculated at:

- the lower edge of the elementary plate panel considered, for plating
- mid-span, for stiffeners.

Table 3 : Still water and wave pressures

Location	Still water sea pressure p_S, in kN/m²	Wave pressure p_W, in kN/m²
Bottom and side below the waterline: $z \le T$	$\rho\, g\, (T - z)$	$\rho g h_1 e^{\frac{-2\pi(T-z)}{L}}$
Side above the waterline: $z > T$	0	$\rho\, g\, (T + h_1 - z)$ without being taken less than 0,15 L
Exposed deck	Pressure due to the load carried **(1)**	$19{,}6 n \varphi_1 \varphi_2 \sqrt{H}$

(1) The pressure due to the load carried is to be defined by the Designer and, in any case, it may not be taken less than 10 φ_1 φ_2 kN/m², where φ_1 and φ_2 are defined hereafter.
The Society may accept pressure values lower than 10 φ_1 φ_2 kN/m² when considered appropriate on the basis of the intended use of the deck.

Note 1:

φ_1 : Coefficient defined in Tab 4

φ_2 : Coefficient taken equal to:
- $\varphi_2 = 1$ if $L \ge 120$ m
- $\varphi_2 = L/120$ if $L < 120$ m

$$H = \left[2{,}66\left(\frac{x}{L} - 0{,}7\right)^2 + 0{,}14\right]\sqrt{\frac{VL}{C_B}} - (z - T)$$

without being taken less than 0,8

V : Maximum ahead service speed, in knots, to be taken not less than 13 knots.

2.3 Load model

2.3.1 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 Tab 3
- the still water internal pressure due to liquids or ballast, defined in Tab 5
- the still water internal pressure due to dry uniform cargoes on deck, defined in Tab 6.

Wave pressure (p_W) includes:

- the wave pressure, defined in Tab 3
- the inertial internal pressure due to liquids or ballast, defined in Tab 5
- the inertial internal pressure due to dry uniform cargoes on deck, defined in Tab 6.

Table 4 : Coefficient for pressure on exposed decks

Exposed deck location	φ_1
Freeboard deck	1,00
Top of lowest tier	0,75
Top of second tier	0,56
Top of third tier	0,42
Top of fourth tier	0,32
Top of fifth tier	0,25
Top of sixth tier	0,20
Top of seventh tier	0,15
Top of eighth tier and above	0,10

Table 5 : Still water and inertial internal pressures due to liquids

Still water pressure p_S in kN/m²	Inertial pressure p_W in kN/m²
$\rho_L\, g\, (z_L - z)$	$\rho_L\, a_{Z1}\, (z_{TOP} - z)$

Note 1:

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank

z_L : Z co-ordinate, in m, of the highest point of the liquid: $z_L = z_{TOP} + 0{,}5\,(z_{AP} - z_{TOP})$

z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}.

Table 6 : Still water and inertial internal pressures due to dry uniform cargoes

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
The value of p_S is, in general, defined by the Designer; in any case it may not be taken less than 10 kN/m². When the value of p_S is not defined by the Designer, it may be taken, in kN/m², equal to 6,9 h_{TD}, where h_{TD} is the compartment 'tweendeck height at side, in m.	$p_S \dfrac{a_{Z1}}{g}$

2.3.2 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 pressures, 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.

2.3.3 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.

2.3.4 Lateral pressure in testing conditions

The lateral pressure in testing conditions, p_T, in kN/m^2, is taken equal to:

- $p_{ST} - p_S$ for bottom shell plating and side shell plating
- p_{ST} otherwise

where:

p_{ST} : Still water pressure defined in Ch 5, Sec 6, Tab 13

p_S : Still water sea pressure defined in Tab 3 and calculated for the draught T_1 at which the testing is carried out.

If the draught T_1 is not defined by the Designer, it may be taken equal to the light ballast draught T_B defined in Ch 5, Sec 1, [2.4.3].

2.4 Longitudinally framed bottom

2.4.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 7 and the minimum values in the same Table.

2.4.2 Floors

Floors are to be fitted at every four frame spacing and generally spaced no more than 2,5 m apart.

The floor dimensions and scantlings are to be not less than those specified in Tab 8.

In no case may the above scantlings be lower than those of the corresponding side transverses, as defined in [2.6.2].

2.4.3 Centre girder

Where no centreline bulkhead is fitted (see [2.10]), a centre bottom girder having the same dimensions and scantlings required in [2.4.2] for floors is to be provided.

The centre bottom girder is to be connected to the collision bulkhead by means of a large end bracket.

2.4.4 Side girders

Side girders, having the same dimensions and scantlings required in [2.4.2] for floors, are generally to be fitted every two longitudinals, in line with bottom longitudinals located aft of the collision bulkhead. Their extension is to be compatible in each case with the shape of the bottom.

2.5 Transversely framed bottom

2.5.1 Plating

The net scantling of plating is to be not less than the value obtained from the formulae in Tab 7 and the minimum values in the same table.

Table 7 : Scantling of bottom plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \dfrac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda R_y}}$	Net minimum thickness, in mm **(1)**: in general: $t = c_F (0{,}03\,L + 5{,}5)\,k^{1/2} - c_E$ for inner bottom: $t = 2 + 0{,}017\,L\,k^{1/2} + 4{,}5\,s$
Ordinary stiffeners	Net section modulus, in cm^3: $w = \gamma_R \gamma_m \beta_b \dfrac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})}\left(1 - \dfrac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the net thickness of the attached plating.
	Net shear sectional area, in cm^2: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}\left(1 - \dfrac{s}{2\ell}\right) s \ell$	

(1) L need not be taken greater than 300 m.

Note 1:

σ_{X1} : Hull girder normal stress, taken equal to:
- the value defined in Ch 7, Sec 2, [3.3.7], for stiffeners contributing to the hull girder longitudinal strength
- $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal strength

λ : Coefficient taken equal to:
- for longitudinally framed bottom: $\lambda = \lambda_L$, defined in Ch 7, Sec 1, [3.3.1]
- for transversely framed bottom: $\lambda = \lambda_T$, defined in Ch 7, Sec 1, [3.4.1].

Table 8 : Longitudinally framed bottom Floor dimensions and scantlings

Dimension or scantling	Specified value
Web height, in m	h_M = 0,085 D + 0,15
Web net thickness, in mm	To be not less than that required for double bottom floors aft of the collision bulkhead; in any case, it may be taken not greater than 10 mm.
Floor face plate net sectional area, in cm²	A_P = 3,15 D
Floor face plate net thickness, in mm	t_P = 0,4 D + 5 may be assumed not greater than 14 mm.

2.5.2 Floors

Solid floors are to be fitted at every frame spacing.

The solid floor dimensions and scantlings are to be not less than those specified in Tab 9.

Table 9 : Transversely framed bottom Floor dimensions and scantlings

Dimension or scantling	Specified value
Web height, in m	h_M = 0,085 D + 0,15
Web net thickness, in mm	To be not less than that required for double bottom floors aft of the collision bulkhead; in any case, it may be taken not greater than 10 mm.
Floor face plate net sectional area, in cm²	A_P = 1,67 D

2.5.3 Centre girder

Where no centreline bulkhead is fitted (see [2.10]), a centre bottom girder is to be fitted according to [2.4.3].

2.6 Longitudinally framed side

2.6.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 10 and the minimum values in the same table.

2.6.2 Side transverses

Side transverses are to be located in way of bottom transverse and are to extend to the upper deck. Their ends are to be amply faired in way of bottom and deck transverses.

Their net section modulus w, in cm³, and net shear sectional area A_{Sh}, in cm², are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

2.7 Transversely framed side

2.7.1 Plating and ordinary stiffeners (side frames)

Side frames fitted at every frame space are to have the same vertical extension as the collision bulkhead.

The net scantlings of plating and side frames are to be not less than the values obtained from the formulae in Tab 10 and the minimum values in the table.

The value of the side frame section modulus is generally to be maintained for the full extension of the side frame.

Table 10 : Scantling of side plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda R_y}}$	Net minimum thickness, in mm **(1)**: $t = c_F (0{,}03 L + 5{,}5) k^{1/2} - c_E$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m (R_y - \gamma_R \gamma_m \sigma_{X1})} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the net thickness of the attached plating
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$	

(1) L need not be taken greater than 300 m.

Note 1:

σ_{X1} : Hull girder normal stress, taken equal to:
- the value defined in Ch 7, Sec 2, [3.3.7], for stiffeners contributing to the hull girder longitudinal strength
- σ_{X1} = 0, for stiffeners not contributing to the hull girder longitudinal strength

λ : Coefficient taken equal to:
- for longitudinally framed side: $\lambda = \lambda_L$, defined in Ch 7, Sec 1, [3.3.1]
- for transversely framed side: $\lambda = \lambda_T$, defined in Ch 7, Sec 1, [3.4.1].

2.7.2 Side girders

Depending on the hull body shape and structure aft of the collision bulkhead, one or more adequately spaced side girders per side are to be fitted.

Their net section modulus w, in cm^3, and net shear sectional area A_{Sh}, in cm^2, are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

Moreover, the depth b_A, in mm, and the net thickness t_A, in mm, of the side girder web are generally to be not less than the values obtained from the following formulae:

$b_A = 2,5\ (180 + L)$

$t_A = (6 + 0,018\ L)\ k^{1/2}$

2.7.3 Panting structures

In order to withstand the panting loads, horizontal structures are to be provided. These structures are to be fitted at a spacing generally not exceeding 2 m and consist of side girders supported by panting beams or side transverses whose ends are connected to deck transverses, located under the tank top, so as to form a strengthened ring structure.

Panting beams, which generally consist of sections having the greater side vertically arranged, are to be fitted every two frames.

2.7.4 Connection between panting beams, side frames and side girders

Each panting beam is to be connected to the side frames by means of brackets whose arms are generally to be not less than twice the panting beam depth.

2.7.5 Connection between side frames and side girders

Side frames not supporting panting beams are to be connected to side girders by means of brackets having the same thickness as that of the side girder and arms which are to be not less than one half of the depth of the side girder.

2.7.6 Panting beam scantlings

The net area A_B , in cm^2, and the net inertia J_B , in cm^4, of the panting beam section are to be not less than the values obtained from the following formulae:

$A_B = 0,5\ L - 18$

$J_B = 0,34\ (0,5\ L - 18)\ b_B^2$

where:

b_B : Beam length, in m, measured between the internal edges of side girders or the internal edge of the side girder and any effective central or lateral support.

Where side girder spacing is other than 2 m, the values A_B and J_B are to be modified according to the relation between the actual spacing and 2 m.

2.7.7 Panting beams of considerable length

Panting beams of considerable length are generally to be supported at the centreline by a wash bulkhead or pillars arranged both horizontally and vertically.

2.7.8 Non-tight platforms

Non-tight platforms may be fitted in lieu of side girders and panting beams. Their openings and scantlings are to be in accordance with [2.9.1].

Their spacing is to be not greater than 2,5 m.

If the peak exceeds 10 m in depth, a non-tight platform is to be arranged at approximately mid-depth.

Table 11 : Scantling of deck plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda R_y}}$	Net minimum thickness, in mm **(1)**: $t = 2,1 + 0,013\ L\ k^{1/2} + 4,5\ s$
Ordinary stiffeners	Net section modulus, in cm^3: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1,5\ L_2^{1/3}\ k^{1/6}$ • the net thickness of the attached plating.
	Net shear sectional area, in cm^2: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$	

(1) L need not be taken greater than 300 m.

Note 1:

σ_{X1} : Hull girder normal stress, taken equal to:
- the value defined in Ch 7, Sec 2, [3.3.7] , for stiffeners contributing to the hull girder longitudinal strength
- $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal strength

λ : Coefficient taken equal to:
- for longitudinally framed deck: $\lambda = \lambda_L$, defined in Ch 7, Sec 1, [3.3.1]
- for transversely framed deck: $\lambda = \lambda_T$, defined in Ch 7, Sec 1, [3.4.1]
- for deck not contributing to the hull girder longitudinal strength: $\lambda = 1$

2.7.9 Additional transverse bulkheads

Where the peak exceeds 10 m in length and the frames are supported by panting beams or non-tight platforms, additional transverse wash bulkheads or side transverses are to be fitted.

2.8 Decks

2.8.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 11 and the minimum values in the same Table.

2.8.2 Primary supporting members

Scantlings of primary supporting members are to be in accordance with Ch 7, Sec 3, considering the loads in [2.3].

2.9 Platforms

2.9.1 Non-tight platforms

Non-tight platforms located inside the peak are to be provided with openings having a total area not less than 10% of that of the platforms. Moreover, the thickness of the plating and the section modulus of ordinary stiffeners are to be not less than those required in [2.10] for the non-tight central longitudinal bulkhead.

The number and depth of non-tight platforms within the peak is considered by the Society on a case by case basis.

The platforms may be replaced by equivalent horizontal structures whose scantlings are to be supported by direct calculations.

2.9.2 Platform transverses

The net sectional area of platform transverses, calculated considering a width of attached plating whose net sectional area is equal to that of the transverse flange, is to be not less than the value obtained, in cm^2, from the following formula:

$$A = 10\gamma_R\gamma_m\frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{C_PR_y}d_Sh_S$$

where:

- p_S, p_W : Still water pressure and wave pressure, defined in Tab 3, acting at the ends of the platform transverse in the direction of its axis
- d_S : Half of the longitudinal distance, in m, between the two transverses longitudinally adjacent to that under consideration
- h_S : Half of the vertical distance, in m, between the two transverses vertically adjacent to that under consideration
- C_P : Coefficient, to be taken equal to:

  $C_P = 1$ for $\frac{d_P}{r_P} \le 70$

  $C_P = 1{,}7 - 0{,}01\frac{d_P}{r_P}$ for $70 < \frac{d_P}{r_P} \le 140$

  When $d_P / r_P > 140$, the scantlings of the struts are considered by the Society on a case by case basis
- d_P : Distance, in cm, from the face plate of the side transverse and that of the bulkhead vertical web, connected by the strut, measured at the level of the platform transverse
- r_P : Radius of gyration of the strut, to be obtained, in cm, from the following formula:

  $$r_P = \sqrt{\frac{J}{A_E}}$$
- J : Minimum net moment of inertia, in cm^4, of the strut considered
- A_E : Actual net sectional area, in cm^2, of the transverse section of the strut considered.

2.9.3 Breasthooks

Breasthooks are to have the same thickness of that required for platforms. They are to be arranged on the stem, in way of every side longitudinal, or at equivalent spacing in the case of transverse framing, extending aft for a length equal to approximately twice the breasthook spacing.

2.10 Central longitudinal bulkhead

2.10.1 General

Except for dry peaks, a centreline longitudinal wash bulkhead may be required in liquid compartments for which there is a risk of resonance in the transverse direction.

2.10.2 Extension

In the case of a bulbous bow, such bulkhead is generally to extend for the whole length and depth of the fore peak.

Where hull structures are flared, such as those situated above the bulb and in the fore part of the peak, the bulkhead may be locally omitted.

Similarly, the extension of the bulkhead may be limited for bows without a bulb, depending on the shape of the hull. However, the bulkhead is to be fitted in the higher part of the peak.

2.10.3 Plating thickness

The net plating thickness of the lower part of the longitudinal bulkhead over a height at least equal to h_M defined in [2.4.2] is to be not less than that required for the centre girder in [2.4.3].

Elsewhere, the net thickness of the longitudinal bulkhead plating is to be not less than the value obtained, in mm, from the following formula:

$$t = 6{,}5 + 0{,}013\ L_1$$

2.10.4 Ordinary stiffeners

The net section modulus of ordinary stiffeners is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 3{,}5\ s\ \ell^2\ k\ (z_{TOP} - z_M)$$

where:

- z_{TOP} : Z co-ordinate, in m, of the highest point of the tank
- z_M : Z co-ordinate, in m, of the stiffener mid-span.

2.10.5 Primary supporting members

Vertical and longitudinal primary supporting members, to be made preferably with symmetrical type sections, are to have a section modulus not less than 50% of that required for the corresponding side transverse or side girder.

The vertical and longitudinal webs are to be provided with adequate fairing end brackets and to be securely connected to the struts, if any.

2.10.6 Openings

Bulkhead openings are to be limited in the zone corresponding to the centre girder to approximately 2% of the total area of the bulkhead, and, in the zone above, to not less than 10% of the total area of the bulkhead. Openings are to be located such as to affect as little as possible the plating sections adjacent to primary supporting members.

2.11 Bulbous bow

2.11.1 General

Where a bulbous bow is fitted, fore peak structures are to effectively support the bulb and are to be adequately connected to its structures.

2.11.2 Shell plating

The thickness of the shell plating of the fore end of the bulb and the first strake above the keel is generally to be not less than that required in [5.2.1] for plate stems. This thickness is to be extended to the bulbous zone, which, depending on its shape, may be damaged by anchors and chains during handling.

2.11.3 Connection with the fore peak

Fore peak structures are to be extended inside the bulb as far as permitted by the size and shape of the latter.

2.11.4 Horizontal diaphragms

At the fore end of the bulb, the structure is generally to be supported by means of horizontal diaphragms, spaced not more than 1 m apart, and a centreline vertical diaphragm.

2.11.5 Longitudinal stiffeners

Bottom and side longitudinals are to extend inside the bulb, forward of the fore end by at least 30% of the bulb length measured from the perpendicular to the fore end of the bulb.

The fore end of longitudinals is to be located in way of a reinforced transverse ring; forward of such ring, longitudinals are to be replaced by ordinary transverse rings.

2.11.6 Floors

Solid floors are to be part of reinforced transverse rings generally arranged not more than 3 frame spaces apart.

2.11.7 Breasthooks

Breasthooks, to be placed in line with longitudinals, are to be extended on sides aft of the stem, so as to form longitudinal side girders.

2.11.8 Longitudinal centreline wash bulkhead

For a bulb of considerable width, a longitudinal centreline wash bulkhead may be required by the Society in certain cases.

2.11.9 Transverse wash bulkhead

In way of a long bulb, transverse wash bulkheads or side transverses of adequate strength arranged not more than 5 frame spaces apart may be required by the Society in certain cases.

3 Reinforcements of the flat bottom forward area

3.1 Area to be reinforced

3.1.1 In addition to the requirements in [2], the structures of the flat bottom forward area are to be able to sustain the dynamic pressures due to the bottom impact. The flat bottom forward area is:

- longitudinally, over the bottom located between ξL and 0,05L aft of the fore end, where the coefficient ξ is obtained from the following formula:

  $\xi = 0,25\ (1,6 - C_B)$

  without being taken less than 0,2 or greater than 0,25
- transversely, over the whole flat bottom and the adjacent zones up to a height, from the base line, not less than 2L, in mm. In any case, it is not necessary that such height is greater than 300 mm.

Note 1: The requirements of this article [3] are not applicable to ships having the navigation notation **sheltered area**.

Note 2: For ships having the navigation notation **coastal area**, a reduction of 20% may be applied on the bottom impact pressure on a case by case basis.

3.1.2 The bottom impact pressure is to be considered if:

$T_F < 0,04L$

where T_F is the minimum forward draught, in m, among those foreseen in operation in ballast conditions or conditions of partial loading.

3.1.3 The value of the minimum forward draught T_F adopted for the calculations is to be specified in the loading manual.

3.1.4 An alternative arrangement and extension of strengthening with respect to the above may also be required where the minimum forward draught exceeds 0,04 L, depending on the shape of the forward hull body and the ship's length and service speed.

3.2 Bottom impact pressure

3.2.1 The bottom impact pressure p_{BI} is to be obtained, in kN/m^2, from the following formula:

$p_{BI} = 62\ C_1\ C_{SL}\ L^{0,6}$ if $L \le 135$

$p_{BI} = (1510 - 2,5\ L)\ C_1\ C_{SL}$ if $L > 135$

where:

C_1 : Coefficient defined as follows:

- general case:

$$C_1 = \frac{119 - 2300\frac{T_F}{L}}{78 + 1800\frac{T_F}{L}}$$

without being taken greater than 1,0

- for non-propelled units:

$$C_1 = \frac{119 - 2300\frac{T_F}{L}}{156 + 3600\frac{T_F}{L}} + 0,09$$

without being taken greater than 0,59

T_F : Draught defined in [3.1.2]

C_{SL} : Longitudinal distribution factor, taken equal to:

$C_{SL} = 0$ for $x \le x_1$

$C_{SL} = \frac{x - x_1}{x_2 - x_1}$ for $x_1 < x < x_2$

$C_{SL} = 1$ for $x \ge x_2$

$$x_1 = \left(0,55 + \frac{L}{2000}\right)L$$

$$x_2 = \left(0,35 + 0,5C_B + \frac{L}{3000}\right)L \text{ with } 0,6 \le C_B \le 0,85$$

3.3 Scantlings

3.3.1 Plating

The net thickness t, in mm, of the hull envelope plating is to be not less than the value obtained from the formula given in Ch 7, Sec 1, [3.6.1].

3.3.2 Ordinary stiffeners

The net plastic section modulus Z_{pl}, in cm³, as defined in Ch 4, Sec 3, [3.4.3] and the net web thickness t_w, in mm, of longitudinal or transverse ordinary stiffeners are not to be less than the values obtained from the formulae given in Ch 7, Sec 2, [3.10.1].

3.3.3 Primary supporting members

The net section modulus w, in cm³, of primary supporting members and their net shear area A_{sh}, in cm², at any position along their span are not to be less than the values obtained from the formulae given in Ch 7, Sec 3, [6.1.1].

3.3.4 Tapering

Outside the flat bottom forward area, scantlings are to be gradually tapered so as to reach the values required for the areas considered.

3.4 Arrangement of primary supporting members and ordinary stiffeners: longitudinally framed bottom

3.4.1 The requirements in [3.4.2] to [3.4.4] apply to the structures of the flat bottom forward area, defined in [3.1], in addition to the requirements of [2.4].

3.4.2 Bottom longitudinals and side girders, if any, are to extend as far forward as practicable, and their spacing may not exceed that adopted aft of the collision bulkhead.

3.4.3 The spacing of solid floors in a single or double bottom is to be not greater than either that required for the midship section in Ch 4, Sec 4 or (1,35 + 0,007 L) m, whichever is the lesser.

However, where the minimum forward draught T_F is less than 0,02 L, the spacing of floors forward of 0,2 L from the stem is to be not greater than (0,9 + 0,0045 L) m.

3.4.4 The Society may require adequately spaced side girders having a depth equal to that of the floors. As an alternative to the above, girders with increased scantlings may be fitted.

3.5 Arrangement of primary supporting members and ordinary stiffeners: transversely framed double bottom

3.5.1 The requirements in [3.5.2] to [3.5.3] apply to the structures of the flat bottom forward area, defined in [3.1], in addition to the requirements of [2.5].

3.5.2 Solid floors are to be fitted:

- at every second frame between 0,75L and 0,8L from the aft end
- at every frame space forward of 0,8L from the aft end.

3.5.3 Side girders with a depth equal to that of the floors are to be fitted at a spacing generally not exceeding 2,4 m. In addition, the Society may require intermediate half height girders, half the depth of the side girders, or other equivalent stiffeners.

4 Reinforcements of the bow flare area

4.1 Area to be reinforced

4.1.1 In addition to the requirements in [2], the structures of the bow flare area are to be able to sustain the dynamic pressures due to the bow impact pressure.

4.1.2 The bow area to be reinforced is that extending forward of 0,9 L from the aft end of L and above the summer load waterline up to the level at which a knuckle with an angle greater than 15° is located on the side shell.

4.2 Bow impact pressure

4.2.1 The bow impact pressure p_{FI} is to be obtained, in kN/m², from the following formula:

$$p_{FI} = nC_S C_L C_Z (0,22 + 0,15\tan\alpha)(0,4V\sin\beta + 0,6\sqrt{L})^2$$

where:

C_S : Coefficient depending on the type of structures on which the bow impact pressure is considered to be acting:

- $C_S = 1,8$ for plating and ordinary stiffeners
- $C_S = 0,5$ for primary supporting members

C_L : Coefficient depending on the ship's length:

- $C_L = 0,0125\ L$ for $L < 80$ m
- $C_L = 1,0$ for $L \geq 80$ m

C_Z : Coefficient depending on the distance between the summer load waterline and the calculation point:

- $C_Z = C - 0,5\ (z - T)$ for $z \geq 2\ C + T - 11$
- $C_Z = 5,5$ for $z < 2\ C + T - 11$

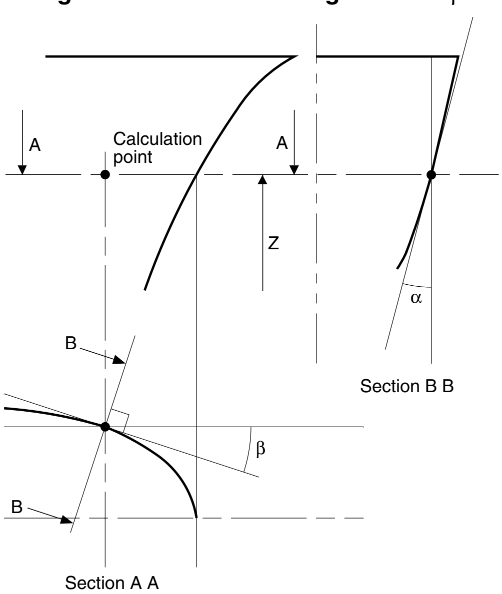
C : Wave parameter, defined in Ch 5, Sec 2

α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the side plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 1)

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 1).

Other values of bow impact pressure may be considered by the Society on a case-by-case basis, provided that they are documented through model tests or full scale measurements.

Figure 1 : Definition of angles α and β



4.3 Scantlings

4.3.1 Plating

The net thickness t, in mm, of the hull envelope plating is to be not less than the value obtained from the formula given in Ch 7, Sec 1, [3.6.1].

4.3.2 Ordinary stiffeners

The net plastic section modulus Z_{pl} , in cm^3, as defined in Ch 4, Sec 3, [3.4.3] and the net web thickness t_w , in mm, of longitudinal or transverse ordinary stiffeners are not to be less than the values obtained from the formulae given in Ch 7, Sec 2, [3.10.1].

4.3.3 Primary supporting members

The net section modulus w, in cm^3, of primary supporting members and their net shear area A_{sh} , in cm^2, at any position along their span are not to be less than the values obtained from the formulae given in Ch 7, Sec 3, [6.1.1].

4.3.4 Tapering

Outside the bow flare area, scantlings are to be gradually tapered so as to reach the values required for the areas considered.

4.3.5 Intercostal stiffeners

Intercostal stiffeners are to be fitted at mid-span where the angle between the stiffeners and the attached plate is less than 70°.

5 Stems

5.1 General

5.1.1 Arrangement

Adequate continuity of strength is to be ensured at the connection of stems to the surrounding structure.

Abrupt changes in sections are to be avoided.

5.1.2 Gross scantlings

With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in [5.2] and [5.3] are gross, i.e. they include the margins for corrosion.

5.2 Plate stems

5.2.1 Where the stem is constructed of shaped plates, the gross thickness of the plates below the load waterline is to be not less than the value obtained, in mm, from the following formula:

$$t_S = 1,37(0,95 + \sqrt{L_3})\sqrt{k}$$

where:

L_3 : Ship's length L, in m, but to be taken not greater than 300.

Above the load waterline this thickness may be gradually tapered towards the stem head, where it is to be not less than that required for side plating at ends.

5.2.2 The expanded width of the stem is not to be less than the rule breadth of the plate keel, defined in Ch 4, Sec 4, [1.3.1].

5.2.3 The plating forming the stems is to be supported by horizontal diaphragms spaced not more than 1200 mm apart and connected, as far as practicable, to the adjacent frames and side stringers.

5.2.4 If considered necessary, and particularly where the stem radius is large, a centreline stiffener or web of suitable scantlings is to be fitted.

5.3 Bar stems

5.3.1 The gross area of bar stems constructed of forged or rolled steel is to be not less than the value obtained, in cm^2, from the following formulae:

$$A_P = \left(0{,}40 + \frac{10T}{L}\right)(0{,}009L^2 + 20)\sqrt{k} \quad \text{for } L \le 90$$

$$A_P = \left(0{,}40 + \frac{10T}{L}\right)(1{,}8L - 69)\sqrt{k} \quad \text{for } 90 < L \le 200$$

where the ratio T/L in the above formulae is to be taken not less than 0,05 or greater than 0,075.

5.3.2 The gross thickness t_B of the bar stem is to be not less than the value obtained, in mm, from the following formula:

$$t_B = (0{,}4L + 13)\sqrt{k}$$

5.3.3 The cross-sectional area of the stem may be gradually tapered from the load waterline to the upper end, where it may be equal to the two thirds of the value as calculated above.

5.3.4 The lower part of the stem may be constructed of cast steel subject to the examination by the Society; where necessary, a vertical web is to be fitted for welding of the centre keelson.

5.3.5 Welding of the bar stem with the bar keel and the shell plating is to be in accordance with Ch 11, Sec 1, [3.5].

6 Transverse thrusters

6.1 Scantlings of the thruster tunnel and connection with the hull

6.1.1 The thickness of the tunnel is to be not less than that of the adjacent hull plating.

6.1.2 When the tunnel is not welded to the hull, the connection devices are examined by the Society on a case by case basis.

SECTION 2 AFT PART

Symbols

p_S, p_W : Still water pressure and wave pressure defined in [2.3]

s : Spacing, in m, of ordinary stiffeners or primary supporting members, as applicable

ℓ : Span, in m, of ordinary stiffeners or primary supporting members, as applicable

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:

$c_r = 1 - 0{,}5\, s / r$

to be taken not less than 0,5

r : Radius of curvature, in m

β_b, β_s : Coefficients defined in Ch 7, Sec 2, [3.4.2]

λ_b, λ_s : Coefficients defined in Ch 7, Sec 2, [3.4.3]

c_E : Coefficient to be taken equal to:

$c_E = 1$ for $L \leq 65$ m

$c_E = 3 - L/30$ for $65 \text{ m} < L < 90$ m

$c_E = 0$ for $L \geq 90$ m

c_F : Coefficient:

$c_F = 0{,}8$ for poop sides

$c_F = 1{,}0$ in other cases

m : Boundary coefficient, to be taken equal to:

- m = 12 in general, for stiffeners considered as clamped
- m = 8 for stiffeners considered as simply supported
- other values of m may be considered, on a case by case basis, for other boundary conditions.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the structures located aft of the after peak bulhead and for the reinforcements of the flat bottom aft area.

1.1.2 Aft peak structures which form vertical watertight boundary between two compartments 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 Part B, Chapter 7.

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 4, Sec 2, [1], 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 4, Sec 2.

2 Aft peak

2.1 Partial safety factors

2.1.1 The partial safety factors to be considered for checking aft peak structures are specified in Tab 1.

Table 1 : Aft peak structures - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors			
	Symbol	Plating	Ordinary stiffeners	Primary supporting members **(1)**
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,20	1,20
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	1,20	1,40	1,60

(1) For primary supporting members analysed through complete ship models, the partial safety factors defined in Ch 7, Sec 3, [1.4].

2.1.2 The partial safety factors to be considered for testing of aft peak structures are specified in Tab 2.

Table 2 : Aft peak structures Partial safety factors for testing

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbols	Plating	Ordinary stiffeners
Still water pressure	γ_{S2}	1,00	1,00
Wave induced pressure	γ_{W2}	N.A.	N.A.
Material	γ_m	1,02	1,02
Resistance	γ_R	1,05	1,20

2.2 Load point

2.2.1 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.

Table 3 : Still water and wave pressures

Location	Still water sea pressure p_S, in kN/m^2	Wave pressure p_W, in kN/m^2
Bottom and side below the waterline: $z \le T$	$\rho\, g\, (T - z)$	$\rho g h_1 e^{\frac{-2\pi(T-z)}{L}}$
Side above the waterline: $z > T$	0	$\rho\, g\, (T + h_1 - z)$ without being taken less than 0,15L
Exposed deck	Pressure due to the load carried **(1)**	$17{,}5\, n\, \varphi_1\, \varphi_2$

(1) The pressure due to the load carried is to be defined by the Designer and, in any case, it may not be taken less than $10\varphi_1\, \varphi_2$ kN/m^2.
The Society may accept pressure values lower than $10\, \varphi_1\, \varphi_2$ kN/m^2 when considered appropriate on the basis of the intended use of the deck.

Note 1:

φ_1 : Coefficient defined in Tab 4

φ_2 : Coefficient taken equal to:
- $\varphi_2 = 1$ if $L \ge 120$ m
- $\varphi_2 = L/120$ if $L < 120$ m

2.3 Load model

2.3.1 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 Tab 3
- the still water internal pressure due to liquids or ballast, defined in Tab 5
- the still water internal pressure due to dry uniform cargoes on deck, defined in Tab 6.

Wave pressure (p_W) includes:

- the wave pressure, defined in Tab 3
- the inertial internal pressure due to liquids or ballast, defined in Tab 5
- the inertial internal pressure due to dry uniform cargoes on deck, defined in Tab 6.

Table 4 : Coefficient for pressure on exposed decks

Exposed deck location	φ_1
Freeboard deck	1,00
Top of lowest tier	0,75
Top of second tier	0,56
Top of third tier	0,42
Top of fourth tier	0,32
Top of fifth tier	0,25
Top of sixth tier	0,20
Top of seventh tier	0,15
Top of eighth tier and above	0,10

Table 5 : Still water and wave internal pressures due to liquids

Still water pressure p_S, in kN/m^2	Inertial pressure p_W, in kN/m^2
$\rho\, g\, (z_L - z)$	$\rho\, a_{Z1}\, (z_{TOP} - z)$

Note 1:

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank

z_L : Z co-ordinate, in m, of the highest point of the liquid:
$z_L = z_{TOP} + 0{,}5\, (z_{AP} - z_{TOP})$

z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}.

Table 6 : Still water and inertial internal pressures due to dry uniform cargoes

Still water pressure p_S, in kN/m^2	Inertial pressure p_W, in kN/m^2
The value of p_S is, in general, defined by the Designer: in any case it may not be taken less than 10 kN/m^2. When the value of p_S is not defined by the Designer, it may be taken, in kN/m^2, equal to $6{,}9\, h_{TD}$, where h_{TD} is the compartment 'tweendeck height at side, in m.	$p_S \frac{a_{Z1}}{g}$

2.3.2 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.

2.3.3 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.

2.3.4 Lateral pressure in testing conditions

The lateral pressure in testing conditions, p_T , in kN/m², is taken equal to:

- $p_{ST} - p_S$ for bottom shell plating and side shell plating
- p_{ST} otherwise

where:

p_{ST} : Still water pressure defined in Ch 5, Sec 6, Tab 13

p_S : Still water sea pressure defined in Tab 2 and calculated for the draught T_1 at which the testing is carried out.

If the draught T_1 is not defined by the Designer, it may be taken equal to the light ballast draught T_B defined in Ch 5, Sec 1, [2.4.3].

3 After peak

3.1 Arrangement

3.1.1 General

The provisions of this Subarticle apply to transversely framed after peak structure.

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.

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 from the formulae in:

- Tab 7 for plating
- Tab 8 for ordinary stiffeners

and not less than the minimum values in the same tables.

3.2.2 Floors

The net thickness of floors is to be not less than that obtained, in mm, from the following formula:

$t_M = 6,5 + 0,02\ L_2\ k^{1/2}$

3.2.3 Side transverses

The net section modulus w, in cm³, and the net shear sectional area A_{SH}, in cm², of side transverses are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

Table 7 : Net thickness of plating

Plating location	Net thickness, in mm	Net minimum thickness, in mm **(1)**
Bottom and side	$14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda R_y}}$	$c_F (0,03 L + 5,5) k^{1/2} - c_E$
Inner bottom		$2 + 0,017 L k^{1/2} + 4,5 s$
Deck		For strength deck: $2,1 + 0,013 L k^{1/2} + 4,5 s$
Platform and wash bulkhead		$1,3 + 0,004 L k^{1/2} + 4,5 s$ for $L < 120$ m $2,1 + 2,2 k^{1/2} + s$ for $L \geq 120$ m

(1) L need not be taken greater than 300 m.
Note 1:
λ : Coefficient taken equal to:
- for longitudinally framed plating: $\lambda = \lambda_L$, defined in Ch 7, Sec 1, [3.3.1]
- for transversely framed plating: $\lambda = \lambda_T$, defined in Ch 7, Sec 1, [3.4.1]
- for plating not contributing to the hull girder longitudinal strength: $\lambda = 1$

Table 8 : Net scantlings of ordinary stiffeners

Ordinary stiffener location	Formulae	Minimum value
Bottom, side and deck	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1,5 L_2^{1/3} k^{1/6}$ • the net thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$	
Platform and wash bulkhead	Net section modulus, in cm³: $w = 3,5 s \ell^2 k (z_{TOP} - z_M)$	

Note 1:
σ_{X1} : Hull girder normal stress, taken equal to:
- the value defined in Ch 7, Sec 2, [3.3.7], for stiffeners contributing to the hull girder longitudinal strength
- $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal strength

z_{TOP} : Z co-ordinate, in m, of the highest point of the peak tank
z_M : Z co-ordinate, in m, of the stiffener mid-span.

3.2.4 Side girders

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of side girders are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

3.2.5 Deck primary supporting members

Scantlings of deck primary supporting members are to be in accordance with Ch 7, Sec 3, considering the loads in [2.3].

4 Reinforcements of the flat area of the bottom aft

4.1 General

4.1.1 Application

Requirements of this Article apply to ships with the service notations **passenger ship**, **liquefied gas carrier** or **LNG bunkering ship**, and having a length L at least equal to 170m. However, for ships with other service notations and shorter length, the Society may require reinforcements of the flat aft on a case by case basis.

4.1.2 Area to be reinforced

In addition to the requirements in Article [2], the structure of the flat area of the bottom aft is to be able to sustain the dynamic pressure due to wave impact.

The scantling pressure defined in [4.2.1] is to be applied to flat areas of the bottom aft having a maximum deadrise angle of 30° and located at a distance not greater than h_{SL} from the design waterline.

4.2 Stern impact pressure

4.2.1 The stern slamming pressure P_{SI} is to be obtained, in kN/m², from the following formula:

$$P_{SI} = 100 \frac{h_{SL}^2 - (z - T_1)^2}{T_{RZ}^2 \tan\beta}$$

where:

h_{SL} : Maximum relative wave elevation, in m, to be taken as follows, without being taken less than 0:

- for x/L = 0: $h_{SL} = 11,65\ H\ C_{B-LC}^{2,5}\ C_{W-LC}^{-4,9}$
- for x/L = 0,2: $h_{SL} = 2,3\ H\ C_{B-LC}^{2,5}\ C_{W-LC}^{-4,9}$
- for x/L > 0,2: $h_{SL} = 0$

with:

C_{B-LC} : Block coefficient at considered loading condition draught T_1

C_{W-LC} : Waterplane coefficient at considered loading condition draught T_1

For intermediate values of x/L, h_{SL} is to be obtained by linear interpolation

H : Wave parameter, in m, to be taken equal to:

$$H = 1 - 1,5\left(1 - \sqrt{\frac{L}{418}}\right)^{2,2}$$

T_{RZ} : Mean up crossing period, in s, to be taken as:

$T_{RZ} = 3\ L^{0,26}$

β : Longitudinal or transverse deadrise angle at the calculation point, whichever is the greater, but not to be taken less than 10°

T_1 : Draught as defined in Part B, Chapter 5, Symbols.

4.3 Scantling

4.3.1 Plating

The net thickness t, in mm, of the hull envelope plating is to be not less than the value obtained from the formula given in Ch 7, Sec 1, [3.6.1].

4.3.2 Ordinary stiffeners

The net plastic section modulus Z_{pl}, in cm^3, as defined in Ch 4, Sec 3, [3.4.3] and the net web thickness t_w, in mm, of longitudinal or transverse ordinary stiffeners are not to be less than the values obtained from the formulae given in Ch 7, Sec 2, [3.10.1]

4.3.3 Primary supporting members

The net section modulus w, in cm^3, of primary supporting members and their net shear area A_{sh}, in cm^2, at any position along their span are not to be less than the values obtained from the formulae given in Ch 7, Sec 3, [6.1.1].

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 sternframe 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 9, Sec 1, [8.2], may be gradually tapered inside the hull.

Connections by slot welds are not acceptable.

5.1.3 Hull structures

Direct calculations are to be performed to check the connection of the rudder horn to the structure of the vessel, taking account of the reactions induced by the rudder on the rudder horn.

In general, 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 spacing in way of the horn
- 4-frame spacing for and aft of the rudder horn
- 6-frame spacing 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 + 6 L 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 sternframe 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 4, Sec 2, [1], 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 9 for single screw ships and Tab 10 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 9 or Tab 10, 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 9 or Tab 10, 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, [3.4].

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:

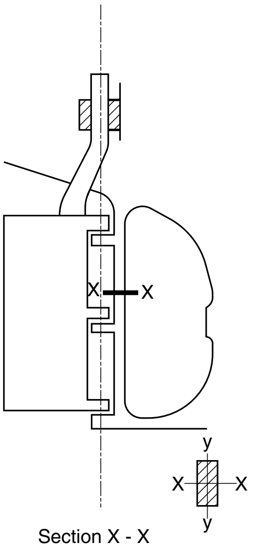
C_R : Rudder force, in N, acting on the rudder blade, defined in Ch 9, Sec 1, [2.1.2] and Ch 9, Sec 1, [2.2.2], as the case may be

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, over the whole shaft bearing length and included in the propeller post, is to be not less than 60% of the thickness b required in [6.3.2] for bar propeller posts with a rectangular section.

Figure 1 : Integral rudder post



6.6 Rudder gudgeons

6.6.1 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.

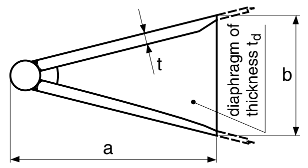
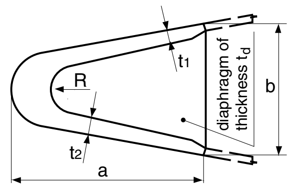
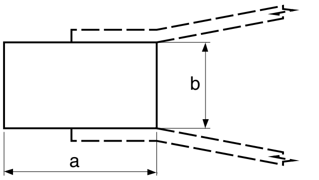
The thickness of the metal around the finished bore of the gudgeons is to be not less than half the diameter of the pintle.

6.7 Sterntubes

6.7.1 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 sternframe.

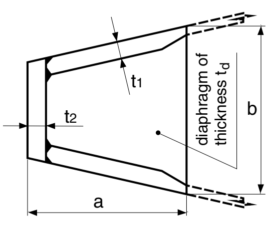
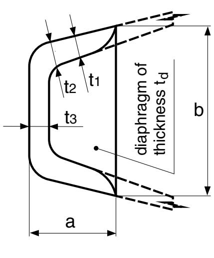
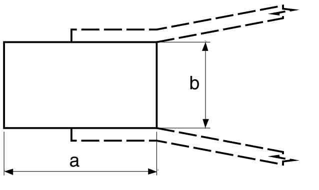
Where the materials adopted for the sterntube and the plating adjacent to the sternframe are different, the sterntube thickness is to be at least equivalent to that of the plating.

Table 9 : 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 $L^{1/2}$	$10\sqrt{2,5(L+10)}$ for $L \le 60$ $10\sqrt{7,2L-256}$ for $L > 60$
b	35 $L^{1/2}$	23 $L^{1/2}$	$10\sqrt{1,6(L+10)}$ for $L \le 60$ $10\sqrt{4,6L-164}$ 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	to be greater than 50 mm	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 10 : Twin 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	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.

SECTION 3 MACHINERY SPACE

Symbols

s : Spacing, in m, of ordinary stiffeners

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 be dealt with at Shipyard diligence.

1.2 Scantlings

1.2.1 Net scantlings

As specified in Ch 4, Sec 2, [1], 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 4, Sec 2.

1.2.2 Plating and ordinary stiffeners

Unless otherwise specified in this Section, the scantlings of plating and ordinary stiffeners in the machinery space are to be determined according to the relevant criteria in Part B, Chapter 7. 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 4, Sec 4, [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 spacing 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 4, Sec 3, [4.7], floors are to have web stiffeners 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 4, Sec 3, [4.7].

Sniped stiffeners are not to be used on structures in the vicinity of engines or generators or propeller impulse zone.

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.

2.2.2 Lower net thickness values for floor and web girder web can be accepted, if based on direct calculations.

3 Single bottom

3.1 Arrangement

3.1.1 Bottom girder

For single bottom girder arrangement, the requirements of Ch 4, Sec 4, [4.1] and Ch 4, Sec 4, [4.4] 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 spacing 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.

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	Refer to Ch 7, Sec 1, Tab 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	

3.1.4 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 The net thicknesses of floor and girder webs are to be not less than the values given in Tab 2.

Table 2 : Single bottom - Minimum net thicknesses of 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 spacing.

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 spacing.

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 Ch 8, Sec 10, [7], 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 8, Sec 10, [7.2].

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 8, 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 Seatings of main engines

8.1 Arrangement

8.1.1 General

The scantlings of seatings of main engines 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

Seatings are to be supported by transversal and longitudinal members welded to a bed plate. The supporting structure may be integral with the bottom structure (integrated directly in the floors and girders).

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 Supporting structure included in the double bottom structure

Where large internal combustion engines or turbines plants are fitted, supporting members are to be integral with the double bottom structure. Longitudinal members 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 longitudinal members in way of seatings are to be continuous from the bedplates to the bottom shell.

8.1.4 Supporting structure above the double bottom plating

Where the supporting structure is 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 supporting 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 longitudinal members in way of seatings of engines

In general, at least two longitudinal members are to be fitted in way of seatings of main engines.

One longitudinal member 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 Scantlings

8.2.1 The net scantlings of the structural elements in way of the seatings of engines are to be determined by the engine manufacturer. They are to be checked on the basis of justificative calculations supplied by the engine manufacturer. If these calculations are not supplied, the net scantlings of the structural elements in way of the seatings of engines are to be not less than those obtained from the formulae in Tab 3.

Table 3 : Scantlings of the structural elements in way of seatings of engines

Scantling	Minimum value
Net cross-sectional area, in cm², of each bedplate of the seatings	$40 + 70\frac{P}{n_r L_E}$
Net thickness, in mm, of each bedplate of the seatings	• Bedplate supported by two or more longitudinal members: $\sqrt{240 + 175\frac{P}{n_r L_E}}$ • Bedplate supported by one longitudinal member: $5 + \sqrt{240 + 175\frac{P}{n_r L_E}}$
Web net thickness, in mm, of girders fitted in way of each bedplate of the seatings	• Bedplate supported by two or more longitudinal members: $\frac{1}{n_G}\sqrt{320 + 215\frac{P}{n_r L_E}}$ where n_G is the number of longitudinal members in way of the bedplate considered • Bedplate supported by one longitudinal member: $\sqrt{95 + 65\frac{P}{n_r L_E}}$
Web net thickness, in mm, of transverse members fitted in way of bedplates of the seating **(1)**	$\sqrt{55 + 40\frac{P}{n_r L_E}}$

(1) When intermediate transverse members welded to the bedplate are fitted, the web minimum net thickness may be reduced on a case-by-case basis.

SECTION 4 SUPERSTRUCTURES AND DECKHOUSES

Symbols

s : Spacing, in m, of ordinary stiffeners

t_c : Corrosion addition, in mm, defined in Ch 4, Sec 2, [3].

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantling of plating and associated structures of front, side and aft bulkheads and decks of superstructures and deckhouses.

1.1.2 The requirements of this Section comply with the applicable regulations of the 1966 International Convention on Load Lines, as amended, with regard to the strength of enclosed superstructures.

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], 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 4, Sec 2.

1.3 Definitions

1.3.1 Superstructures

Superstructures are defined in Ch 1, Sec 2, [3.13].

1.3.2 Deckhouses

Deckhouses are defined in Ch 1, Sec 2, [3.16].

1.4 Connections of superstructures and deckhouses with the hull structure

1.4.1 Superstructure and deckhouse frames are to be fitted as far as practicable as extensions of those underlying and are to be effectively connected to both the latter and the deck beams above.

Ends of superstructures and deckhouses are to be efficiently supported by bulkheads, diaphragms, webs or pillars.

Where hatchways are fitted close to the ends of superstructures, additional strengthening may be required.

1.4.2 Connection to the deck of corners of superstructures and deckhouses is considered by the Society on a case by case basis. Where necessary, doublers or reinforced welding may be required.

1.4.3 As a rule, the frames of sides of superstructures and deckhouses are to have the same spacing as the beams of the supporting deck.

Web frames are to be arranged to support the sides and ends of superstructures and deckhouses.

1.4.4 The side plating at ends of superstructures is to be tapered into the bulwark or sheerstrake of the strength deck.

Where a raised deck is fitted, this arrangement is to extend over at least a 3-frame spacing.

1.5 Structural arrangement of superstructures and deckhouses

1.5.1 Strengthening in way of superstructures and deckhouses

Web frames, transverse partial bulkheads or other equivalent strengthening are to be fitted inside deckhouses of at least 0,5 B in breadth extending more than 0,15 L in length within 0,4 L amidships. These transverse strengthening reinforcements are to be spaced approximately 9 m apart and are to be arranged, where practicable, in line with the transverse bulkheads below.

Web frames are also to be arranged in way of large openings, boats davits and other areas subjected to point loads.

Web frames, pillars, partial bulkheads and similar strengthening are to be arranged, in conjunction with deck transverses, at ends of superstructures and deckhouses.

1.5.2 Strengthening of the raised quarter deck stringer plate

When a superstructure is located above a raised quarter deck, the thickness of the raised quarter deck stringer plate is to be increased by 30% and is to be extended within the superstructure.

The increase above may be reduced when the raised quarter deck terminates outside 0,5 L amidships.

1.5.3 Openings

Openings are to be in accordance with Ch 6, Sec 1.

Continuous coamings are to be fitted above and below doors or similar openings.

1.5.4 Access and doors

Access openings cut in sides of enclosed superstructures are to be fitted with doors made of steel or other equivalent material, and permanently attached.

Special consideration is to be given to the connection of doors to the surrounding structure.

Securing devices which ensure watertightness are to include tight gaskets, clamping dogs or other similar appliances, and are to be permanently attached to the bulkheads and doors. These doors are to be operable from both sides.

Unless otherwise permitted by the Society, doors open outwards to provide additional security against the impact of the sea.

1.5.5 Strengthening of deckhouses in way of lifeboats and rescue boats

Sides of deckhouses are to be strengthened in way of lifeboats and rescue boats and the top plating is to be reinforced in way of their lifting appliances.

1.5.6 Constructional details

Lower tier stiffeners are to be welded to the decks at their ends.

Brackets are to be fitted at the upper and preferably also the lower ends of vertical stiffeners of exposed front bulkheads of engine casings and superstructures or deckhouses protecting pump room openings.

1.5.7 Use of aluminium alloys

Unprotected front bulkheads of first tier superstructures or deckhouses are generally to be built of steel and not of aluminium alloy.

Aluminium alloys may be adopted for front bulkheads of superstructures or deckhouses above the first tier.

2 Design loads

2.1 Side bulkheads of superstructures

2.1.1 Load point

Lateral pressure is to be calculated at:

- the lower edge of the elementary plate panel, for plating
- mid-span, for stiffeners.

2.1.2 Lateral pressure

The lateral pressure is constituted by the still water sea pressure (p_S) and the wave pressure (p_W), defined in Ch 5, Sec 5.

Moreover, when the side is a tank boundary, the lateral pressure constituted by the still water internal pressure (p_S) and the inertial pressure (p_W), defined in Ch 5, Sec 6, [1], is also to be considered.

2.2 Side and end bulkheads of deckhouses and end bulkheads of superstructures

2.2.1 Load point

Lateral pressure is to be calculated at:

- mid-height of the bulkhead, for plating
- mid-span, for stiffeners.

2.2.2 Lateral pressure

The lateral pressure to be used for the determination of scantlings of front, side and aft bulkheads of deckhouses and of front and aft bulkheads of superstructures is to be obtained, in kN/m², from the following formula:

$$p = 10\, n\, a\, c\, [b\, f - (z - T)]$$

without being less than p_{min}

where:

n : Navigation coefficient, defined in Ch 5, Sec 1, [2.6]

a : Coefficient defined in Tab 1

c : Coefficient taken equal to:

$$c = 0{,}3 + 0{,}7\frac{b_1}{B_1}$$

For exposed parts of machinery casings, c is to be taken equal to 1

b_1 : Breadth of the superstructure or deckhouse, in m, at the position considered, to be taken not less than 0,25 B_1

B_1 : Actual maximum breadth of ship on the exposed weather deck, in m, at the position considered

b : Coefficient defined in Tab 2

f : Coefficient defined in Tab 3

p_{min} : Minimum lateral pressure defined in Tab 4.

Table 1 : Lateral pressure for superstructures and deckhouses - Coefficient a

Type of bulkhead	Location	a	a maximum
Unprotected front	Lowest tier	$2 + \frac{L}{120}$	4,5
	Second tier	$1 + \frac{L}{120}$	3,5
	Third tier	$0{,}5 + \frac{L}{150}$	2,5
	Fourth tier	$0{,}9\left(0{,}5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0{,}8\left(0{,}5 + \frac{L}{150}\right)$	2,0
Protected front	Lowest, second and third tiers	$0{,}5 + \frac{L}{150}$	2,5
	Fourth tier	$0{,}9\left(0{,}5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0{,}8\left(0{,}5 + \frac{L}{150}\right)$	2,0
Side **(1)**	Lowest, second and third tiers	$0{,}5 + \frac{L}{150}$	2,5
	Fourth tier	$0{,}9\left(0{,}5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0{,}8\left(0{,}5 + \frac{L}{150}\right)$	2,0
Aft end	All tiers, when: x/L ≤ 0,5	$0{,}7 + \frac{L}{1000} - 0{,}8\frac{x}{L}$	$1 - 0{,}8\frac{x}{L}$
	All tiers, when: x/L > 0,5	$0{,}5 + \frac{L}{1000} - 0{,}4\frac{x}{L}$	$0{,}8 - 0{,}4\frac{x}{L}$

(1) Applicable only to side bulkheads of deckhouses

Table 2 : Lateral pressure for superstructures and deckhouses - Coefficient b

Location of bulkhead **(1)**	b
$\frac{x}{L} \le 0,45$	$1 + \left(\frac{\frac{x}{L} - 0,45}{C_B + 0,2}\right)^2$
$\frac{x}{L} > 0,45$	$1 + 1,5\left(\frac{\frac{x}{L} - 0,45}{C_B + 0,2}\right)^2$
(1) For deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding 0,15L each, and x is to be taken as the co-ordinate of the centre of each part considered. **Note 1:** C_B : Block coefficient, with $0,6 \le C_B \le 0,8$	

Table 3 : Lateral pressure for superstructures and deckhouses - Coefficient f

Length L of ship, in m	f
L < 150	$\frac{L}{10}e^{-L/300} - \left[1 - \left(\frac{L}{150}\right)^2\right]$
150 ≤ L < 300	$\frac{L}{10}e^{-L/300}$
L ≥ 300	11,03

Table 4 : Minimum lateral pressure for superstructures and deckhouses

Location and type of bulkhead	p_{min}, in kN/m²
Lowest tier of unprotected fronts	$30 \le 25,0 + 0,10L \le 50$
Elsewhere:	
• if $z \le T + 0,5\ B\ A_R + 0,5\ h_w$	$15 \le 12,5 + 0,05L \le 25$
• if $T + 0,5\ B\ A_R + 0,5\ h_w < z$ and $z \le T + 0,5\ B\ A_R + h_w$	linear interpolation
• if $z > T + 0,5\ B\ A_R + h_w$	2,5
Note 1: A_R : Roll amplitude, in rad, defined in Ch 5, Sec 3, [2.4] or taken equal to 0,35 for ships less than 65 m in length. h_w : Wave parameter, in m, defined in Ch 5, Sec 3.	

2.3 Decks

2.3.1 The lateral pressure for the determination of deck scantlings is constituted by the still water internal pressure (p_S) and the inertial pressure (p_W), defined in Ch 5, Sec 6, [4].

Moreover, when the deck is a tank boundary, the lateral pressure constituted by the still water internal pressure (p_S) and the inertial pressure (p_W), defined in Ch 5, Sec 6, [1], is also to be considered.

3 Plating

3.1 Front, side and aft bulkheads

3.1.1 Plating of side bulkheads of superstructures

The net thickness of plating of side bulkheads of superstructures is to be determined in accordance with the applicable requirements of Ch 7, Sec 1, considering the lateral pressure defined in [2.1.2].

3.1.2 Plating of side and end bulkheads of deckhouses and of end bulkheads of superstructures

The net thickness of plating of side and end bulkheads of deckhouses and of end bulkheads of superstructures is to be not less than the value obtained, in mm, from the following formula:

$$t = 0,95 s\sqrt{kp} - t_c$$

where:

p : is the lateral pressure, in kN/m², defined in [2.2.2].

For plating which forms tank boundaries, the net thickness is to be determined in accordance with [3.1.1], considering the hull girder stress equal to 0.

This net thickness is to be not less than:

- the values given in Tab 5 for steel superstructures,
- the following values for aluminium superstructures:
  - 4 mm for rolled products
  - 2,5 mm for extruded products.

Table 5 : Minimum thicknesses of superstructures and deckhouses

Location	Minimum thickness, in mm
Lowest tier **(1)**	$(5 + 0,01\ L)\ k^{1/2} - t_c$
Second tier and above **(2)**	$(4 + 0,01\ L)\ k^{1/2} - t_c$
(1) L is to be taken not greater than 300 m **(2)** L is to be taken not less than 100 m and not greater than 300 m	

3.2 Decks

3.2.1 The net thickness of deck plating is to be determined in accordance with the applicable requirements of Ch 7, Sec 1.

3.2.2 For decks sheathed with wood, the net thickness obtained from [3.2.1] may be reduced by 10 percent.

4 Ordinary stiffeners

4.1 Front, side and aft bulkheads

4.1.1 General

The net scantlings of ordinary stiffeners are to be determined according to:

- [4.1.2] for single span vertical ordinary stiffeners of deckhouses side and end bulkheads and of superstructures end bulkheads.
- Ch 7, Sec 2 for all the other cases.

4.1.2 Ordinary stiffeners of side and end bulkheads of deckhouses and of end bulkheads of superstructures

The net section modulus of ordinary stiffeners of side and end bulkheads of deckhouses and of end bulkheads of superstructures is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 0{,}35\ \varphi\ k\ s\ \ell^2\ p\ (1 - \alpha\ t_c) - \beta\ t_c$$

where:

- ℓ : Span of the ordinary stiffener, in m, equal to the 'tweendeck height and to be taken not less than 2 m
- p : Lateral pressure, in kN/m^2, defined in [2.2.2]
- φ : Coefficient depending on the stiffener end connections, and taken equal to:
  - 1 for lower tier stiffeners
  - value defined in Tab 6 for stiffeners of upper tiers
- α, β : Parameters defined in Ch 4, Sec 2, Tab 1.

The section modulus of side ordinary stiffeners need not be greater than that of the side ordinary stiffeners of the tier situated directly below taking account of spacing and span.

For ordinary stiffeners of plating forming tank boundaries, the net scantlings are to be determined in accordance with [4.1.1], considering the hull girder stress equal to 0.

4.2 Decks

4.2.1 The net scantlings of deck ordinary stiffeners are to be determined in accordance with the applicable requirements of Ch 7, Sec 2.

Table 6 : Coefficient φ for end connections of stiffeners of superstructures and deckhouses

Coefficient φ	Upper end welded to deck	Bracketed upper end	Sniped upper end
Lower end welded to deck	1,00	0,85	1,15
Bracketed lower end	0,85	0,85	1,00
Sniped lower end	1,15	1,00	1,15

5 Primary supporting members

5.1 Front, side and aft bulkheads

5.1.1 Primary supporting members of side bulkheads of superstructures

The net scantlings of primary supporting members of side bulkheads of superstructures are to be determined in accordance with the applicable requirements of Ch 7, Sec 3.

5.1.2 Primary supporting members of side and end bulkheads of deckhouses and of end bulkheads of superstructures

The net scantlings of primary supporting members of side and end bulkheads of deckhouses and of end bulkheads of superstructures are to be determined in accordance with the applicable requirements of Ch 7, Sec 3, using the lateral pressure defined in [2.2].

5.2 Decks

5.2.1 The net scantlings of deck primary supporting members are to be determined in accordance with the applicable requirements of Ch 7, Sec 3.

6 Additional requirements applicable to movable wheelhouses

6.1 General

6.1.1 The requirements of this Article apply in addition of those in [1] to [5].

6.1.2 The structures of movable wheelhouses are to be checked in low and in high position.

6.1.3 Mechanical locking devices are to be fitted in addition to hydraulic systems.

6.2 Supports and guides, connections with the deck, under deck reinforcements, locking devices

6.2.1 Still water and inertial forces

The supports or guides of movable wheelhouses, connections with the deck, under deck reinforcements and locking devices are to be checked considering the sum of the following forces:

- still water and inertial forces, determined according to Ch 5, Sec 6, [5]
- wind forces, corresponding to a lateral pressure of $1{,}2 kN/m^2$.

6.2.2 Checking criteria

It is to be checked that the equivalent stress σ_{VM}, calculated according to Ch 7, App 1, [5.1.2] or Ch 7, App 1, [5.2.2], as applicable, is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

where:

- R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to 235/k, unless otherwise specified
- γ_R : Partial safety factor covering uncertainties regarding resistance, to be taken equal to:
  - 1,10 in general
  - 1,40 for checking locking devices
- γ_m : Partial safety factor covering uncertainties regarding material, to be taken equal to 1,02.

SECTION 5 BOW DOORS AND INNER DOORS

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement, strength and securing of bow doors and inner doors leading to a complete or long forward enclosed superstructure or to a long non-enclosed superstructure, where fitted to attain minimum bow height equivalence.

The requirements apply to ships engaged on international voyages and also to ships engaged only in domestic (non international) voyages, except where specifically indicated otherwise in this Section.

1.1.2 Two types of bow door are provided for:

- visor doors opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary supporting members of the door by longitudinally arranged lifting arms
- side-opening doors opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the ship. It is anticipated that side-opening bow doors are arranged in pairs.

Other types of bow door are considered by the Society on a case by case basis in association with the applicable requirements of this Section.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangement

1.3.1 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck for the purpose of this requirement.

1.3.2 An inner door is to be fitted as part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, as per Ch 2, Sec 1, [3.1].

A vehicle ramp may be arranged for this purpose, provided its position complies with Ch 2, Sec 1, [3.1].

If this is not possible, a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

1.3.3 Bow doors are to be so fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors.

Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

1.3.4 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in [1.3.2].

1.3.5 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in stowed position.

1.4 Definitions

1.4.1 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges.

1.4.2 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship's structure.

1.4.3 Locking device

A locking device is a device that locks a securing device in the closed position.

2 Design loads

2.1 Bow doors

2.1.1 Design external pressure

The design external pressure to be considered for the scantlings of primary supporting members and securing and supporting devices of bow doors is to be not less than that obtained, in kN/m², from the following formula:

$$p_E = 0,5\,n_D C_L C_Z (0,22 + 0,15\tan\alpha)(0,4V\sin\beta + 0,6\sqrt{L_1})^2$$

where:

n_D : Navigation coefficient, defined in Tab 1

V : Maximum ahead service speed, in knots

C_L : Coefficient depending on the ship's length:

$C_L = 0,0125\ L$ for $L < 80$ m

$C_L = 1,0$ for $L \geq 80$ m

C_Z : Coefficient defined in Ch 8, Sec 1, [4.2.1], to be taken equal to 5,5

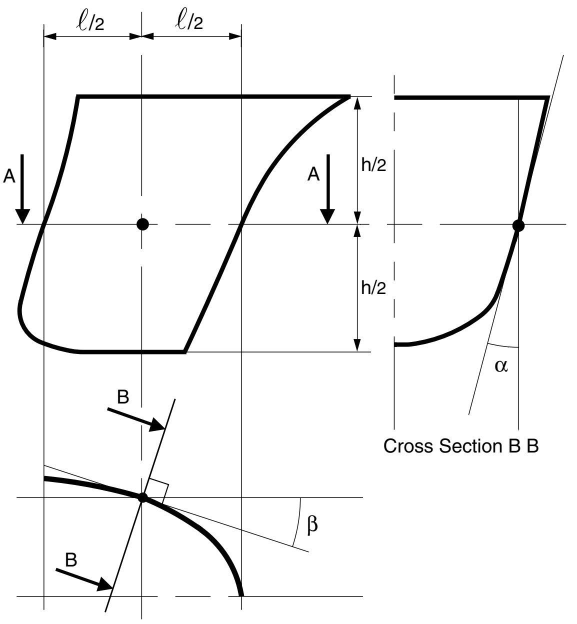
α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the side plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 1)

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 1).

Table 1 : Navigation coefficient

Navigation notation	Navigation coefficient n_D
Unrestricted navigation	1,00
Summer zone	1,00
Tropical zone	0,80
Coastal area	0,80
Sheltered area	0,50

Figure 1 : Definition of angles α and β



Cross Section A A

2.1.2 Design external forces

The design external forces F_X, F_Y, F_Z to be considered for the scantlings of securing and supporting devices of bow doors are to be not less than those obtained, in kN, from the following formulae:

$F_X = p_E\ A_X$

$F_Y = p_E\ A_Y$

$F_Z = p_E\ A_Z$

where:

p_E : External pressure, in kN/m², to be calculated according to [2.1.1], assuming the angles α and β measured at the point on the bow door located $\ell/2$ aft of the stem line on the plane h/2 above the bottom of the door, as shown in Fig 1

h : Height, in m, to be taken as the lesser of h_1 and h_2

h_1 : Height, in m, of the door between the levels of its bottom and the upper deck

h_2 : Height, in m, of the door between its bottom and top

ℓ : Length, in m, of the door at a height h/2 above the bottom of the door

A_X : Area, in m², of the transverse vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded

A_Y : Area, in m², of the longitudinal vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser

A_Z : Area, in m², of the horizontal projection of the door between the bottom of the door and the top of the upper deck bulwark or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser.

For bow doors, including bulwark, of unusual form or proportions, e.g. ships with a rounded nose and large stem angles, the areas and angles used for determination of the design values of external forces will be considered on a case by case basis.

2.1.3 Closing moment

For visor doors, the closing moment under external loads is to be obtained, in kN.m, from the following formula:

$M_Y = F_X\ a + 10\ W\ c - F_Z\ b$

where:

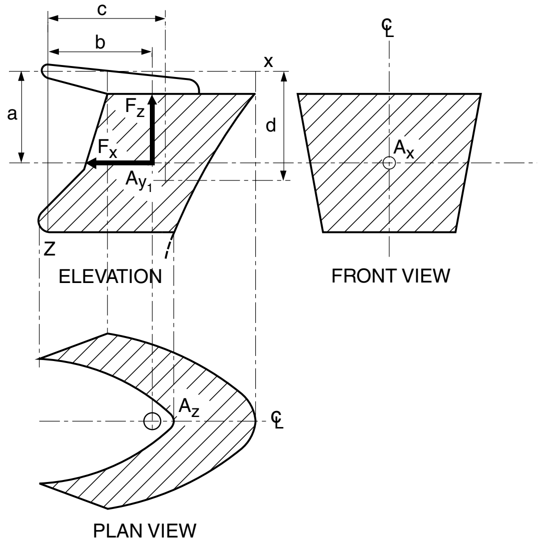
W : Mass of the visor door, in t

a : Vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig 2

b : Horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Fig 2

c : Horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Fig 2.

Figure 2 : Bow doors of visor type



2.1.4 Forces acting on the lifting arms

The lifting arms of a visor door and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m^2 is to be taken into account.

2.2 Inner doors

2.2.1 Design external pressure

The design external pressure to be considered for the scantlings of primary supporting members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of the values obtained, in kN/m^2, from the following formulae:

$p_E = 0,45\ L_1$

$p_E = 10\ h$

where:

h : Distance, in m, from the calculation point to the top of the cargo space.

2.2.2 Design internal pressure

The design internal pressure p_I to be considered for the scantlings of securing devices of inner doors is to be not less than 25 kN/m^2.

3 Scantlings of bow doors

3.1 General

3.1.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

3.1.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed.

For visor doors, adequate strength for opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the ship's structure.

3.2 Plating and ordinary stiffeners

3.2.1 Plating

The thickness of the bow door plating is to be not less than that obtained according to the requirements in Ch 8, Sec 1 for the fore part, using the bow door stiffener spacing. In no case may it be less than the minimum required thickness of fore part shell plating.

3.2.2 Ordinary stiffeners

The section modulus of bow door ordinary stiffeners is to be not less than that obtained according to the requirements in Ch 8, Sec 1 for the fore part, using the bow door stiffener spacing.

Consideration is to be given, where necessary, to differences in conditions of fixity between the ends of ordinary stiffeners of bow doors and those of the fore part shell.

3.3 Primary supporting members

3.3.1 Bow door ordinary stiffeners are to be supported by primary supporting members constituting the main stiffening of the door.

3.3.2 The primary supporting members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

3.3.3 Scantlings of primary supporting members are generally to be verified through direct calculations on the basis of the external pressure p_E in [2.1.1] and the strength criteria in [6.1.1] and [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

Members are to be considered to have simply supported end connections.

4 Scantlings of inner doors

4.1 General

4.1.1 The gross scantlings of the primary supporting members are generally to be verified through direct strength calculations on the basis of the external pressure p_E in [2.1.1] and the strength criteria in [6.1.1] and [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

4.1.2 Where inner doors also serve as vehicle ramps, their scantlings are to be not less than those obtained according to Ch 8, Sec 9.

4.1.3 The distribution of the forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the structure and the actual position and stiffness of the supports.

5 Securing and supporting of bow doors

5.1 General

5.1.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case by case basis.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

5.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [5.2.5].

The number of securing and supporting devices is generally to be the minimum practical while taking into account the requirements for redundant provision given in [5.2.6] and [5.2.7] and the available space for adequate support in the hull structure.

5.1.3 For visor doors which open outwards, the pivot arrangement is generally to be such that the visor is self-closing under external loads, i.e. it is to be checked that the closing moment M_Y, defined in [2.1.3], is in compliance with the following formula:

$M_Y > 0$

Moreover, the closing moment M_Y is to be not less than the value M_{Y0}, in kN.m, obtained from the following formula:

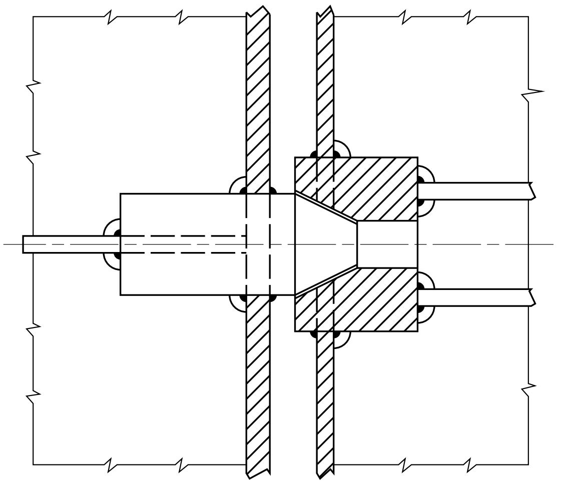
$$M_{Y0} = 10Wc + 0{,}1\sqrt{a^2 + b^2}\sqrt{F_X^2 + F_Z^2}$$

5.1.4 For side-opening doors, a thrust bearing is to be provided in way of girder ends at the closing of the two leaves to prevent one leaf from shifting towards the other under the effect of unsymmetrical pressure (see example in Fig 3).

The parts of the thrust bearing are to be kept secured to each other by means of securing devices.

The Society may consider any other arrangement serving the same purpose.

Figure 3 : Thrust bearing



5.2 Scantlings

5.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the allowable stresses defined in [6.1.1].

5.2.2 For visor doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

- Case 1: F_X and F_Z
- Case 2: $0{,}7F_Y$ acting on each side separately together with $0{,}7F_X$ and $0{,}7F_Z$,

where F_X, F_Y and F_Z are to be calculated as indicated in [2.1.2] and applied at the centroid of projected areas.

5.2.3 For side-opening doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

- Case 1: F_X , F_Y and F_Z acting on both doors
- Case 2: $0{,}7F_X$ and $0{,}7F_Z$ acting on both doors and $0{,}7F_Y$ acting on each door separately,

where F_X, F_Y and F_Z are to be calculated as indicated in [2.1.2] and applied at the centroid of projected areas.

5.2.4 The support forces as calculated according to Case 1 in [5.2.2] and Case 1 in [5.2.3] are to generally give rise to a zero moment about the transverse axis through the centroid of the area A_X.

For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be in the forward direction.

5.2.5 The distribution of the reaction forces acting on the securing and supporting devices may need to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

5.2.6 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that, in the event of failure of any single securing or supporting device, the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the allowable stresses defined in [6.1.1].

5.2.7 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the allowable stresses defined in [6.1.1].

The opening moment M_0 to be balanced by this reaction force is to be taken not less than that obtained, in kN.m, from the following formula:

$M_0 = 10\ W\ d + 5\ A_X\ a$

where:

d	:	Vertical distance, in m, from the hinge axis to the centre of gravity of the door, as shown in Fig 2
a	:	Vertical distance, in m, defined in [2.1.3].

5.2.8 For visor doors, the securing and supporting devices excluding the hinges are to be capable of resisting the vertical design force ($F_Z - 10\ W$), in kN, within the allowable stresses defined in [6.1.1].

5.2.9 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets.

6 Strength criteria

6.1 Primary supporting members and securing and supporting devices

6.1.1 Yielding check

It is to be checked that the normal stresses σ, the shear stress τ and the equivalent stress σ_{VM}, induced in the primary supporting members and in the securing and supporting devices of bow doors by the design load defined in [2], are in compliance with the following formulae:

$\sigma \le \sigma_{ALL}$

$\tau \le \tau_{ALL}$

$\sigma_{VM} = (\sigma^2 + 3\ \tau^2)^{0,5} \le \sigma_{VM,ALL}$

where:

σ_{ALL}	:	Allowable normal stress, in N/mm², equal to: $\sigma_{ALL} = 120/k$
τ_{ALL}	:	Allowable shear stress, in N/mm², equal to: $\tau_{ALL} = 80/k$
$\sigma_{VM,ALL}$	:	Allowable equivalent stress, in N/mm², equal to: $\sigma_{VM,ALL} = 150/k$
k	:	Material factor, defined in Ch 4, Sec 1, [2.3], but to be taken not less than 0,72 unless a fatigue analysis is carried out.

6.1.2 Buckling check

The buckling check of primary supporting members is to be carried out according to Ch 7, Sec 3, [7].

6.1.3 Bearings

For steel to steel bearings in securing and supporting devices, it is to be checked that the nominal bearing pressure σ_B, in N/mm², is in compliance with the following formula:

$\sigma_B \le 0,8\ R_{e,HB}$

where:

$$\sigma_B = 10\frac{F}{A_B}$$

F	:	Design force, in kN, defined in [2.1.2]
A_B	:	Projected bearing area, in cm²
$R_{e,HB}$	:	Yield stress, in N/mm², of the bearing material.

For other bearing materials, the allowable bearing pressure is to be determined according to the manufacturer's specification.

6.1.4 Bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

It is to be checked that the tension σ_T in way of threads of bolts not carrying support forces is in compliance with the following formula:

$\sigma_T \le \sigma_{T,ALL}$

where:

$\sigma_{T,ALL}$	:	Allowable tension in way of threads of bolts, in N/mm², equal to: $\sigma_{T,ALL} = 125/k$
k	:	Material coefficient defined in [6.1.1].

7 Securing and locking arrangement

7.1 Systems for operation

7.1.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.

The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

7.1.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

- the closing and opening of the doors, and
- associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations.

The operating panels for operation of doors are to be inaccessible to unauthorised persons.

A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

7.1.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

7.2 Systems for indication/monitoring

7.2.1 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

7.2.2 The indicator system is to be designed on the fail safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured.

The power supply for the indicator system for operating and closing doors is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply from the emergency source of power or other secure power supply, e.g. UPS.

The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

Note 1: The indicator system is considered designed on the fail-safe principal when:

- The indication panel is provided with:
  - a power failure alarm
  - an earth failure alarm
  - a lamp test
  - separate indication for door closed, door locked, door not closed and door not locked
- Limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series)
- Limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series)
- Two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked
- In case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in place - as appropriate.

7.2.3 The indication panel on the navigation bridge is to be equipped with a mode selection function “harbour/sea voyage”, so arranged that an audible alarm is given on the navigation bridge if the ship leaves harbour with the bow door or the inner door not closed or with any of the securing devices not in the correct position.

7.2.4 A water leakage detection system with an audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

Note 1: The indicator system is considered designed on the fail-safe principal when:

- The indication panel is provided with:
  - a power failure alarm
  - an earth failure alarm
  - a lamp test
  - separate indication for door closed, door locked, door not closed and door not locked
- Limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series)
- Limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series)
- Two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked
- In case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in place - as appropriate.

7.2.5 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room.

The system is to monitor the position of the doors and a sufficient number of their securing devices.

Special consideration is to be given for the lighting and contrasting colour of the objects under surveillance.

Note 1: The indicator system is considered designed on the fail-safe principal when:

- The indication panel is provided with:
  - a power failure alarm
  - an earth failure alarm
  - a lamp test
  - separate indication for door closed, door locked, door not closed and door not locked
- Limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series)
- Limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series)
- Two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked
- In case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in place - as appropriate.

7.2.6 The indicator system for the closure of the doors and the television surveillance systems for the doors and water leakage detection, and for special category and ro-ro spaces are to be suitable to operate correctly in the ambient conditions on board and to be type approved on the basis of the applicable tests required in Part D, Chapter 1 and/or Part D, Chapter 12.

7.2.7 A drainage system is to be arranged in the area between bow door and ramp or, where no ramp is fitted, between the bow door and the inner door.

The system is to be equipped with an audible alarm function to the navigation bridge being set off when the water levels in these areas exceed 0,5 m or the high water level alarm, whichever is lesser.

Note 1: The indicator system is considered designed on the fail-safe principal when:

- The indication panel is provided with:
  - a power failure alarm
  - an earth failure alarm
  - a lamp test
  - separate indication for door closed, door locked, door not closed and door not locked
- Limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series)
- Limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series)
- Two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked
- In case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in place - as appropriate.

7.2.8 For ro-ro passenger ships on international voyages, the special category spaces and ro-ro spaces are to be continuously patrolled or monitored by effective means, such as television surveillance, so that any movement of vehicles in adverse weather conditions or unauthorized access by passengers thereto, can be detected whilst the ship is underway.

8 Operating and Maintenance Manual

8.1 General

8.1.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and is to contain the necessary information on:

a) main particulars and design drawings:
   - special safety precautions
   - details of ship
   - equipment and design loading (for ramps)
   - key plan of equipment (doors and ramps)
   - manufacturer's recommended testing for equipment
   - description of equipment:
     - bow doors
     - inner bow doors
     - bow ramp/doors
     - central power pack
     - bridge panel
     - engine control room panel

b) service conditions:
   - limiting heel and trim of ship for loading/unloading
   - limiting heel and trim for door operations
   - doors/ramps operating instructions
   - doors/ramps emergency operating instructions

c) maintenance:
   - schedule and extent of maintenance
   - trouble shooting and acceptable clearances
   - manufacturer's maintenance procedures

d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This manual is to be submitted in duplicate to the Society for approval that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, troubleshooting and acceptance/rejection criteria.

Note 1: It is recommended that inspections of the doors and supporting and securing devices be carried out by ship's personnel at monthly intervals or following any incidents which could result in damage, including heavy weather or contact in the region of the shell doors. A record is to be kept and any damage found during such inspections is to be reported to the Society.

8.1.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

SECTION 6 SIDE DOORS AND STERN DOORS

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement, strength and securing of side doors located abaft the collision bulkhead, and of stern doors leading to enclosed spaces.

The requirements apply to ships assigned with the service notation **ro-ro passenger ship** or **ro-ro cargo ship** engaged on international voyages and also in domestic (non-international) voyages, except where specifically indicated otherwise in this section.

Shell doors not covered by this Section are dealt with in Ch 8, Sec 12.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangement

1.3.1 Side doors and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure.

1.3.2 Where the sill of any side door is below the uppermost load line, the arrangement is considered by the Society on a case by case basis.

1.3.3 Doors are preferably to open outwards.

1.4 Definitions

1.4.1 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges or about pivoted attachments to the ship.

1.4.2 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship's structure.

1.4.3 Locking device

A locking device is a device that locks a securing device in the closed position.

2 Design loads

2.1 Side and stern doors

2.1.1 Design forces in intact ship conditions

The design external forces F_E and the design internal forces F_I to be considered for the scantlings of primary supporting members and securing and supporting devices of side doors and stern doors are to be obtained, in kN, from the formulae in Tab 1.

2.1.2 Design pressure in damaged ship conditions

In damaged ship conditions, where doors are located partly or totally below the deepest equilibrium waterline, the scantlings of plating, ordinary stiffeners, primary supporting members and securing and supporting devices are to be obtained according to Articles [3] and [4] considering the following external design pressures, in kN/m²:

- points at or below the deepest equilibrium waterline:

  $p_S = \rho\ g\ d_F$

  $$p_W = 0,6\ \rho g h_1 e^{\frac{-2\pi(d_F)}{L}}$$

- points above the deepest equilibrium waterline:

  $p_S = 0$

  $p_W = 0,6\ \rho\ g\ (h_1 - d_F)$, without being taken less than 0.

where:

d_F : Distance, in m, from the calculation point to the deepest equilibrium waterline.
The deepest equilibrium waterlines are to be provided by the Designer under his own responsibility.

h_1 : Reference values of the ship relative motions in the upright ship condition, defined in Ch 5, Sec 3, [3.3].

Note 1: Note: flooding partial safety factors are to be considered for plating and ordinary stiffeners assessment.

3 Scantlings of side doors and stern doors

3.1 General

3.1.1 The strength of side doors and stern doors is to be commensurate with that of the surrounding structure.

3.1.2 Side doors and stern doors are to be adequately stiffened and means are to be provided to prevent any lateral or vertical movement of the doors when closed.

Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship's structure.

Table 1 : Design forces

Structural elements	External force F_E , in kN	Internal force F_I , in kN
Securing and supporting devices of doors opening inwards	$A\ p_E + F_P$	$F_0 + 10\ W$
Securing and supporting devices of doors opening outwards	$A\ p_E$	$F_0 + 10\ W + F_P$
Primary supporting members **(1)**	$A\ p_E$	$F_0 + 10\ W$

(1) The design force to be considered for the scantlings of the primary supporting members is the greater of F_E and F_I.

Note 1:

- A : Area, in m², of the door opening
- W : Mass of the door, in t
- F_P : Total packing force, in kN; the packing line pressure is normally to be taken not less than 5 N/mm
- F_0 : The greater of F_C and 5 A, in kN
- F_C : Accidental force, in kN, due to loose cargoes etc., to be uniformly distributed over the area A and to be taken not less than 300 kN. For small doors such as bunker doors and pilot doors, the value of F_C may be appropriately reduced. However, the value of F_C may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes.
- p_E : External design pressure determined at the centre of gravity of the door opening and to be taken not less than that obtained, in kN/m², from the following formulae:
  - $p_E = 10\ (T - Z_G) + 25$ for $Z_G < T$
  - $p_E = 25$ for $Z_G \geq T$

  Moreover, for stern doors of ships fitted with bow doors, p_E is to be taken not less than that obtained, in kN/m², from the following formula:

$$p_E = 0{,}6 n_D C_L (0{,}8 + 0{,}6\sqrt{L_1})^2$$

- T : Draught, in m, at the highest subdivision load line
- Z_G : Height of the centre of the area of the door, in m, above the baseline
- n_D : Navigation coefficient, defined in Tab 2
- C_L : Coefficient depending on the ship's length:
  - $C_L = 0{,}0125\ L$ for $L < 80$ m
  - $C_L = 1{,}0$ for $L \geq 80$ m.

Table 2 : Navigation coefficient

Navigation notation	Navigation coefficient n_D
Unrestricted navigation	1,00
Summer zone	1,00
Tropical zone	0,80
Coastal area	0,80
Sheltered area	0,50

3.1.3 Where doors also serve as vehicle ramps, the design of the hinges is to take into account the ship angle of trim and heel which may result in uneven loading on the hinges.

3.1.4 Shell door openings are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below.

3.2 Plating and ordinary stiffeners

3.2.1 Plating

The thickness of the door plating is to be not less than that obtained according to the requirements in Ch 7, Sec 1, for side plating, using the door stiffener spacing. In no case may it be less than the minimum required thickness of side plating.

Where doors also serve as vehicle ramps, the thickness of the door plating is to be not less than that obtained according to Ch 8, Sec 9.

3.2.2 Ordinary stiffeners

The scantling of door ordinary stiffeners is to be not less than that obtained according to the requirements in Ch 7, Sec 2, for the side, using the door stiffener spacing.

Consideration is to be given, where necessary, to differences in conditions of fixity between the ends of ordinary stiffeners of doors and those of the side.

Where doors also serve as vehicle ramps, the scantling of ordinary stiffeners is to be not less than that obtained according to Ch 8, Sec 9.

3.3 Primary supporting members

3.3.1 The door ordinary stiffeners are to be supported by primary supporting members constituting the main stiffening of the door.

3.3.2 The primary supporting members and the hull structure in way are to have sufficient stiffness to ensure structural integrity of the boundary of the door.

3.3.3 Scantlings of primary supporting members are generally to be verified through direct strength calculations on the basis of the design forces in Article [2] and the strength criteria in Ch 8, Sec 5, [5.1.1] and Ch 8, Sec 5, [5.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

Members are to be considered to have simply supported end connections.

4 Securing and supporting of doors

4.1 General

4.1.1 Side doors and stern doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case by case basis.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

4.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [4.2.2].

The number of securing and supporting devices is generally to be the minimum practical while taking into account the requirements for redundant provision given in [4.2.3] and the available space for adequate support in the hull structure.

4.2 Scantlings

4.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the allowable stresses defined in Ch 8, Sec 5, [5.1.1].

4.2.2 The distribution of the reaction forces acting on the securing and supporting devices may need to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position of the supports.

4.2.3 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that, in the event of failure of any single securing or supporting device, the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the allowable stresses defined in [5.1.1] for normal or damaged conditions.

4.2.4 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices. These elements include pins, support brackets and back-up brackets.

5 Strength criteria

5.1 Primary supporting members and securing and supporting devices

5.1.1 Yielding check

It is to be checked that the normal stress σ, the shear stress τ and the equivalent stress σ_{VM}, induced in the primary supporting members and in the securing and supporting devices of doors by the design load defined in Article [2], are in compliance with the following formulae:

$\sigma \le \sigma_{ALL}$

$\tau \le \tau_{ALL}$

$\sigma_{VM} = (\sigma^2 + 3\,\tau^2)^{0,5} \le \sigma_{VM,ALL}$

where:

σ_{ALL} : Allowable normal stress, in N/mm^2:

$\sigma_{ALL} = 120 / k$

τ_{ALL} : Allowable shear stress, in N/mm^2:

$\tau_{ALL} = 80 / k$

$\sigma_{VM,ALL}$: Allowable equivalent stress, in N/mm^2:

$\sigma_{VM,ALL} = 150 / k$

k : Material factor, defined in Ch 4, Sec 1, [2.3], but to be taken not less than 0,72 unless a fatigue analysis is carried out.

In case of damaged ship conditions assessment, the above allowable stresses are to be increased by 20%.

5.1.2 Buckling check

The buckling check of primary supporting members is to be carried out according to Ch 7, Sec 3, [7].

5.1.3 Bearings

For steel to steel bearings in securing and supporting devices, it is to be checked that the nominal bearing pressure σ_B, in N/mm^2, is in compliance with the following formula:

$\sigma_B \le 0{,}8\ R_{eH,B}$

where:

$$\sigma_B = 10\frac{F}{A_B}$$

with:

F : Design force, in KN, defined in [2.1.1]

A_B : Projected bearing area, in cm^2

$R_{eH,B}$: Yield stress, in N/mm^2, of the bearing material.

For other bearing materials, the allowable bearing pressure is to be determined according to the manufacturer's specification.

5.1.4 Bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

It is to be checked that the tension σ_T in way of threads of bolts not carrying support forces is in compliance with the following formula:

$\sigma_T \leq \sigma_{T,ALL}$

where:

$\sigma_{T,ALL}$: Allowable tension in way of threads of bolts, in N/mm^2:

$\sigma_{T,ALL} = 125 / k$

k : Material factor, defined in Ch 8, Sec 5, [6.1.1].

6 Securing and locking arrangement

6.1 Systems for operation

6.1.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.

The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

6.1.2 Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

- the closing and opening of the doors
- associated securing and locking devices.

For doors which are required to be equipped with a remote control arrangement, indication of the open/closed position of the door and the securing and locking device is to be provided at the remote control stations.

The operating panels for operation of doors are to be inaccessible to unauthorised persons.

A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

6.1.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

6.2 Systems for indication / monitoring

6.2.1 The following requirements apply to doors in the boundary of special category spaces or ro-ro spaces, as defined in Pt D, Ch 12, Sec 2, [1.2], through which such spaces may be flooded.

For cargo ships, where no part of the door is below the uppermost waterline and the area of the door opening is not greater than $6m^2$, then the requirements of this sub-article need not be applied.

6.2.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It shall not be possible to turn off the indicator light.

6.2.3 The indicator system is to be designed on the fail safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a backup power supply from the emergency source of power or secure power supply, e.g. UPS.

The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

Note 1: See Ch 8, Sec 5, [7.2.2] for fail safe principal design.

6.2.4 The indication panel on the navigation bridge is to be equipped with a mode selection function "harbour/sea voyage", so arranged that audible alarm is given on the navigation bridge if the ship leaves harbour with any side shell or stern door not closed or with any of the securing devices not in the correct position.

6.2.5 For passenger ships, a water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors.

For cargo ships, a water leakage detection system with audible alarm is to be arranged to provide an indication to the navigation bridge.

6.2.6 For ro-ro passenger ships, on international voyages, the special category spaces and ro-ro spaces are to be continuously patrolled or monitored by effective means, such as television surveillance, so that any movement of vehicles in adverse weather conditions and unauthorized access by passengers thereto, can be detected whilst the ship is underway.

7 Operating and Maintenance Manual

7.1 General

7.1.1 An Operating and Maintenance Manual for the side doors and stern doors is to be provided on board and is to contain the necessary information on:

a) main particulars and design drawings:
   - special safety precautions
   - details of ship
   - equipment and design loading (for ramps)
   - key plan of equipment (doors and ramps)
   - manufacturer's recommended testing for equipment
   - description of equipment:
     - side doors
     - stern doors
     - central power pack
     - bridge panel
     - engine control room panel

b) service conditions:
   - limiting heel and trim of ship for loading / unloading
   - limiting heel and trim for door operations
   - doors / ramps operating instructions
   - doors / ramps emergency operating instructions

c) maintenance:
   - schedule and extend of maintenance
   - trouble shooting and acceptable clearances
   - manufacturer's maintenance procedures

d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This manual is to be submitted in duplicate to the Society for approval that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance / rejection criteria.

Note 1: It is recommended that inspections of the door and supporting and securing devices be carried out by ship's personnel at monthly intervals or following any incidents which could result in damage, including heavy weather or contact in the region of the shell doors. A record is to be kept and any damage recorded during such inspections is to be reported to the Society.

7.1.2 Documented operating procedures for closing and securing the side and stern doors are to be kept on board and posted at an appropriate place.

SECTION 7 LARGE HATCH COVERS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

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

D_{min} : Least moulded depth, in m, as defined in ICLL Regulation 3

h_s : Standard height of superstructure, as defined in Ch 1, Sec 2, [3.19]

L_3 : L, but to be taken not greater than 300 m

L_{LL} : Load line length L_{LL} , in m, as defined in Ch 1, Sec 2, [3.2]

p_W : Wave pressure, in kN/m^2, as defined in [3.1.1]

s : Stiffener spacing, in m

t_C : Corrosion additions, in mm, as defined in [1.4]

w : Net section modulus, in cm^3, of the ordinary stiffener or primary supporting member.

1 General

1.1 Application

1.1.1 The requirements of this Section apply to large cargo hatch covers and coamings on exposed decks of all ships except:

- ships granted with one of the service notation listed in Pt D, Ch 4, Sec 1, [1.1.1], for which Pt D, Ch 4, Sec 4 applies.
- ships granted with the service notation **ore carrier** or **combination carrier**, for which Pt D, Ch 4, Sec 4 applies.

1.2 Definitions

1.2.1 Large hatches

Large hatches are hatches with openings greater than 2,5 m^2.

1.2.2 ICLL

Where ICLL is referred to in the text, this is to be taken as the International Convention on Load Lines, 1966 as amended by the 1988 protocol, as amended in 2003.

1.2.3 Single skin cover

A hatch cover made of steel or equivalent material which has continuous top and side plating, but is open underneath with the stiffening structure exposed. The cover is weathertight and fitted with gaskets and clamping devices unless such fittings are specifically excluded.

1.2.4 Double skin cover

A hatch cover as above but with continuous bottom plating such that all the stiffening structure and internals are protected from the environment.

1.2.5 Pontoon type cover

A special type of portable cover, secured weathertight by tarpaulins and battening devices.

1.3 Materials

1.3.1 Steel

The materials used for construction of the steel large hatch covers are to comply with the applicable requirements of NR216 Materials and Welding, Chapter 2.

1.3.2 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.

With regards to material grade selection according to Ch 4, Sec 1, material class I is to be applied for top plate, bottom plate and primary supporting members.

Table 1 : Corrosion additions t_c for hatch covers and hatch coamings

Application	Structure	t_C , in mm
Weather deck hatches of container ships, car carriers, paper carriers, passenger ships	Hatch covers	1,0
	Hatch coamings	1,5
Weather deck hatches of all other ship types covered by this Section	Hatch covers in general	2,0
	Weather exposed plating and bottom plating of double skin hatch covers	1,5
	Internal structure of double skin hatch covers and closed box girders	1,0
	Hatch coamings	1,5
	Coaming stays and stiffeners	1,5

1.4 Net scantling approach

1.4.1 Corrosion additions for steel other than stainless steel

Unless otherwise specified, the thicknesses t in this Section are net thicknesses.

The net thicknesses are the member thicknesses necessary to obtain the minimum net scantlings required in [4] and [8].

The required gross thicknesses are obtained by adding corrosion additions t_C given in Tab 1.

Strength calculations using grillage analysis or finite element (FE) analysis are to be performed with net scantlings.

1.4.2 Corrosion additions for aluminium alloys

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

2 Arrangements

2.1 Height of hatch coamings

2.1.1 *The height above the deck of hatch coamings 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 values* given in [2.1.1] *or the coamings may be omitted entirely, on condition that* the Society *is satisfied that the safety of the ship is not thereby impaired in any sea conditions.*

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. However, non-weathertight hatch covers may be fitted for cargo holds solely dedicated to the transport of containers, provided they comply with [6.2.2].

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 Primary supporting members and ordinary stiffeners of hatch covers are to be continuous over the breadth and length of hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to 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. When strength calculation is carried out by finite element analysis using plane strain or shell elements, this requirement can be waived.

2.2.4 Flange breadth of the primary supporting members 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 the primary supporting members.

2.2.5 The covers used in 'tweendecks are to be fitted with an appropriate system ensuring an efficient stowing when the ship is sailing with open 'tweendecks.

2.2.6 Efficient retaining arrangements are to be provided to prevent translation of the hatch covers under the action of the longitudinal and transverse forces exerted by the stacks of containers on the covers. These retaining arrangements are to be located in way of the hatch coaming side brackets.

Solid fittings are to be welded on the hatch covers where the corners of the containers are resting. These parts are intended to transmit the loads of the container stacks onto the hatch covers on which they are resting as well as to prevent horizontal translation of the stacks by means of special intermediate parts arranged between the corner supports and the container corners.

Longitudinal stiffeners are to stiffen the hatch cover plates in way of these supports and connect the nearest transverse stiffeners. Extension is to be calculated to ensure a satisfactory strength.

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 to secure and to move the hatch covers, as well as the forces due to the cargoes stowed on the latter.

2.3.2 Special attention is to be paid to the strength of the fore transverse coaming of the foremost hatch and to the scantlings of the hatch cover closing devices on this coaming.

2.3.3 The longitudinal coamings are to extend at least to the lower edge of the deck beams.

Where they are not part of the continuous deck girders, the longitudinal coamings are to extend over at least two-frame spaces beyond the ends of the openings.

Where the longitudinal coamings are part of the continuous deck girders, their scantlings are to be as required in Ch 7, Sec 3.

2.3.4 The transverse coamings are to extend below the deck at least to the lower edge of the longitudinals.

The transverse coamings not in line with the ordinary deck beams are to extend below the deck over at least three longitudinal frame spaces beyond the side coamings.

2.3.5 Ordinary stiffeners of hatch coamings are to be continuous over the breadth and the length of hatch coamings.

3 Hatch cover and coaming load model

3.1 Weather loads

3.1.1 Vertical weather design load

The pressure p_W, in kN/m², on the hatch cover panels is given in Tab 2. The vertical weather design load need not be combined with the cargo loads defined in [3.2].

The positions 1 and 2, as specified in Ch 1, Sec 2, [3.22], are illustrated in Fig 1 for an example ship.

When an increased freeboard is assigned, the design load for hatch covers, as defined in Tab 2, on the actual freeboard deck may be as required for a superstructure deck, provided the summer freeboard is such that the resulting draught is not greater than that corresponding to the minimum freeboard calculated from an assumed freeboard deck situated at a distance at least equal to the standard superstructure height h_S below the actual freeboard deck. See Fig 2.

Table 2 : Design load p_W of weather deck hatches

Load line length L_{LL}, in m	Hatchway location	Design load p_W, in kN/m²	
		Position 1	Position 2
$L_{LL} < 100$	$0 \le x \le 0,75\ L_{LL}$	$14,9 + 0,195\ L_{LL}$	$11,3 + 0,142\ L_{LL}$
	$0,75\ L_{LL} < x \le L_{LL}$	$15,8 + \frac{L_{LL}}{3}\left(1 - \frac{5}{3}\frac{(L_{LL} - x)}{L_{LL}}\right) - \left(3,6\frac{(L_{LL} - x)}{L_{LL}}\right)$ **(1)**	
$L_{LL} \ge 100$	$0 \le x \le 0,75\ L_{LL}$	$34,3$	$25,5$ **(2)**
	$0,75\ L_{LL} < x \le L_{LL}$	$34,3 + \frac{p_{WP} - 34,3}{0,25}\left(\frac{x}{L_{LL}} - 0,75\right)$ **(1)**	

(1) Upon exposed superstructure decks located at least one superstructure standard height h_s above the freeboard deck, the design load p_W may be taken equal to:
- $14,9 + 0,195\ L_{LL}$ if $L_{LL} < 100$
- $34,3$ if $L_{LL} \ge 100$

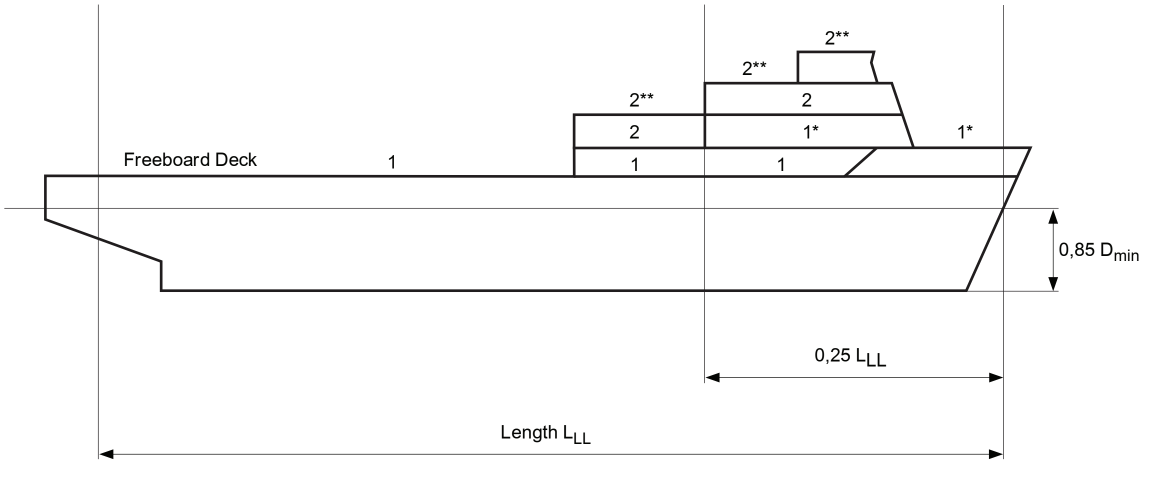
(2) Upon exposed superstructure decks located at least one superstructure standard height h_s above the lowest position 2 deck, the design load p_W may be taken equal to 20,6 kN/m².

Note 1:

p_{WP} : Pressure, in kN/m², at the forward perpendicular, to be taken equal to:
- $49,1 + 0,0726\ (L_{LL} - 100)$ for type B ships
- $49,1 + 0,3560\ (L_{LL} - 100)$ for type B-60 or type B-100 ships

x : Longitudinal coordinate, in m, of the assessed structural member mid-point, measured from the aft end of length L or L_{LL}, as applicable.

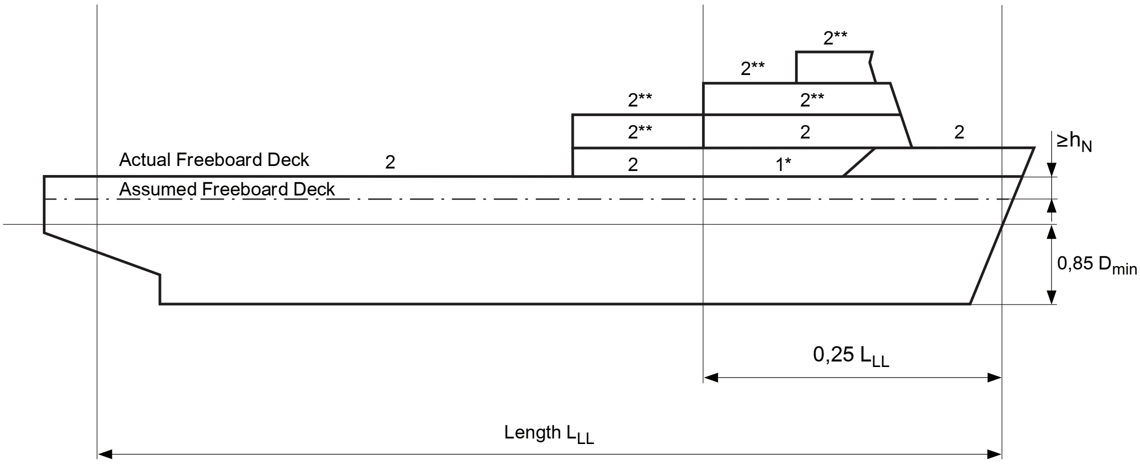
Figure 1 : Positions 1 and 2



* : Reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck

** : Reduced load upon exposed superstructure decks of ships with $L_{LL} > 100$ m located at least one superstructure standard height above the lowest position 2 deck.

Figure 2 : Positions 1 and 2 for an increased freeboard



* : Reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck

** : Reduced load upon exposed superstructure decks of ships with L_{LL} > 100 m located at least one superstructure standard height above the lowest position 2 deck.

3.1.2 Horizontal weather design load

The horizontal weather design load p_A , in kN/m², for determining the scantlings of outer edge girders (skirt plates) of weather deck hatch covers and of hatch coamings is not to be taken less than the greater of:

- the minimum values p_{Amin} given in Tab 3
- $p_A = a\ c\ (b\ c_L\ f - z)$

where:

a : Coefficient taken equal to:

- for unprotected front coamings and hatch cover skirt plates:

$$a = 20 + \frac{L_3}{12}$$

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

$$a = 10 + \frac{L_3}{12}$$

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

$$a = 5 + \frac{L_3}{15}$$

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

$$a = 7 + \frac{L_3}{100} - 8\frac{x'}{L}$$

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

$$a = 5 + \frac{L_3}{100} - 4\frac{x'}{L}$$

Table 3 : Minimum design load p_{Amin}

L	P_{Amin} , in kN/m²	
	For unprotected fronts	Elsewhere
L ≤ 50	30	15
50 < L < 250	25 + L/10	12,5 + L/20
L ≥ 250	50	25

c : Coefficient taken equal to 0,3 + 0,7 b'/B'
with b'/B' to be taken not less than 0,25

b' : Breadth of coaming, in m, at the position considered

B' : Actual maximum breadth of ship, in m, on the exposed weather deck at the position considered

b : Coefficient taken equal to:

- for x'/L < 0,45:

$$b = 1,0 + \left(\frac{\frac{x'}{L} - 0,45}{C_B + 0,2}\right)^2$$

- for x'/L ≥ 0,45:

$$b = 1,0 + 1,5\left(\frac{\frac{x'}{L} - 0,45}{C_B + 0,2}\right)^2$$

with 0,6 ≤ C_B ≤ 0,8. When determining scantlings of aft ends of coamings and aft hatch cover skirt plates forward of amidships, C_B need not be taken less than 0,8

x' : Distance, in m, between the transverse coaming or the hatch cover skirt plate considered and aft end of the length L. When determining side coamings or side hatch cover skirt plates, the side is to be subdivided into parts of approximately equal length, not exceeding 0,15 L each, and x' is to be taken as the distance between aft end of the length L and the centre of each part considered

c_L : Coefficient taken equal to:

- for L< 90 m:

$$c_L = \sqrt{\frac{L}{90}}$$

- for L ≥ 90 m:

$c_L = 1$

f : Wave parameter, taken equal to:

$$f = \frac{L}{25} + 4,1 \quad \text{for } L < 90m$$

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

$$f = 10,75 \quad \text{for } 300m \le L \le 350m$$

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

z : Vertical distance, in m, from the summer load line to the midpoint of the stiffener span or to the middle of the plate field.

Note 1: The horizontal weather design load need not be included in the direct strength calculation of the hatch cover, unless it is utilised for the design of substructures of horizontal support according to [9.2.3].

3.2 Cargo loads

3.2.1 Distributed loads

The distributed load on hatch covers p_L, in kN/m², due to uniform cargo loads and resulting from heave and pitch (i.e. ship in upright condition), is to be determined according to the following formula:

$p_L = p_C (1 + \alpha_V)$

where:

p_C : Uniform cargo load, in kN/m²

α_V : Vertical acceleration addition, taken equal to:

$\alpha_V = m F$

m : Coefficient taken equal to:

- for 0 ≤ x/L ≤ 0,2:

$$m = m_0 - 5(m_0 - 1)\frac{x}{L}$$

- for 0,2 < x/L ≤ 0,7:

m = 1

- for 0,7 < x/L ≤ 1,0:

$$m = 1 + \left(\frac{m_0 + 1}{0,3}\right)\left(\frac{x}{L} - 0,7\right)$$

m_0 : Coefficient taken equal to:

$m_0 = 1,5 + F$

F : Coefficient taken equal to:

$$F = 0,11\frac{V_0}{\sqrt{L}}$$

V_0 : Maximum speed, in knots, at summer load line draught, to be taken not less than $L^{1/2}$.

3.2.2 Concentrated loads

The concentrated load P, in kN, due to unit cargo (except container) and resulting from heave and pitch (i.e. ship in upright condition), is to be determined as follows:

$P = P_S (1 + \alpha_V)$

where:

P_S : Concentrated force due to unit cargo, in kN

α_V : Vertical acceleration addition, as defined in [3.2.1].

3.2.3 Container loads in upright condition

Where containers are stowed on hatch covers, the load P, in kN, applied at each corner of a container stack and resulting from heave and pitch (i.e. ship in upright condition), is to be determined as follows:

$$P = 9,81\frac{M}{4}(1 + \alpha_V)$$

where:

M : Maximum designed mass of the container stack, in t

α_V : Vertical acceleration addition, as defined in [3.2.1].

3.2.4 Container loads in heel condition

Where containers are stowed on hatch covers, the following loads A_Z, B_Z and B_y, in kN, applied at each corner of a container stack and resulting from heave, pitch and rolling motion (i.e. ship in heel condition), are to be determined as follows (see Fig 3):

A_Z, B_Z : Support forces in z-direction at the forward and aft stack corners, taken respectively equal to:

$$A_Z = 9,81\frac{M}{2}(1 + \alpha_V)\left(0,45 - 0,42\frac{h_m}{b}\right)$$

$$B_Z = 9,81\frac{M}{2}(1 + \alpha_V)\left(0,45 + 0,42\frac{h_m}{b}\right)$$

B_y : Support force in y-direction at the forward and aft stack corners, taken equal to:

$B_y = 2,4 M$

where:

M : Maximum designed mass of the container stack, in t, taken as:

$$M = \sum_i W_i$$

α_V : Vertical acceleration addition, as defined in [3.2.1]

h_m : Designed height of the centre of gravity of the stack above hatch cover top, in m, calculated as weighted mean value of the stack, where the centre of gravity of each tier is assumed to be located at the centre of each container:

$$h_m = \sum_i \frac{z_i W_i}{M}$$

z_i : Distance from hatch cover top to the centre of *i*th container, in m

W_i : Weight of *i*th container, in t

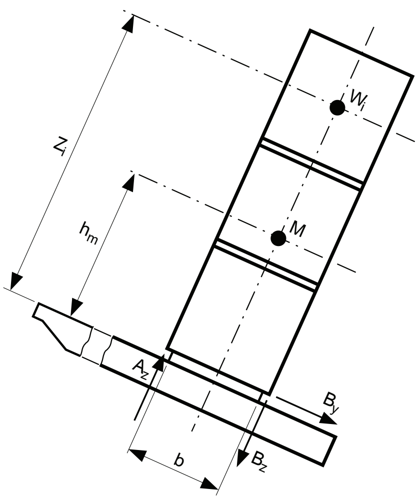
b : Distance between midpoints of foot points, in m.

When strength of the hatch cover structure is assessed by grillage analysis, h_m and z_i need to be taken above the hatch cover supports. Forces B_y does not need to be considered in this case.

Values of A_z and B_z applied for the assessment of hatch cover strength are to be shown in the drawings of the hatch covers.

Note 1: It is recommended that container loads as calculated above are considered as limit for foot point loads of container stacks in the calculations of cargo securing (container lashing).

Figure 3 : Forces due to container loads



3.2.5 Load cases with partial loading

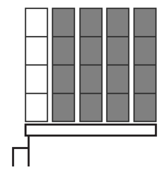
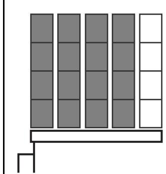
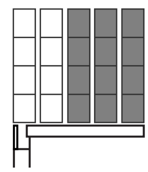
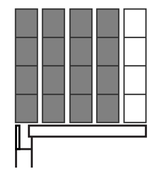
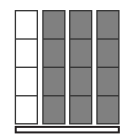
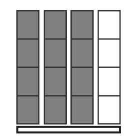
The loads defined in [3.2.1], [3.2.2] and [3.2.4] are also to be considered for partial non homogeneous loading which may occur in practice, e.g. where specified container stack places are empty. For each hatch cover, the heel directions, as shown in Tab 4, are to be considered.

The load case “partial loading of container hatch covers” can be evaluated using a simplified approach, where the hatch cover is loaded without the outermost stacks that are located completely on the hatch cover. If there are additional stacks that are supported partially by the hatch cover and partially by container stanchions then the loads from these stacks are also to be neglected (see Tab 4).

In addition, the case where only the stack places supported partially by the hatch cover and partially by container stanchions are left empty is to be assessed in order to consider the maximum loads in the vertical hatch cover supports.

It may be necessary to also consider partial load cases where more or different container stack places are left empty. The Society may require that additional partial load cases are to be considered.

Table 4 : Partial loading of container hatch covers

Heel direction	<	>
Hatch covers supported by the longitudinal hatch coaming with all container stacks located completely on the hacth cover		
Hatch covers supported by the longitudinal hatch coaming with the outermost container stacks supported partially by the hacth cover and partially by container stanchions		
Hatch covers not supported by the longitudinal hatch coaming (center hatch covers)		

3.2.6 Mixed stowage of 20’ and 40’ container on hatch cover

In the case of mixed stowage (20′ and 40′ container combined stack), the foot point forces at the fore and aft end of the hatch cover are not to be higher than resulting from the design stack weight for 40′ containers, and the foot point forces at the middle of the cover are not to be higher than resulting from the design stack weight for 20′ containers.

3.3 Global loads

3.3.1 Loads due to elastic deformations of the hull

Hatch covers which are, in addition to the loads defined in [3.1] and [3.2], loaded in the ship's transverse direction by forces due to elastic deformations of the hull, are to be designed such that the sum of stresses does not exceed the permissible values given in [4.2.1].

4 Yielding strength

4.1 General

4.1.1 Hatch covers supporting wheeled loads

The scantlings of hatch covers supporting wheeled loads are to be obtained in accordance with the applicable requirements of:

- Ch 7, Sec 1, for plating
- Ch 7, Sec 2, or by direct calculations under consideration of the permissible stresses given in [4.2.1], for ordinary stiffeners
- Ch 7, Sec 3, for primary supporting members.

4.2 Permissible stresses and deflections

4.2.1 Stresses

The equivalent stress σ_V in steel hatch cover structures related to the net thickness is not to exceed 0,8 R_{eH} , where R_{eH} is the minimum yield stress of the material, in N/mm².

For design loads defined in [3.1.2], [3.2] and [3.3], the equivalent stress σ_V related to the net thickness is not to exceed 0,9 R_{eH} when the stresses are assessed by means of finite element analysis.

- For grillage analysis, the equivalent stress σ_V, in N/mm², may be taken as follows:

  $$\sigma_V = \sqrt{\sigma^2 + 3\tau^2}$$

  where:

  σ : Normal stress, in N/mm²

  τ : Shear stress, in N/mm².

- For finite element analysis, the equivalent stress σ_V, in N/mm², may be taken as follows:

  $$\sigma_V = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau^2}$$

  where:

  σ_x : Normal stress, in N/mm², in x-direction

  σ_y : Normal stress, in N/mm², in y-direction

  τ : Shear stress, in N/mm², in the x-y plane.

  Indices x and y are coordinates of a two-dimensional Cartesian system in the plane of the considered structural element.

  In case of finite element analysis using shell or plane strain elements, the stresses are to be read from the centre of the individual element. It is to be observed that, in particular, at flanges of unsymmetrical girders, the evaluation of stress from element centre may lead to non-conservative results. Thus, a sufficiently fine mesh is to be applied in these cases or, the stress at the element edges shall not exceed the allowable stress.Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

4.2.2 Deflection

The vertical deflection of primary supporting members due to the vertical weather design load defined in [3.1.1] is to be not more than $\mu\,\ell_g$,

where:

ℓ_g : Greatest span of primary supporting members

μ : Coefficient taken equal to:

- for weathertight hatch covers:

  μ = 0,0056

- for pontoon hatch covers and portable beams:

  μ = 0,0044

Note 1: Where hatch covers are arranged for carrying containers and mixed stowage is allowed, i.e. a 40'-container stowed on top of two 20'-containers, particular attention is to be paid to the deflections of hatch covers. Further the possible contact of deflected hatch covers with in hold cargo is to be observed.

4.3 Plating

4.3.1 Local net plate thickness

The local net plate thickness t, in mm, of the hatch cover top plating is not to be less than the greater of:

- $t = 15{,}8\,F_p\,s\sqrt{\dfrac{p}{0{,}95R_{eH}}}$
- 1% of the spacing of the stiffeners
- 6 mm,

where:

F_p : Factor for combined membrane and bending response, equal to:

- F_p = 1,5, in general
- $F_p = 1{,}9\,\sigma/\sigma_a$, for the attached plating of primary supporting members when $\sigma \geq 0{,}8\,\sigma_a$

σ : Maximum normal stress, in N/mm², of hatch cover top plating. It may be taken equal to:

$\sigma = \max(\sigma_x, \sigma_y)$

For the distribution of normal stress σ between two parallel girders, refer to [5.3.4]

σ_x : Normal stress, in N/mm², parallel to ordinary stiffeners (see Fig 4)

σ_y : Normal stress, in N/mm², perpendicular to ordinary stiffeners (see Fig 4)

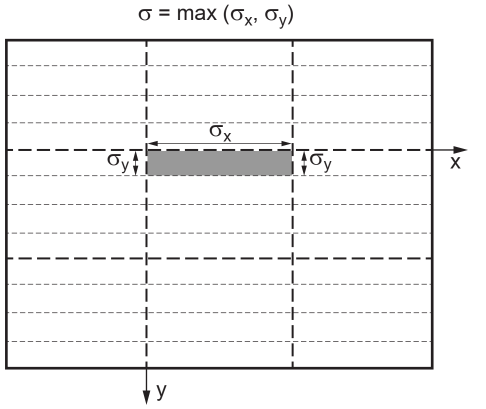
σ_a : Allowable normal stress, in N/mm², equal to:

$\sigma_a = 0{,}8\,R_{eH}$

p : Pressure p_W or p_L , in kN/m², as defined in [3].

For flange plates under compression, sufficient buckling strength according to [5] is to be demonstrated.

Figure 4 : Determination of normal stress of the hatch cover plating



4.3.2 Lower plating of double skin hatch covers and box girders

The thickness to fulfil the strength requirements is to be obtained from the calculations according to [4.5] under consideration of the permissible stresses defined in [4.2.1].

When the lower plating is taken into account as a strength member of the hatch cover, its net thickness, in mm, is not to be less than 5 mm.

When project cargo is intended to be carried on a hatch cover, the net thickness must not be less than:

$t = 6{,}5\ s$

When the lower plating is not considered as a strength member of the hatch cover, the thickness of the lower plating is to be determined according to Ch 7, Sec 1.

Note 1: Project cargo means especially large or bulky cargo lashed to the hatch cover. Examples are parts of cranes or wind power stations, turbines, etc. Cargoes that can be considered as uniformly distributed over the hatch cover, e.g., timber, pipes or steel coils need not to be considered as project cargo.

4.4 Ordinary stiffeners and primary supporting members

4.4.1 Net scantling of ordinary stiffeners

The net section modulus w, in cm^3, and the net shear area A_{Sh}, in cm^2, of uniformly loaded hatch cover stiffeners constraint at both ends are not to be less than:

$$w = \frac{\kappa_1}{R_{eH}} s \ell^2 p$$

$$A_{Sh} = \frac{\kappa_2 s \ell p}{R_{eH}}$$

where:

κ_1 : Coefficient taken equal to:

- κ_1 = 104 for weathertight hatch covers loaded according to [3.1]
- κ_1 = 93 for weathertight hatch covers loaded according to [3.2.1]
- κ_1 = 123 for pontoon hatch covers loaded according to [3.1]
- κ_1 = 110 for pontoon hatch covers loaded according to [3.2.1]

κ_2 : Coefficient taken equal to:

- κ_2 = 10,8 for weathertight hatch covers loaded according to [3.1]
- κ_2 = 9,6 for weathertight hatch covers loaded according to [3.2.1]

ℓ : Ordinary stiffener span, in m, to be taken as the spacing, in m, of the primary supporting members or the distance between a primary supporting member and the edge support, as applicable

p : Pressure p_W or p_L, in kN/m^2, as defined in [3].

For secondary stiffeners of lower plating of double skin hatch covers, requirements mentioned above are not applied due to the absence of lateral loads.

The net thickness, in mm, of the stiffener (except u-beams/trapeze stiffeners) web is to be taken not less than 4 mm.

The net section modulus of the ordinary stiffeners is to be determined based on an attached plate width assumed equal to the stiffener spacing.

For flat bar ordinary stiffeners and buckling stiffeners on webs of primary supporting members, the ratio h_w / t_w is to be in compliance 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 ordinary stiffener

t_w : Net thickness, in mm, of the ordinary stiffener.

Stiffeners parallel to primary supporting members and arranged within the effective breadth according to [4.5.2] are to be continuous at crossing primary supporting members and may be regarded for calculating the cross-sectional properties of primary supporting members. It is to be verified that the combined stress of those stiffeners induced by the bending of primary supporting members and lateral pressures does not exceed the permissible stresses defined in [4.2.1]. The requirements of this paragraph are not applied to stiffeners of lower plating of double skin hatch covers if the lower plating is not considered as strength member.

For hatch cover stiffeners under compression, sufficient safety against lateral and torsional buckling according to [5.3.5] and [5.3.6] is to be verified.

4.4.2 Net scantlings of primary supporting members

Scantlings of primary supporting members are obtained from the calculations according to [4.5] under consideration of the permissible stresses defined in [4.2.1].

For all components of primary supporting members, sufficient safety against buckling is to be verified according to [5]. For biaxial compressed flange plates, this is to be verified within the effective widths according to [5.3.3].

The net thickness, in mm, of webs of primary supporting members is not to be less than the greater of:

- $t = 6{,}5\ s$
- $t_{min} = 5$ mm.

4.4.3 Edge girders (skirt plates)

Scantlings of edge girders are obtained from the calculations according to [4.5] under consideration of the permissible stresses defined in [4.2.1].

The net thickness, in mm, of the outer edge girders exposed to wash of sea is not to be less than the greatest of:

- $t = 15{,}8\ s \sqrt{\frac{p_A}{0{,}95 R_{eH}}}$
- $t = 8{,}5\ s$
- $t_{min} = 5$ mm,

where:

p_A : Horizontal pressure, in kN/m^2, as defined in [3.1.2].

The stiffness of edge girders is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia I, in cm^4, of edge girders is not to be less than:

$I = 6\ q\ s_{SD}^4$

where:

q : Packing line pressure, in N/mm, to be taken not less than 5 N/mm

s_{SD} : Spacing, in m, of securing devices.

4.4.4 Ordinary stiffeners and primary supporting members of variable cross-section

The net section modulus of ordinary stiffeners and primary supporting members with a variable cross-section is to be not less than the greater of the values obtained, in cm³, 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 cm³, for a constant cross-section, obtained according to [4.4.1]

$$\alpha = \frac{\ell_1}{\ell_0}$$

$$\psi = \frac{w_1}{w_0}$$

ℓ_1 : Length of the variable section part, in m (see Fig 5)

ℓ_0 : Span measured, in m, between end supports (see Fig 5)

w_1 : Net section modulus at end, in cm³ (see Fig 5)

w_0 : Net section modulus at mid-span, in cm³ (see Fig 5).

Moreover, the net moment of inertia of ordinary stiffeners and primary supporting members with a variable cross-section is to be not less than the greater of the values obtained, in cm⁴, 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 cm⁴, calculated with wave pressure, as given in [3.1.1] or distributed load as given in [3.2.1]. It is to be such that the deflection does not exceed (μ α), with μ as defined in [4.2.2]

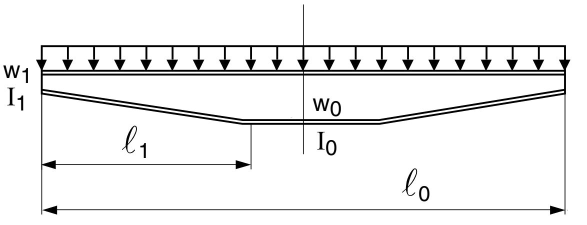
$$\varphi = I_1 / I_0$$

I_1 : Net moment of inertia at end, in cm⁴ (see Fig 5)

I_0 : Net moment of inertia at mid-span, in cm⁴ (see Fig 5).

The use of these formulae are limited to the determination of the strength of ordinary stiffeners and primary supporting members in which abrupt changes in the cross-section do not occur along their length.

Figure 5 : Variable cross-section stiffener



4.5 Strength calculations

4.5.1 General

Strength calculations for hatch covers may be carried out by either grillage analysis or finite element analysis. Double skin hatch covers or hatch covers with box girders are to be assessed using finite element analysis according to [4.5.3].

4.5.2 Effective cross-sectional properties for calculation by grillage analysis

Cross-sectional properties are to be determined considering the effective breadth. Cross-sectional areas of ordinary stiffeners parallel to the primary supporting member under consideration within the effective breadth can be included (see Fig 7).

The effective breadth of plating e_m of primary supporting members is to be determined according to Tab 5, considering the type of loading. Special calculations may be required for determining the effective breadth of one-sided or non-symmetrical flanges.

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

For flange plates under compression with ordinary stiffeners perpendicular to the web of the primary supporting member, the effective width is to be determined according to [5.3.3].

Table 5 : Effective breadth e_m of plating of primary supporting members

ℓ/e	0	1	2	3	4	5	6	7	≥ 8
e_{m1}	0	0,36 e	0,64 e	0,82 e	0,91 e	0,96 e	0,98 e	1,00 e	1,00 e
e_{m2}	0	0,20 e	0,37 e	0,52 e	0,65 e	0,75 e	0,84 e	0,89 e	0,90 e

Note 1:

ℓ : Length of zero-points of bending moment curve:
- $\ell = \ell_0$ for simply supported primary supporting members
- $\ell = 0{,}6\ \ell_0$ for primary supporting members with both ends constraint,

ℓ_0 : Unsupported length of the primary supporting member

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

e_{m1} : To be applied where primary supporting members are loaded by uniformly distributed loads or else by not less than 6 equally spaced single loads

e_{m2} : To be applied where primary supporting members are loaded by 3 or less single loads.

Note 2: Intermediate values may be obtained by direct interpolation.

4.5.3 General requirements for finite element analysis

For strength calculations of hatch covers by means of finite elements, the cover geometry is to be idealized as realistically as possible. Element size is to be appropriate to account for effective breadth. In no case element width is to be larger than stiffener spacing. In way of force transfer points and cutouts, the mesh has to be refined where applicable. The ratio of element length to width is not to exceed 4.

The element height of webs of primary supporting members is not to exceed one-third of the web height. Stiffeners, supporting plates against pressure loads, have to be included in the idealization. Stiffeners may be modelled by using shell elements, plane stress elements or beam elements. Buckling stiffeners may be disregarded for the stress calculation.

5 Buckling strength

5.1 General

5.1.1 Coamings

The buckling strength assessment of coaming parts is to be carried out according to Ch 7, Sec 1, Ch 7, Sec 2 and Ch 7, Sec 3.

5.1.2 Definitions

a : Length of the longer side of a single plate field, in mm (x-direction)

b : Breadth of the shorter side of a single plate field, in mm (y-direction)

α : Aspect ratio of the single plate field: $\alpha = a / b$

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

t : Net plate thickness, in mm

σ_x : Membrane stress, in N/mm², in x-direction

σ_y : Membrane stress, in N/mm², in y-direction

τ : Shear stress, in N/mm², in the x-y plane

F_1 : Correction factor for boundary condition at the longitudinal stiffeners, according to Tab 6

σ_e : Reference stress, in N/mm², taken equal to:

$\sigma_e = 0,9\ E\ (t/b)^2$

Ψ : Edge stress ratio taken equal to σ_1 / σ_2

σ_1 : Maximum compressive stress, in N/mm²

σ_2 : Minimum compressive stress or tension stress, in N/mm²

S : Safety factor (based on net scantling approach), taken equal to:

- S = 1,25 for hatch covers when subjected to the vertical weather design load according to [3.1.1]
- S = 1,10 for hatch covers when subjected to loads according to [3.1.2], [3.2] and [3.3]

λ : Reference degree of slenderness, taken equal to:

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

K : Buckling factor according to Tab 7.

Table 6 : Correction factor F_1

Stiffeners sniped at both ends		F_1 = 1,00
Stiffeners with both ends effectively connected to adjacent structures	flat bars	F_1 = 1,05 **(1)**
	bulb sections	F_1 = 1,10 **(1)**
	angles and tee-sections	F_1 = 1,20 **(1)**
	u-type sections **(2)** and girders of high rigidity	F_1 = 1,30 **(1)**

(1) F_1 values are guidance values. Exact values may be determined by direct calculations.
(2) A higher value may be taken, if it is verified by a buckling strength check of the partial plate field using non-linear finite element analysis, but not greater than 2,0.
Note 1: An average value of F_1 is to be used for plate panels having different edge stiffeners.

5.1.3 Sign convention

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

5.2 Plating

5.2.1 Proof of hatch cover top and lower plating

Proof is to be provided that the following condition, in which the first two terms and the last term are not to exceed 1,0, is complied with for the single plate field a · b:

$$\left(\frac{|\sigma_x|S}{\kappa_x R_{eH}}\right)^{e1} + \left(\frac{|\sigma_y|S}{\kappa_y R_{eH}}\right)^{e2} - B\left(\frac{\sigma_x\sigma_y S^2}{R_{eH}^{\ 2}}\right) + \left(\frac{|\tau| S\sqrt{3}}{\kappa_\tau R_{eH}}\right)^{e3} \leq 1,0$$

where:

$e_1 = 1 + \kappa_x^4$

$e_2 = 1 + \kappa_y^4$

$e_3 = 1 + \kappa_x\ \kappa_y\ \kappa_\tau^2$

B : Factor taken equal to:

- for σ_x and σ_y positive (compression stress):
  $B = (\kappa_x\ \kappa_y)^5$
- for σ_x or σ_y negative (tension stress):
  B = 1,00

κ_x, κ_y, κ_τ : Reduction factors as given in Tab 7, with:

- $\kappa_x = 1,0$ when $\sigma_x \leq 0$ (tension stress)
- $\kappa_y = 1,0$ when $\sigma_y \leq 0$ (tension stress).

5.2.2 Poisson-effect

If stresses in the x- and y-directions already contain the Poisson-effect (calculated using finite element analysis), the following modified stress values may be used. Both stresses σ_x^* and σ_y^* are to be compressive stresses, in order to apply the stress reduction according to the following formulae:

$\sigma_x = (\sigma_x^* - 0,3\ \sigma_y^*) / 0,91$

$\sigma_y = (\sigma_y^* - 0,3\ \sigma_x^*) / 0,91$

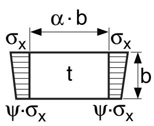
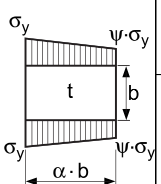
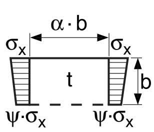
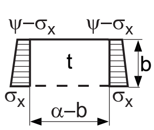
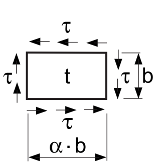
with:

σ_x^*, σ_y^* : Stresses containing the Poisson-effect.

Where the compressive stress fulfils the condition:

- $\sigma_y^* < 0,3\ \sigma_x^*$, then: $\sigma_y = 0$ and $\sigma_x = \sigma_x^*$
- $\sigma_x^* < 0,3\ \sigma_y^*$, then: $\sigma_x = 0$ and $\sigma_y = \sigma_y^*$

Table 7 : Buckling factor K and reduction factor κ for plane elementary plate panels

Case	Stress ratio ψ	Aspect ratio α α = a/b	Buckling factor K	Reduction factor κ
1 	$1 \ge \psi \ge 0$	$\alpha \ge 1$	$K = \frac{8,4}{\psi + 1,1}$	$\kappa_x = 1$ for $\lambda \le \lambda_c$ $\kappa_x = c\left(\frac{1}{\lambda} - \frac{0,22}{\lambda^2}\right)$ for $\lambda > \lambda_c$
	$0 > \psi > -1$		$K = 7,63 - \psi\ (6,26 - 10\psi)$	where: $c = (1,25 - 0,12\psi) \le 1,25$
	$\psi \le -1$		$K = 5,975(1 - \psi)^2$	$\lambda_c = \frac{c}{2}\left(1 + \sqrt{1 - \frac{0,88}{c}}\right)$
2 	$1 \ge \psi \ge 0$	$\alpha \ge 1$	$K = F_1\left(1 + \frac{1}{\alpha^2}\right)^2 \frac{2,1}{(\psi + 1,1)}$	$\kappa_y = c\left(\frac{1}{\lambda} - \frac{R + F^2\ (H - R)}{\lambda^2}\right)$ where: $c = (1,25 - 0,12\psi) \le 1,25$
	$0 > \psi > -1$	$1 \le \alpha \le 1,5$	$K = F_1\left[\left(1 + \frac{1}{\alpha^2}\right)^2 \frac{2,1\ (1 + \psi)}{1,1} - \frac{\psi}{\alpha^2}(13,9 - 10\psi)\right]$	$R = \lambda\ (1 - \lambda / c)$ for $\lambda < \lambda_c$ $R = 0,22$ for $\lambda \ge \lambda_c$
		$\alpha > 1,5$	$K = F_1\left[\left(1 + \frac{1}{\alpha^2}\right)^2 \frac{2,1\ (1 + \psi)}{1,1} - \frac{\psi}{\alpha^2}\left(5,87 + 1,87\ \alpha^2 + \frac{8,6}{\alpha^2} - 10\psi\right)\right]$	$\lambda_c = \frac{c}{2}\left(1 + \sqrt{1 - \frac{0,88}{c}}\right)$
	$\psi \le -1$	$1 \le \alpha \le \frac{3(1 - \psi)}{4}$	$K = 5,975\ F_1\left(\frac{1 - \psi}{\alpha}\right)^2$	$F = c_1\left[1 - \left(\frac{K}{0,91} - 1\right) / \lambda_p^2\right] \ge 0$ $\lambda_p^2 = \lambda^2 - 0,5$ for $1 \le \lambda_p^2 \le 3$
		$\alpha > \frac{3(1 - \psi)}{4}$	$K = F_1\left[3,9675\left(\frac{1 - \psi}{\alpha}\right)^2 + 0,5375\left(\frac{1 - \psi}{\alpha}\right)^4 + 1,87\right]$	$c_1 = (1 - F_1/\alpha) \ge 0$ $H = \lambda - \frac{2\lambda}{c\ (T + \sqrt{T^2 - 4})} \ge R$ $T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$
3 	$1 \ge \psi \ge 0$	$\alpha > 0$	$K = \left[4\left(0,425 + \frac{1}{\alpha^2}\right)\right] / (3\psi + 1)$	$\kappa_x = 1$ for $\lambda \le 0,7$ $\kappa_x = \frac{1}{\lambda^2 + 0,51}$ for $\lambda > 0.7$
	$0 > \psi \ge -1$		$K = 4\left(0,425 + \frac{1}{\alpha^2}\right)\ (1 + \psi) - 5\psi\ (1 - 3,42\ \psi)$	
4 	$1 \ge \psi \ge -1$	$\alpha > 0$	$K = \left(0,425 + \frac{1}{\alpha^2}\right)\frac{3 - \psi}{2}$	
5 			$K = K_\tau \sqrt{3}$	$\kappa_\tau = 1$ for $\lambda \le 0,84$
		$\alpha \ge 1$	$K_\tau = 5,34 + \frac{4}{\alpha^2}$	
		$0 < \alpha < 1$	$K_\tau = 4 + \frac{5,34}{\alpha^2}$	$\kappa_\tau = \frac{0,84}{\lambda}$ for $\lambda > 0,84$

Note 1: Explanations for boundary conditions:
- - - - - - - - - - - - plate edge free
______________ plate edge simply supported.

5.2.3 Webs and flanges of primary supporting members

For non-stiffened webs and flanges of primary supporting members, sufficient buckling strength as for the hatch cover top and lower plating is to be demonstrated according to [5.2.1].

5.3 Proof of partial and total fields of hatch covers

5.3.1 Longitudinal and transverse ordinary stiffeners

The continuous longitudinal and transverse stiffeners of partial and total plate fields are to comply with the conditions set out in [5.3.5] through [5.3.7], taking account of the effective width of attached plating defined in [5.3.2].

For u-type stiffeners, the proof of torsional buckling strength according to [5.3.6] can be omitted.

Single-side welding is not permitted to use for secondary stiffeners except for u-stiffeners.

5.3.2 Effective width of attached plating of ordinary stiffeners

The effective width of attached plating of ordinary stiffeners, to be considered for buckling assessment, may be determined by the following formulae (see also Fig 6):

- for longitudinal stiffeners: $b_m = \kappa_x b$
- for transverse stiffeners: $a_m = \kappa_y a$

The effective width of attached plating is not to be taken greater than the value obtained from [4.5.2].

5.3.3 Effective width of attached plating of primary supporting members

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

- Stiffening parallel to web of primary supporting members (see Fig 7):

  $b < e_m$

  $e'_m = n\, b_m$

  n : Integer number of stiffener spacings b inside the effective breadth e_m according to [4.5.2]:

  $n = \text{int}(e_m / b)$

- Stiffening perpendicular to web of primary supporting members (see Fig 8):

  $a \geq e_m$

  $e'_m = n\, a_m$, to be taken less than e_m

  $n = 2{,}7\, e_m / a$, to be taken not greater than 1,0

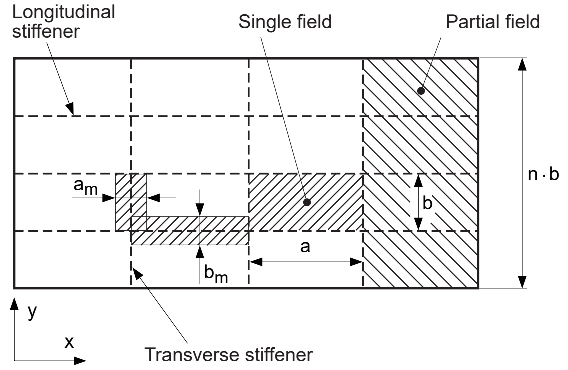
where:

e_m : Effective width of plating, as defined in [4.5.2].

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

a_m and b_m for flange plates are in general to be determined for $\Psi = 1$.

Figure 6 : General arrangement of panel



Longitudinal stiffener: in the direction of length a

Transverse stiffener: in the direction of breadth b.

Figure 7 : Stiffening parallel to web of primary supporting members

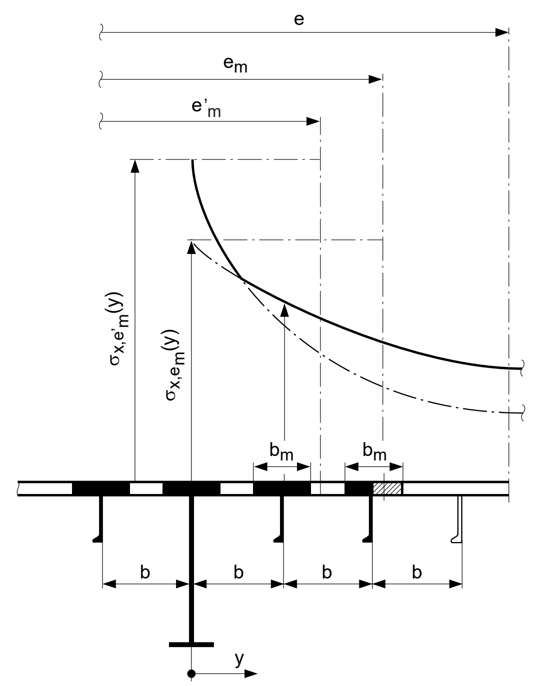
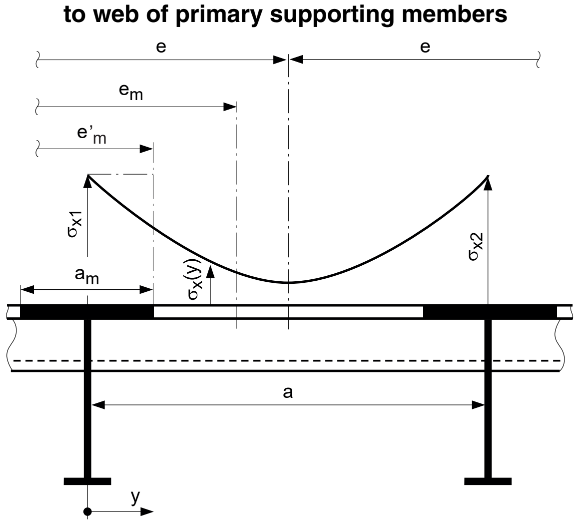


Figure 8 : Stiffening perpendicular to web of primary supporting members



5.3.4 Stress distribution between two primary supporting members

Scantlings of plates and stiffeners are in general to be determined according to the maximum stresses $\sigma_x(y)$ at webs of primary supporting member and stiffeners, respectively. For stiffeners with spacing b under compression arranged parallel to primary supporting members, no value less than 0,25 R_{eH} is to be inserted for $\sigma_x(y=b)$.

The stress distribution between two primary supporting members can be obtained by the following formula:

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

where:

$$c_1 = \frac{\sigma_{x2}}{\sigma_{x1}} \quad \text{with } 0 \le c_1 \le 1$$

$$c_2 = \frac{1,5}{e}(e''_{m1} + e''_{m2}) - 0,5$$

e''_{m1} : Proportionate effective breadth e_{m1} or proportionate effective width e'_{m1} of primary supporting member 1 within the distance e, as appropriate

e''_{m2} : Proportionate effective breadth e_{m2} or proportionate effective width e'_{m2} of primary supporting member 2 within the distance e, as appropriate

σ_{x1} σ_{x2} : Normal stresses in flange plates of adjacent primary supporting members 1 and 2 with spacing e, based on cross-sectional properties considering the effective breadth or effective width, as appropriate

y : Distance of considered location from primary supporting member 1.

5.3.5 Lateral buckling of ordinary stiffeners

The longitudinal and transverse ordinary stiffeners are to comply with the following criteria:

$$\frac{\sigma_a + \sigma_b}{R_{eH}} S \le 1$$

where:

σ_a : Uniformly distributed compressive stress, in N/mm², in the direction of the stiffener axis:

- for longitudinal stiffeners: $\sigma_a = \sigma_x$
- for transverse stiffeners: $\sigma_a = \sigma_y$

σ_b : Bending stress, in N/mm², in the stiffener, taken equal to:

$$\sigma_b = \frac{M_0 + M_1}{w_{st}10^3}$$

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)

w_{st} : Net section modulus of stiffener (longitudinal or transverse), in cm³, including effective width of plating according to [5.3.2]

M_0 : Bending moment, in N·mm, due to the deformation δ of stiffener, taken equal to:

$$M_0 = F_{Ki}\left(\frac{p_z\,\delta}{c_f - p_z}\right) \text{ with } (c_f - p_z) > 0$$

M_1 : Bending moment, in N·mm, due to the lateral load p, taken equal to:

- for longitudinal stiffeners:

$$M_1 = \frac{pba^2}{24 \cdot 10^3}$$

- for transverse stiffeners:

$$M_1 = \frac{pa(nb)^2}{8c_s10^3}$$

with n to be taken equal to 1 for ordinary transverse stiffeners

p : Lateral load, in kN/m²

F_{Ki} : Ideal buckling force, in N, of the stiffener, taken equal to:

- for longitudinal stiffeners:

$$F_{Kix} = \left(\frac{\pi}{a}\right)^2 EI_x10^4$$

- for transverse stiffeners:

$$F_{Kiy} = \left(\frac{\pi}{nb}\right)^2 EI_y10^4$$

I_x, I_y : Net moments of inertia, in cm⁴, of the longitudinal or transverse stiffener including effective width of attached plating according to [5.3.2].

I_x and I_y are to comply with the following criteria:

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

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

p_z : Nominal lateral load of the stiffener, in N/mm², due to σ_x, σ_y and τ:

- for longitudinal stiffeners:

$$p_{zx} = \frac{t}{b}\left[\sigma_{xl}\left(\frac{\pi\,b}{a}\right)^2 + 2c_y\sigma_y + \sqrt{2}\tau_1\right]$$

- for transverse stiffeners:

$$p_{zy} = \frac{t}{a}\left[2c_x\sigma_{xl} + \sigma_y\left(\frac{\pi\,a}{nb}\right)^2\left(1 + \frac{A_y}{at}\right) + \sqrt{2}\tau_1\right]$$

$$\sigma_{xl} = \sigma_x\left(1 + \frac{A_x}{bt}\right)$$

c_x, c_y : Factors taking into account the stresses perpendicular to the stiffener's axis and distributed variable along the stiffener's length, taken equal to:

- 0,5 (1 + Ψ) for 0 ≤ Ψ ≤ 1
- 0,5 / (1 − Ψ) for Ψ < 0

A_x, A_y : Net sectional areas, in mm², of the longitudinal or transverse stiffener, respectively, without attached plating

$$\tau_1 = \left[\tau - t\sqrt{R_{eH}E\left(\frac{m_1}{a^2}+\frac{m_2}{b^2}\right)}\right] \geq 0$$

m_1 , m_2 : Coefficients taken equal to:

- for longitudinal stiffeners:

  if a/b ≥ 2,0: m_1 = 1,47 and m_2 = 0,49

  if a/b < 2,0: m_1 = 1,96 and m_2 = 0,37

- for transverse stiffeners:

  if a/(n·b) ≥ 0,5: m_1 = 0,37 and m_2 = 1,96/n^2

  if a/(n·b) < 0,5: m_1 = 0,49 and m_2 = 1,47/n^2

$\delta = \delta_0 + \delta_1$

δ_0 : Assumed imperfection, in mm

- for longitudinal stiffeners:

  δ_{0x} ≤ min (a/250 ; b/250 ; 10)

- for transverse stiffeners:

  δ_{0y} ≤ min (a/250 ; n·b/250 ; 10)

For stiffeners sniped at both ends, δ_0 is not to be taken less than the distance from the midpoint of plating to the neutral axis of the profile including effective width of plating

δ_1 : Deformation of stiffener, in mm, at midpoint of stiffener span, due to lateral load p.

In case of uniformly distributed load, the following values may be used:

- for longitudinal stiffeners:

$$\delta_1 = \frac{pba^4}{384EI_x10^7}$$

- for transverse stiffeners:

$$\delta_1 = \frac{5ap(nb)^4}{384EI_yc_s^2 10^7}$$

c_f : Elastic support provided by the stiffener, in N/mm², taken equal to:

- for longitudinal stiffeners:

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

$$c_{px} = \frac{1}{1+\frac{0.91}{c_{xa}}\left(\frac{12I_x}{bt^3}10^4-1\right)}$$

c_{xa} : Coefficient taken equal to:

- for a ≥ 2 b:

$$c_{xa} = \left(\frac{a}{2b}+\frac{2b}{a}\right)^2$$

- for a < 2 b:

$$c_{xa} = \left[1+\left(\frac{a}{2b}\right)^2\right]^2$$

- for transverse stiffeners:

$$c_{fy} = c_sF_{Kiy}\left(\frac{\pi}{nb}\right)^2(1+c_{py})$$

$$c_{py} = \frac{1}{1+\frac{0.91}{c_{ya}}\left(\frac{12I_y}{at^3}10^4-1\right)}$$

c_{ya} : Coefficient taken equal to:

- for (n b) ≥ 2 a:

$$c_{ya} = \left(\frac{nb}{2a}+\frac{2a}{nb}\right)^2$$

- for (n b) < 2 a:

$$c_{ya} = \left[1+\left(\frac{nb}{2a}\right)^2\right]^2$$

c_s : Factor accounting for the boundary conditions of the transverse stiffener, taken equal to:

- c_s = 1,0 for simply supported stiffeners
- c_s = 2,0 for partially constraint stiffeners.

5.3.6 Torsional buckling of longitudinal ordinary stiffeners

The longitudinal ordinary stiffeners are to comply with the following criteria:

$$\frac{\sigma_x S}{\kappa_T R_{eH}} \leq 1,0$$

where:

κ_T : Coefficient taken equal to:

- for $\lambda_T \leq 0,2$:

  $\kappa_T = 1,0$

- for $\lambda_T > 0,2$:

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

$$\Phi = \frac{1}{2}[1+0,21(\lambda_T-0,2)+\lambda_T^2]$$

λ_T : Reference degree of slenderness, taken equal to:

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

$$\sigma_{KiT} = \frac{E}{I_P}\left(\frac{\varepsilon\pi^2 I_\omega 10^2}{a^2}+0,385I_T\right), \text{ in N/mm}^2$$

I_p : Net polar moment of inertia of the stiffener, in cm⁴, defined in Tab 8 and related to the point C

I_T : Net St. Venant's moment of inertia of the stiffener, in cm⁴, defined in Tab 8

I_ω : Net sectorial moment of inertia of the stiffener, in cm⁶, defined in Tab 8 and related to the point C

ε : Degree of fixation, taken equal to:

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

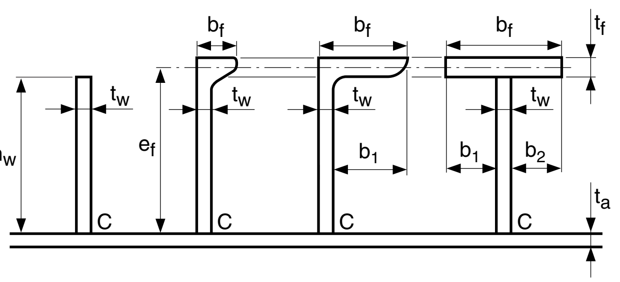
h_w , t_w : As defined in Tab 8.

Table 8 : Moments of inertia

Moment of inertia	Flat bars	Bulb sections	Angle sections	T-sections
I_p	$\dfrac{h_w^3\ t_w}{3 \cdot 10^4}$	$\left(\dfrac{A_w h_w^2}{3} + A_f\ e_f^2\right)\ 10^{-4}$		
I_T	$\dfrac{h_w\ t_w^3}{3 \cdot 10^4}\left(1 - 0,63\ \dfrac{t_w}{h_w}\right)$	$\dfrac{h_w\ t_w^3}{3 \cdot 10^4}\left(1 - 0,63\ \dfrac{t_w}{h_w}\right) + \dfrac{b_f\ t_f^3}{3 \cdot 10^4}\left(1 - 0,63\ \dfrac{t_f}{b_f}\right)$		
I_ω	$\dfrac{h_w^3\ t_w^3}{36 \cdot 10^6}$	$\dfrac{A_f\ e_f^2\ b_f^2}{12 \cdot 10^6}\left(\dfrac{A_f + 2,6A_w}{A_f + A_w}\right)$		$\dfrac{b_f^3\ t_f\ e_f^2}{12 \cdot 10^6}$

Note 1:

- h_w : Web height, in mm
- t_w : Net web thickness, in mm
- b_f : Flange breadth, in mm
- t_f : Net flange thickness, in mm
- A_w : Net web area, in mm², equal to: $A_w = h_w\ t_w$
- A_f : Net flange area, in mm², equal to: $A_f = b_f\ t_f$
- e_f : Distance, in mm, equal to: $e_f = h_w + t_f / 2$



5.3.7 Torsional buckling of transverse ordinary stiffeners

For transverse ordinary stiffeners loaded by compressive stresses and which are not supported by longitudinal stiffeners, sufficient torsional buckling strength is to be demonstrated analogously in accordance with [5.3.6].

6 Weathertightness

6.1 Weathertightness

6.1.1 Where the hatchway is exposed, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality.

Weathertightness may also be ensured by means of tarpaulins.

6.1.2 In general, a minimum of two securing devices or equivalent is to be provided on each side of the hatch cover.

6.2 Gaskets

6.2.1 Packing material

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.

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
- made of a corrosion-resistant material.

The gasket is to be effectively secured to the hatch cover.

The packing material is to be:

- suitable for all expected service conditions of the ship
- compatible with the cargoes to be transported, and
- selected with regard to dimensions and elasticity in such a way that expected deformations can be carried.

The packings are to be compressed so as to give the necessary tightness effect for all expected operating conditions. Special consideration is to be given to the packing arrangement in ships with large relative movements between hatch covers and coamings or between hatch cover sections.

If necessary, suitable devices are to be fitted to limit such movements.

Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

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.

6.2.2 Dispensation of weathertight gaskets

For hatch covers of cargo holds solely for the transport of containers, upon request by the Owner and subject to compliance with the following conditions, the fitting of weathertight gaskets according to [6.2.1] may be dispensed:

- The hatchway coamings are to be not less than 600 mm in height.
- The exposed deck on which the hatch covers are located is situated above a depth H(x). H(x), in m, is to be shown to comply with the following criterion:

  $H(x) \geq T + f_b + h$

where:

f_b : Minimum required freeboard, in m, determined according to ICLL Reg.28, as amended

h : Distance, in m, taken equal to:

- for $x / L_{LL} \le 0,75$: $h = 2\ h_s$
- for $x / L_{LL} > 0,75$: $h = 3\ h_s$

h_s : Standard height of superstructure, defined in Ch 1, Sec 2, Tab 2.

- Labyrinths, gutter bars or equivalent are to be fitted near the edges of each panel in way of the gaps to minimise the amount of water that can enter the container hold from the top surface of each panel.
- The labyrinths and gaps between hatch cover panels are to be considered as unprotected openings with respect to the requirements of intact and damage stability calculations.
- The non-weathertight gaps between hatch cover panels are to be as small as possible commensurate with the capacity of the bilge system and expected water ingress, and the capacity and operational effectiveness of the fire-fighting system and, in general, not greater than 50 mm.
- With regard to drainage of cargo holds and the necessary fire-fighting system, reference is made to applicable requirements in Part C, Chapter 1 and Part C, Chapter 4.
- Bilge alarms are to be provided in each hold fitted with non-weathertight covers.
- Scantlings of the hatch cover panels are to be equivalent to those for weathertight covers and in accordance with the applicable requirements of the present Section.

7 Construction details

7.1 Container foundations on hatch covers

7.1.1 Strength requirements

The substructures of container foundations are to be designed for cargo and container loads according to [3.2], applying the permissible stresses according to [4.2.1].

8 Hatch coamings

8.1 Arrangement of hatch coamings

8.1.1 Longitudinal strength

Hatch coamings which are part of the longitudinal hull structure are to comply with the applicable requirements of Part B, Chapter 6.

For structural members welded to coamings and for cutouts in the top of coamings, fatigue strength calculations may be required by the Society.

Longitudinal hatch coamings with a length exceeding, in m, 0,1 L are to be provided with tapered brackets or equivalent transitions and a corresponding substructure at both ends. At the end of the brackets, they are to be connected to the deck by full penetration welds of minimum 300 mm in length.

8.1.2 Local details

The design of local details is to be adequate for the purpose of transferring the loads 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.

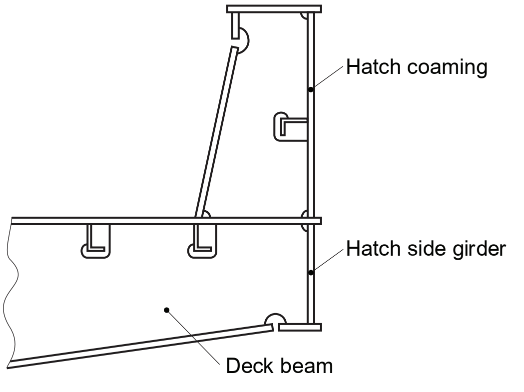
8.1.3 Stays

On ships carrying cargo on deck, such as timber, coal or coke, the stays are to be spaced not more than 1,5 m apart.

8.1.4 Extent of coaming plates

Coaming plates are to extend to the lower edge of the deck beams or hatch side girders are to be fitted that extend to the lower edge of the deck beams. Extended coaming plates and hatch side girders are to be flanged or fitted with face bars or half-round bars. Fig 9 gives an example.

Figure 9 : Example for the extent of coaming plates



8.2 Stiffening

8.2.1 The ordinary stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

8.2.2 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.

8.2.3 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.

8.2.4 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.

8.2.5 Where watertight metallic hatch covers are fitted, other arrangements of equivalent strength may be adopted.

8.3 Hatch coaming strength criteria

8.3.1 Local net plate thickness of coamings

The net thickness of weather deck hatch coamings, in mm, is to be not less than the greater of the following values:

$$t = 14{,}2\, s \sqrt{\frac{p_A}{0{,}95 R_{eH}}}$$

$$t_{min} = 6 + \frac{L_3}{100}$$

8.3.2 Net scantling of ordinary stiffeners of coamings

For stiffeners with both ends constraint, the elastic net section modulus w, in cm^3, and net shear area A_{Sh}, in cm^2, calculated on the basis of net thickness, are to be not less than:

$$w = \frac{83}{R_{eH}} s \ell^2 p_A$$

$$A_{Sh} = \frac{10 s \ell p_A}{R_{eH}}$$

where:

ℓ : Ordinary stiffener span, in m, to be taken as the spacing of coaming stays.

For sniped stiffeners of coaming at hatch corners, the section modulus and shear area at the fixed support are to be increased by 35%. The gross thickness of the coaming plate, in mm, at the sniped stiffener end is to be not less than:

$$t = 19{,}6 \sqrt{\frac{p_A s(\ell - 0{,}5\, s)}{R_{eH}}}$$

Horizontal stiffeners on hatch coamings, which are part of the longitudinal hull structure, are to be designed according to the applicable requirements in Ch 7, Sec 2, using the horizontal weather design load p_A as defined in [3.1].

8.3.3 Coaming stays

Coaming stays are to be designed for the loads transmitted through them and permissible stresses according to [4.2.1].

8.3.4 Coaming stay section modulus and web thickness

At the connection with deck, the net section modulus w, in cm^3, and the gross thickness t_w , in mm, of coaming stays designed as beams with flange as shown in examples 1 and 2 of Fig 10 are to be taken not less than:

$$w = \frac{526}{R_{eH}} e h_s^2 p_A$$

$$t_w = \frac{2}{R_{eH}} \frac{e h_s p_A}{h_w} + t_s$$

where:

e : Spacing of coaming stays, in m

h_s : Height of coaming stays, in m

h_w : Web height of coaming stay at its lower end, in m

t_C : Corrosion addition, in mm, according to [1.4].

For other designs of coaming stays, such as those shown in examples 3 and 4 of Fig 10, the stresses are to be determined through a grillage analysis or finite element analysis. The calculated stresses are to comply with the permissible stresses according to [4.2.1].

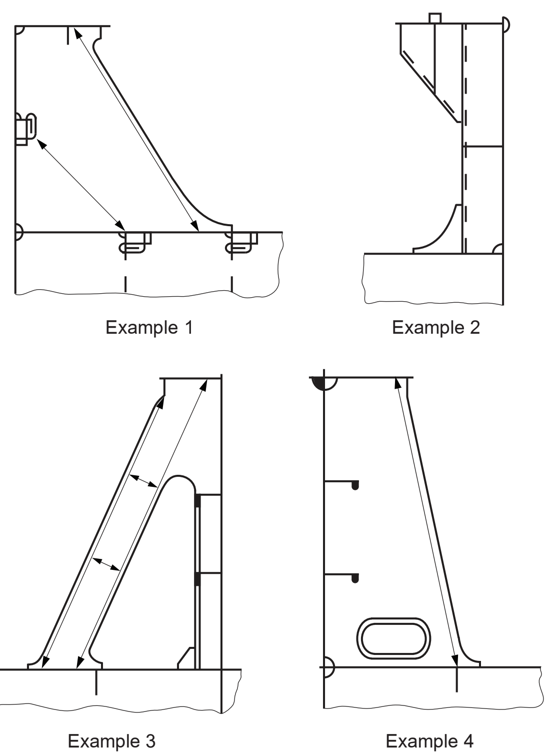
Coaming stays are to be supported by appropriate substructures. Face plates may only be included in the calculation if an appropriate substructure is provided and welding provides an adequate joint.

Webs are to be connected to the deck by fillet welds on both sides with a throat thickness of not less than 0,44 t_w.

8.3.5 Coaming stays under friction load

For coaming stays, which transfer friction forces at hatch cover supports, fatigue strength is to be checked (refer also to [9.2.2]).

Figure 10 : Examples of coaming stays



9 Closing arrangements

9.1 Securing devices

9.1.1 General

Securing devices between cover and coaming and at cross-joints are to be installed to provide weathertightness. Sufficient packing line pressure is to be maintained.

Securing devices are to be appropriate to bridge displacements between cover and coaming due to hull deformations.

Securing devices are to be of reliable construction and effectively attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

Sufficient number of securing devices is to be provided at each side of the hatch cover considering the requirements of [4.4.3]. This applies also to hatch covers consisting of several parts.

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 [9.1.7]. Lifting forces from cargo secured on the hatch cover during rolling are also to be taken into account.

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.

9.1.2 Arrangements

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.

9.1.3 Spacing

The spacing of the securing arrangements is to be generally not greater than 6 m.

The spacing of securing arrangements of tank hatch covers in 'tweendecks is to be not greater than 600 mm.

9.1.4 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.

9.1.5 Materials

The materials of stoppers, securing devices and their weldings are to comply with the applicable requirements of Ch 4, Sec 1 and Part B, Chapter 11 respectively. Specifications of the materials are to be shown in the drawings of the hatch covers.

9.1.6 Cleats

Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

Where hydraulic cleating is adopted, a positive means is to be provided so that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

9.1.7 Cross-sectional area of the securing devices

The gross cross-sectional area, in cm², of the securing devices is not to be less than:

$$A = 0,28\, q s_{SD} k_\ell$$

where:

q : Packing line pressure, in N/mm, to be taken not less than 5 N/mm

s_{SD} : Spacing between securing devices, in m, to be taken not less than 2 m

$$k_\ell = (235 / R_{eH})^e$$

R_{eH} : Minimum yield strength of the material, in N/mm², without being taken greater than 0,7 R_m

R_m : Tensile strength of the material, in N/mm²

e : Coefficient taken equal to:

- for $R_{eH} > 235$ N/mm²: e = 0,75
- for $R_{eH} \leq 235$ N/mm²: e = 1,00

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5 m² in area.

Securing devices of special design in which significant bending or shear stresses occur may be designed as anti-lifting devices according to [9.1.8]. As load, the packing line pressure q multiplied by the spacing between securing devices s_{SD} is to be applied.

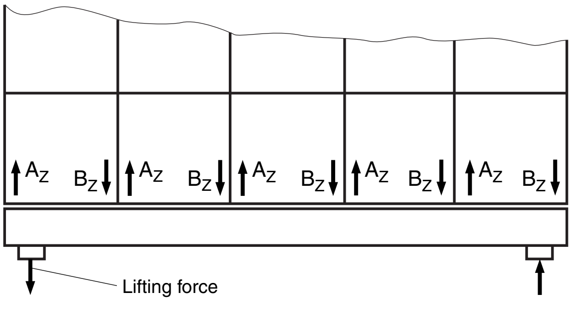
9.1.8 Anti lifting devices

The securing devices of hatch covers, on which cargo is to be lashed, are to be designed for the lifting forces resulting from loads according to [3.2.4] (see Fig 11). Unsymmetrical loadings, which may occur in practice, are to be considered. Under these loadings, the equivalent stress, in N/mm², in the securing devices is not to exceed:

$\sigma_v = 150 / k_\ell$

Note 1: The partial load cases given in Tab 4 may not cover all unsymmetrical loadings, critical for hatch cover lifting.

Figure 11 : Lifting forces at a hatch cover



9.2 Hatch cover supports, stoppers and supporting structures

9.2.1 Horizontal forces

For the design of hatch cover supports, the horizontal force F_h, in kN, to be considered is given by the following formula:

$F_h = m\, \alpha$

where:

α : Acceleration taken equal to:
- in longitudinal direction: $\alpha_X = 0{,}2$ g
- in transverse direction: $\alpha_Y = 0{,}5$ g

m : Sum of mass of cargo lashed on the hatch cover and mass of hatch cover, in t.

The accelerations in longitudinal and transverse direction do not need to be considered as acting simultaneously.

9.2.2 Hatch cover supports

For the transmission of the support forces resulting from the load cases specified in [3] and of the horizontal mass forces specified in [9.2.1], supports are to be provided which are to be designed such that the nominal surface pressures, in N/mm², do not exceed in general the following values:

$p_{n\,max} = d\, p_n$

where:

d : Parameter taken equal to:

$d = 3{,}75 - 0{,}015\, L$,

to be taken not greater than $d_{max} = 3{,}0$ and not less than d_{min}

d_{min} : Parameter defined as follows:
- $d_{min} = 1{,}0$ in general
- $d_{min} = 2{,}0$ for partial loading conditions, see [3.2.5]

p_n : Permissible nominal surface pressure, in N/mm², as defined in Tab 9.

Table 9 : Permissible nominal surface pressure p_n

Support material	p_n, in N/mm², when loaded by:	
	vertical force	horizontal force (on stoppers)
Hull structural steel	25	40
Hardened steel	35	50
Lower friction materials	50	–

For metallic supporting surfaces not subjected to relative displacements, the nominal surface pressure, in N/mm², is to be taken equal to:

$p_{n\,max} = 3\; p_n$

Note 1: When the vertical hatch cover support material manufacturer can provide proof that the material is sufficient for the increased surface pressure, not only statically but under dynamic conditions including relative motion for adequate number of cycles, permissible nominal surface pressure may be relaxed on a case-by-case basis, pending realistic long term distribution of spectra for vertical loads and relative horizontal motion.

Drawings of the supports are to be submitted, specifying the permitted maximum pressure given by the material manufacturer related to long time stress.

Where large relative displacements of the supporting surfaces are to be expected, the use of material having low wear and frictional properties is recommended.

The substructures of the supports are to be of such a design, that a uniform pressure distribution is achieved.

Irrespective of the arrangement of stoppers, the supports are to be able to transmit the following force P_h, in kN, in the longitudinal and transverse directions:

$$P_h = \mu_1 \frac{P_V}{\sqrt{d}}$$

where:

P_V : Vertical supporting force, in kN.

μ_1 : Frictional coefficient, taken equal generally to 0,5

For non-metallic, low-friction support materials on steel, μ_1 may be reduced, without being taken less than 0,35.

Supports as well as the adjacent structures and substructures are to be designed such that the permissible stresses according to [4.2.1] are not exceeded.

For substructures and adjacent structures of supports subjected to horizontal forces P_h, fatigue strength may be checked.

9.2.3 Hatch cover stoppers

Hatch covers are to be sufficiently secured against horizontal shifting. Stoppers are to be provided for hatch covers on which cargo is carried.

The greater of the loads resulting from [3.1.2] and [9.2.1] is to be applied for the dimensioning of the stoppers and their substructures.

The permissible stress in stoppers and their substructures, in the cover, and of the coamings is to be determined according to [4.2.1]. In addition, the provisions in [9.2.2] are to be observed.

9.3 Tarpaulins

9.3.1 *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.

9.4 Wedges, battens and locking bars

9.4.1 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.*

9.4.2 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.

10 Drainage

10.1 Drainage arrangement at the coaming

10.1.1 If drain channels are provided inside the line of gasket by means of a gutter bar or vertical extension of the hatch side and end coaming, drain openings are to be provided at appropriate positions of the drain channels.

10.1.2 Drain openings in hatch coamings are to be arranged with sufficient distance to areas of stress concentration (e.g. hatch corners, transitions to crane posts).

10.1.3 Drain openings are to be arranged at the ends of drain channels and are to be provided with non-return valves to prevent ingress of water from outside. It is unacceptable to connect fire hoses to the drain openings for this purpose.

10.1.4 Cross-joints of multi-panel covers are to be provided with efficient drainage arrangements.

10.1.5 If a continuous outer steel contact between cover and ship structure is arranged, drainage from the space between the steel contact and the gasket is also to be provided for.

11 Testing

11.1 Initial test of watertight hatches

11.1.1 Watertight hatches are to be tested by water pressure to the maximum head of water they might sustain in a final or intermediate stage of flooding.

For cargo ships not covered by damage stability requirements, watertight hatches are to be tested by water pressure to a head of water measured from the lower edge of the opening to one metre above the freeboard deck.

11.2 Prototype test

11.2.1 *Where testing of individual hatches is not carried out because of possible damage to insulation or outfitting items, testing of individual hatches may be replaced by a prototype pressure test of each type and size of hatch with a test pressure corresponding at least to the head required for the individual location. The prototype test is to be carried out before the hatch is fitted. The installation method and procedure for fitting the hatch on board is to correspond to that of the prototype test. When fitted on board, each door is to be checked for proper seating between the deck, the coaming and the hatch.*

SECTION 8 SMALL HATCHES

1 General

1.1 Definition

1.1.1 Small hatches are hatches designed for access to spaces below the deck and are capable to be closed weathertight or watertight, as applicable. Their opening is generally equal to or less than 2,5 m^2.

1.2 Application

1.2.1 The requirements in Article [2] apply to small hatch covers fitted on exposed decks.

1.2.2 The requirements in Article [3] apply to small hatch covers fitted on the exposed fore deck over the forward 0,25 L, for ships equal to or greater than 80 m in length, 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.

1.2.3 The requirements in Article [4] apply to small hatch covers fitted on non-exposed decks.

1.3 Materials

1.3.1 Steel

Materials used for the construction of steel small hatch covers are to comply with the applicable requirements of NR216 Materials and Welding, Chapter 2.

1.3.2 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.

2 Small hatches fitted on exposed decks

2.1 General

2.1.1 Hatch covers on exposed decks are to be weathertight.

2.1.2 The height of small hatch 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 secured weathertight by gaskets and swing bolts, the height of the coamings may be reduced or the coamings may be omitted altogether.

2.1.3 In any case the gross thickness of covers is to be not less than that of the adjacent plating, based on the same spacing and the same steel.

2.1.4 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.

2.1.5 Hatches of special design are considered by the Society on a case-by-case basis.

2.1.6 Hold access points 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 access points located on the forecastle deck and leading directly to a dry cargo hold through a trunk.

2.1.7 Access points to cofferdams and ballast tanks are to be manholes-fitted with watertight covers fixed with bolts sufficiently closely spaced.

2.2 Gaskets

2.2.1 The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness.

2.2.2 Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

2.2.3 For non-bolted hatch covers, metal-to-metal contacts are to be provided in order to prevent over compression of the gasket. They are to be designed in order to withstand the bearing force induced by any relevant lateral load on the hatch cover.

3 Small hatches fitted on the exposed fore deck

3.1 Application

3.1.1 Small hatches designed for emergency escape need not comply with the requirements in [3.4.1], items a) and b), [3.4.3] and [3.5.1].

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

3.2 Strength

3.2.1 The gross thickness of covers is to be not less than that of the adjacent plating based on the same spacing and the same steel.

3.2.2 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 1 and Fig 1.

Ordinary stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in [3.3.1] (see also Fig 1).

Primary stiffeners are to be continuous.

All stiffeners are to be welded to the inner edge stiffener (see Fig 2).

Table 1 : Gross scantlings for small steel hatch covers on the fore deck

Nominal size (mm x mm)	Cover plate thickness (mm)	Primary stiffeners	Ordinary 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

3.2.3 The upper edge of the hatch coamings is to be suitably reinforced by an horizontal section, generally not more than 170 to 190 mm from the upper edge of the coamings.

3.2.4 For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement are to comply with Ch 8, Sec 7, [4].

3.2.5 For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

3.3 Weathertightness

3.3.1 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 1 and of a sufficient capacity to withstand the bearing force.

3.4 Primary securing devices

3.4.1 Small hatches located on exposed fore deck are to be fitted with primary securing devices such that their hatch covers can be secured in place and made weathertight 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.

3.4.2 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.

3.4.3 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 upwards, 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 2.

3.4.4 For small hatch covers located on the exposed deck forward of the foremost cargo hatch, the hinges are to be fitted such that the predominant direction of green seas is to cause the cover to close, which means that the hinges are normally to be located on the fore edge.

3.4.5 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.

3.5 Secondary securing devices

3.5.1 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.

4 Small hatch covers fitted on non-exposed decks

4.1 General

4.1.1 Hatch covers on non-exposed decks may not be weathertight.

4.1.2 Small hatch covers fitted on non-exposed decks are to have strength equivalent to that required for the adjacent deck (see Part B, Chapter 7).

4.1.3 Small hatch covers fitted on non-exposed decks are to have a level of tightness equivalent to that required for adjacent compartment(s).

4.1.4 If the hatch cover is weathertight or watertight and non-bolted, metal-to-metal contacts are to be provided in order to prevent over compression of the gasket. They are to be designed in order to withstand the bearing force induced by any relevant lateral load on the hatch cover.

5 Testing

5.1 Initial test of watertight hatches

5.1.1 Watertight hatches are to be tested by water pressure to the maximum head of water they might sustain in a final or intermediate stage of flooding.

For cargo ships not covered by damage stability requirements, watertight hatches are to be tested by water pressure to a head of water measured from the lower edge of the opening to one metre above the freeboard deck.

5.2 Prototype test

5.2.1 *Where testing of individual hatches is not carried out because of possible damage to insulation or outfitting items, testing of individual hatches may be replaced by a prototype pressure test of each type and size of hatch with a test pressure corresponding at least to the head required for the individual location. The prototype test is to be carried out before the hatch is fitted. The installation method and procedure for fitting the hatch on board is to correspond to that of the prototype test. When fitted on board, each door is to be checked for proper seating between the deck, the coaming and the hatch.*

Figure 1 : Arrangement of stiffeners

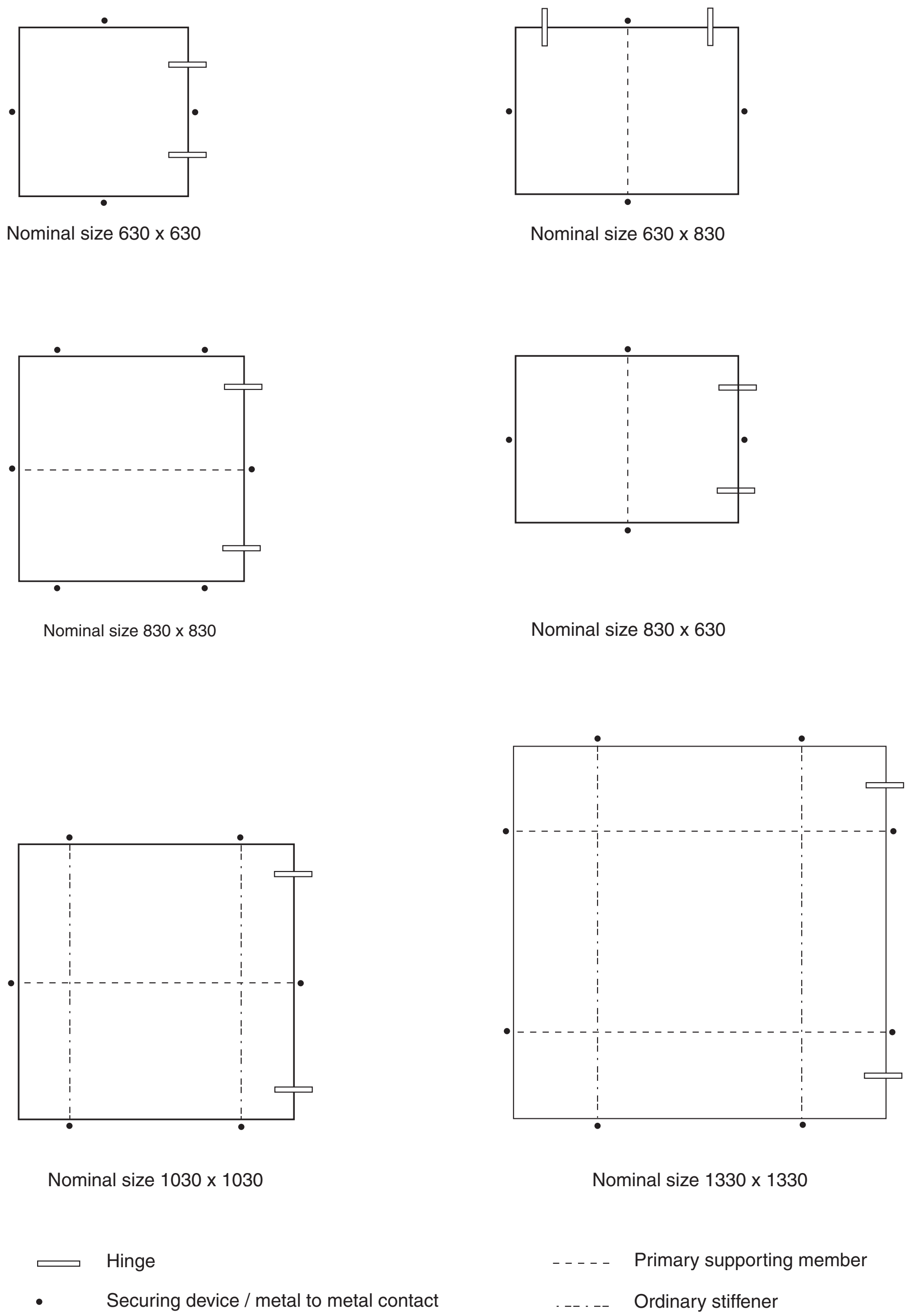
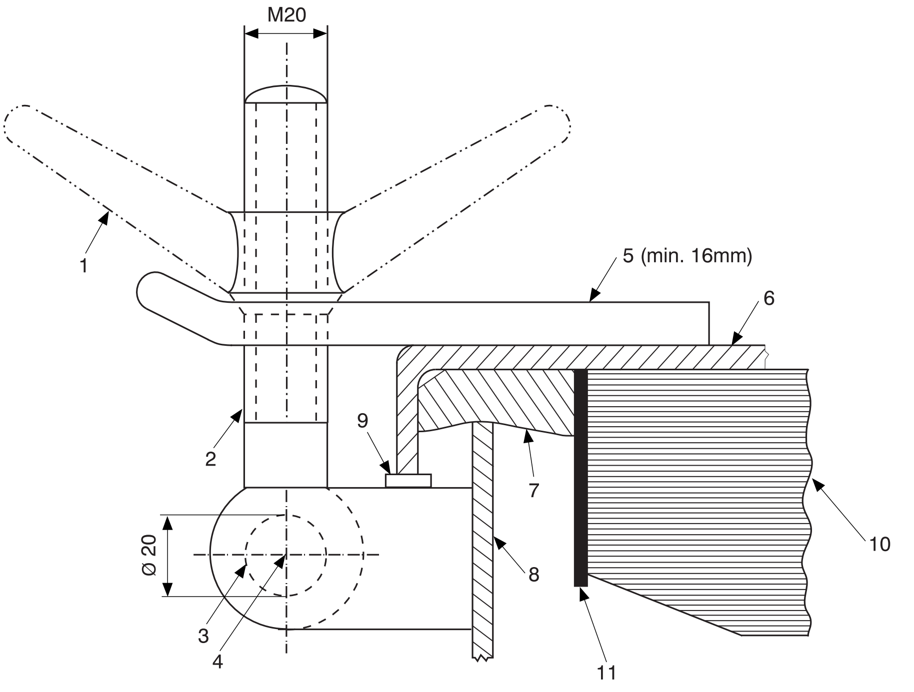


Figure 2 : Example of a primary securing method



1 : Butterfly nut
2 : Bolt
3 : Pin
4 : Centre 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 9 MOVABLE DECKS AND INNER RAMPS - EXTERNAL RAMPS

1 Movable decks and inner ramps

1.1 Application

1.1.1 The requirements of this Article apply to movable decks and inner ramps when the additional class notation **ALP** is not granted and when no cargo gear register is issued.

1.1.2 On special request of the owner the movable inner ramps under load may be examined by the Society in the scope of application of additional class notation **ALP** (see Pt A, Ch 1, Sec 2, [6.12.1]).

1.2 Materials

1.2.1 The decks and inner ramps are to be made of steel or aluminium alloys complying with the requirements of NR216 Materials. Other materials of equivalent strength may be used, subject to a case by case examination by the Society.

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], 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 4, Sec 2.

1.4 Plating

1.4.1 The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained from Ch 7, Sec 1, [4.3], where nP_0 is not to be taken less than 5 kN.

1.5 Ordinary stiffeners

1.5.1 The net section modulus and the net shear sectional area of ordinary stiffeners subjected to wheeled loads is to be not less than the value obtained from Ch 7, Sec 2, [3.7.5].

1.6 Primary supporting members

1.6.1 General

The supporting structure of movable decks and inner ramps is to be verified through direct calculation, considering the following cases:

- movable deck stowed in upper position, empty and locked, at sea
- movable deck in service, loaded, in lower position, resting on supports or supporting legs and locked, at sea
- movable inner ramp in sloped position, supported by hinges at one end and by a deck at the other, with possible intermediate supports, loaded, at harbour
- movable inner ramp in horizontal position, loaded and locked, at sea.

1.6.2 Loading cases

The scantlings of the structure are to be verified in both sea and harbour conditions for the following cases:

- loaded movable deck or inner ramp under loads according to the load distribution indicated by the Designer
- loaded movable deck or inner ramp under uniformly distributed loads corresponding to a pressure, in kN/m², equal to $p_0 + p_1$
- empty movable deck under uniformly distributed masses corresponding to a pressure, in kN/m², equal to p_0

where:

$$p_0 = \frac{P_P}{A_P}$$

$$p_1 = n_V \frac{P_V}{A_P}$$

P_P : Mass of the movable deck, in kN

P_V : Mass of a vehicle, in kN

n_V : Maximum number of vehicles loaded on the movable deck

A_P : Effective area of the movable deck, in m².

1.6.3 Lateral pressure

The lateral pressure is constituted by still water pressure and inertial pressure. The lateral pressure is to be obtained, in kN/m², from the following formula:

$$p = \gamma_{S2}\, p_S + \gamma_{W2}\, p_W$$

where:

γ_{S2}, γ_{W2} : Partial safety factors defined in Ch 7, Sec 3, [1.4]

p_S, p_W : Still water and inertial pressures transmitted to the movable deck or inner ramp structures, obtained, in kN/m², from Tab 1.

1.6.4 Checking criteria

It is to be checked that the combined stress σ_{VM} is in accordance with the criteria defined in Ch 7, Sec 3, [4.4.2].

1.6.5 Allowable deflection

The scantlings of main stiffeners and the distribution of supports are to be such that the deflection of the loaded movable deck or loaded inner ramp does not exceed 5 mm/m.

1.7 Supports, suspensions and locking devices

1.7.1 Scantlings of wire suspensions are to be determined by direct calculation on the basis of the loads in [1.6.2] and [1.6.3], taking account of a safety factor at least equal to 5.

1.7.2 It is to be checked that the combined stress σ_{VM} in rigid supports and locking devices is in accordance with the criteria defined in Ch 7, Sec 3, [4.4.2].

1.8 Tests and trials

1.8.1 Tests and trials defined in [1.8.2] to [1.8.4] are to be carried out in the presence of the Surveyor. Upon special request, these conditions of tests and trials may be modified to comply with any relevant national regulations in use.

1.8.2 The wire ropes are to be submitted to a tensile test on test-piece.

1.8.3 The loose gears used for the platform and ramp handling (chain, shackles, removable blocks, etc.) are to have a maximum safe working load (SWL) and are to be submitted to an individual test before fitting on board.

The test of these loose gears are to be in accordance with the applicable requirements of Rule Note NR526, Rules for the classification of lifting appliances onboard ships and offshore units.

1.8.4 A trial to verify the correct operation of lowering and lifting devices of the platform is to be carried out before going into service.

This trial is made without overload unless special requirement of National Authorities.

2 External ramps

2.1 General

2.1.1 The net thicknesses of plating and the net scantlings of ordinary stiffeners and primary supporting members are to be determined under vehicle loads in harbour condition, at rest, as defined in Tab 1.

2.1.2 The external ramps are to be examined for their watertightness, if applicable.

2.1.3 The locking of external ramps in stowage position at sea is examined by the Society on a case by case basis.

2.1.4 The ship's structure under the reactions due to the ramp is examined by the Society on a case by case basis.

Table 1 : Movable decks and inner ramps Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m^2
Still water condition		$p_S = p_0$ in harbour condition during lifting $p_S = p_0 + p_1$ in other cases
Upright sea condition	"a"	No inertial pressure
	"b"	$p_{W,X} = \frac{a_{X1}}{g}(p_0 + p_1)$ in x direction $p_{W,Z} = \frac{a_{Z1}}{g}(p_0 + \alpha p_1)$ in z direction
Inclined sea condition (negative roll angle)	"c"	$p_{W,Y} = \frac{C_{FA} a_{Y2}}{g}(p_0 + p_1)$ in y direction
	"d"	$p_{W,Z} = \frac{C_{FA} a_{Z2}}{g}(p_0 + \alpha p_1)$ in z direction
Harbour condition **(1)**	during lifting	$p_{W,X} = 0{,}035\ p_0$ in x direction $p_{W,Y} = 0{,}087\ p_0$ in y direction $p_{W,Z} = 0{,}200\ p_0$ in z direction
	at rest	$p_{W,X} = 0{,}035\ (p_0 + p_1)$ in x direction $p_{W,Y} = 0{,}087\ (p_0 + p_1)$ in y direction $p_{W,Z} = 0{,}100\ (p_0 + p_1)$ in z direction

(1) For harbour conditions, a heel angle of 5° and a trim angle of 2° are taken into account. In case the designer is proposing a heel angle of less than 5° based on specific operational conditions, the used angle is to be clearly specified on the loading manual.

Note 1:

p_0, p_1 : Pressures, in kN/m^2, to be calculated according to [1.6.2] for the condition considered.

α : Coefficient taken equal to 0,5

C_{FA} : Combination factor, to be taken equal to:

- $C_{FA} = 0{,}7$ for load case "c"
- $C_{FA} = 1{,}0$ for load case "d"

SECTION 10 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 8, Sec 7 and Ch 8, Sec 8 apply.

1.2 Definitions

1.2.1 Standard height of superstructure

The standard height of superstructure is that defined in Ch 1, Sec 2, Tab 2.

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, recessed promenades 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 sidescuttles of the non-opening type are allowed if complying with Pt C, Ch 4, Sec 5, [3.2.3], item c).

2.1.4 *Openings in the shell plating below the deck limiting the vertical extent of damage shall be fitted with a device that prevents unauthorized opening if they are accessible during the voyage.*

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

3 Sidescuttles, windows and skylights

3.1 General

3.1.1 Application

The requirements in [3.1] to [3.4] apply to sidescuttles 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 Sidescuttle definition

Sidescuttles 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

Sidescuttles 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 sidescuttles 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 sidescuttles

All sidescuttles, the sills of which are below the bulkhead deck for passenger ships or the freeboard deck for cargo ships, 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

Sidescuttles are not to be fitted in such a position that their sills are below a line drawn parallel to the freeboard deck at side and having its lowest point 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 Sidescuttles below (1,4 + 0,025 B) m above the water

Where in 'tweendecks the sills of any of the sidescuttles are below a line drawn parallel to the bulkhead deck at side of passenger ships and the freeboard deck at side of cargo ships, and having its lowest point 1,4+0,025B m above the water when the voyage commences, all the sidescuttles in that 'tweendecks are to be closed watertight and locked before the voyage commences, 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 sidescuttles 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 sidescuttles are to have their sills above the line drawn parallel to the bulkhead deck at side of passenger ships and the freeboard deck at side of cargo ships, 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 for the voyage to commence without them being closed and locked and to be opened during navigation on the responsibility of the master. 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 sidescuttles may be fitted in any spaces which are appropriated exclusively for the carriage of cargo.

Sidescuttles 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.

3.2.4 Non-opening type sidescuttles

Sidescuttles 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 waterplane 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 Ships with several decks

In ships having several decks above the bulkhead deck, such as passenger ships, the arrangement of sidescuttles and rectangular windows is considered by the Society on a case by case basis.

Particular consideration is to be given to the ship side up to the upper deck and the front bulkhead of the superstructure.

3.2.7 Automatic ventilating scuttles

Automatic ventilating sidescuttles are not to be fitted in the shell plating below the bulkhead deck of passenger ships and the freeboard deck of cargo ships without the special agreement of the Society.

3.2.8 Window arrangement

Windows may not be fitted below the freeboard deck, in first tier end bulkheads or sides of enclosed superstructures and in first tier deckhouses considered as being buoyant in the stability calculations or protecting openings leading below.

3.2.9 Skylights

Fixed or opening skylights are to have glass thickness appropriate to their size and position as required for sidescuttles 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.

3.2.10 Gangway, cargo and coaling ports

Gangway, cargo and fuelling ports fitted below the bulkhead deck of passenger ships and the freeboard deck of cargo ships are to be watertight and in no case they are to be so fitted as to have their lowest point below the summer 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.

Direct metal to glass contact is to be avoided.

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 8, Sec 4, [2].

In damaged ship conditions, where windows or sidescuttles are located below the deepest equilibrium waterline, the design pressure p, in kN/m², is to be taken equal to:

$$p = p_S + p_W$$

where:

p_S : Still water pressure, taken equal to:

$p_S = \rho\, g\, d_F$

p_W : Wave pressure, taken equal to:

$$p_W = 0,6 \rho g h_1 e^{\frac{-2\pi(d_F)}{L}}$$

d_F : Distance, in m, from the calculation point to the deepest equilibrium waterline.

The deepest equilibrium waterlines are to be provided by the Designer under his own responsibility.

h_1 : Reference values of the ship relative motions in the upright ship condition, defined in Ch 5, Sec 3, [3.3]

3.3.3 Scantling

The windows and sidescuttles assessment methodology defined in this Article is equivalent to Standard ISO 11336-1:2012.

The scantling of windows and sidescuttle defined in this sub-article are provided for the following types of window or sidescuttle:

- monolithic window or sidescuttle (see [3.3.4])
- laminated window or sidescuttle (see [3.3.5])
- double windows unit with gap (see [3.3.9]).

All the window and sidescuttle edges are considered as simply supported.

3.3.4 Thickness of monolithic window

The thicknesses, in mm, of monolithic windows and sidescuttles are to be obtained from the following formula:

- rectangular window or sidescuttle:

$$t = 31,6 s \sqrt{\frac{\beta p S_f}{R_m}}$$

- circular window or sidescuttle:

$$t = 17,4 d \sqrt{\frac{p S_f}{R_m}}$$

where:

s : Shorter side, in m, of rectangular window or sidescuttle

Where the window is supported only on 2 edges, s is to be taken as the unsupported side

ℓ : Longer side, in m, of rectangular window or sidescuttle

d : Diameter, in m, of circular window or sidescuttle

R_m : Guaranteed minimum flexural strength, in N/mm², of material used. For guidance only, the guaranteed minimum flexural strength R_m for glass window is:

- for thermally or chemically toughened glass:

  $R_m = 160$ N/mm²

- for polymethylmethacrilate (PMMA) glass:

  $R_m = 100$ N/mm²

- for polycarbonate (PC) glass:

  $R_m = 90$ N/mm²

S_f : Safety factor taken equal to:

- 4,0 for thermally or chemically toughened glass:
- 3,5 for polymethylmethacrilate (PMMA) or polycarbonate (PC) glass:

β : Aspect ratio coefficient of the rectangular window or sidescuttle, obtained in Tab 1

Where the window is supported only by 2 edges, β is to be taken equal to 1,0.

The thickness of windows or sidescuttles having other shapes may be obtained by considering rectangles or circles of equivalent dimensions s_{eq}, ℓ_{eq} or d_{eq} as defined in Tab 2.

Table 1 : Coefficient β

ℓ/s	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

3.3.5 Laminated window

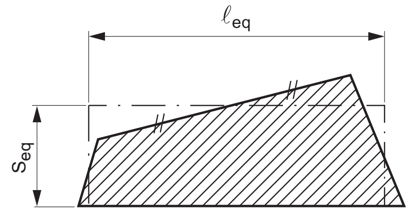
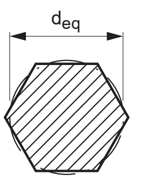
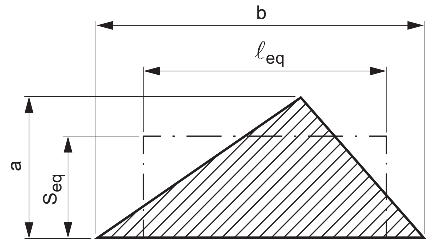
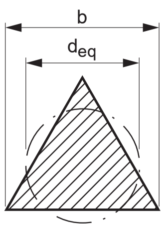
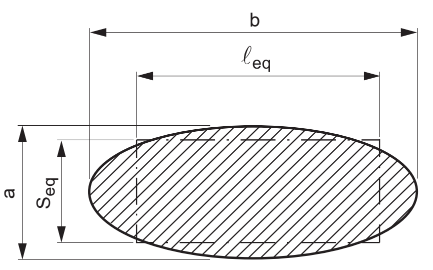
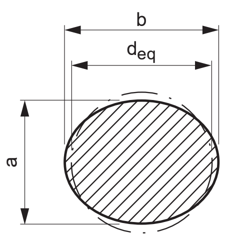
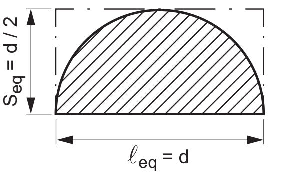
Laminated windows are windows realized by placing an interlayer of resin (polyvinyl butyral as a general rule) between plies of same or different materials.

For laminated windows made with plies of the same material:

- When the mechanical properties of the interlayer material (the laminating adhesive material) are not known, the plies of the laminated window are considered as mechanically independent, and the equivalent thickness is to be calculated as defined in [3.3.6].
- When the mechanical properties of the interlayer material are known in terms of shear modulus, G, in N/mm², the plies of the laminated window are considered as mechanically collaborating, and the equivalent thickness is to be calculated as defined in [3.3.7].

When the laminated window is made with plies of different materials, they are considered as mechanically independent, and the equivalent thickness is to be calculated as defined in [3.3.8].

Table 2 : Equivalent dimensions for windows having other shapes

a) Quadrangle The equivalent rectangle has the same area 	b) Polygon The equivalent circle has the same area 	c) Triangle s_{eq} = 2a/3 l_{eq} = 3b/4 	
d) Equilateral triangle d_{eq} = 3b/4 	e) Flat ellipse s_{eq} = 0,87a l_{eq} = 0,87b 	f) Round ellipse $d_{eq} = \sqrt{ab}$ 	g) Semi circle s_{eq} = d/2 l_{eq} = d 

3.3.6 Thickness of laminated window with independent plies

The equivalent thickness t_{eq}, in mm, of laminates made of n independent plies of thicknesses $t_{p,1}$, $t_{p,2}$, ..., $t_{p,n}$, is to comply with the following formula:

$t_{eq} \geq t$

where:

$$t_{eq} = \min[t_{eq,j}]$$

$$t_{eq,j} = \sqrt{\frac{\sum_{j=1}^{n} t_{p,j}^3}{t_{p,j}}}$$

j : Ply index, ranging from 1 to n

t : Thickness, in mm, of a monolithic window, calculated according to [3.3.4].

3.3.7 Thickness of laminated window with collaborating plies

The equivalent thickness t_{eq}, in mm, of laminates made of two collaborating plies of the same material, and of thicknesses t_1 and t_2 separated by an interlayer of thickness t_I is to comply with the following formula:

$t_{eq} \geq t$

where:

$$t_{eq} = \min[t_{1eq,s}, t_{2eq,s}]$$

$t_{1eq,s}$, $t_{2eq,s}$: Equivalent thickness for strength as obtained from the following formulae:

$$t_{1eq,s} = \sqrt{\frac{t_{eq,d}^3}{t_1 + 2\Gamma t_{s2}}}$$

$$t_{2eq,s} = \sqrt{\frac{t_{eq,d}^3}{t_2 + 2\Gamma t_{s1}}}$$

$t_{eq,d}$: Equivalent thickness for deflection as obtained from the following formula:

$$t_{1eq,d} = \sqrt[3]{t_1^3 + t_2^3 + 12\Gamma I_S}$$

Γ : Shear transfer coefficient as obtained from the following formula, without being taken less than 0 (independent plies behaviour) and more than 1,0 (monolithic behaviour):

$$\Gamma = \frac{1}{1 + 9{,}6\,\dfrac{E}{G}\cdot\dfrac{I_S}{hs^2}\cdot\dfrac{t_I}{s^2}\cdot\dfrac{1}{10^6}}$$

$$t_{s1} = \frac{hs \cdot t_1}{t_1 + t_2}$$

$$t_{s2} = \frac{hs \cdot t_2}{t_1 + t_2}$$

$$I_S = t_1 t_{s2}^2 + t_2 t_{s1}^2$$

$$hs = 0{,}5(t_1 + t_2) + t_I$$

G : Shear modulus of the interlayer at 25 °C, in N/mm², generally taken equal to 1,6 N/mm² for polyvinyl butyral (PVB).

For other interlayer materials the shear modulus value at 25 °C for short time duration load (60 s) shall be declared by the interlayer material manufacturer

E : Young's modulus of the plies, in N/mm²

s : Shorter side, in m, of rectangular window or sidescuttle.

In case of multiple (more than two plies) laminates the calculation is to be iterated. The iteration is to start from the outer ply (the one directly loaded by water pressure) and end with the inner ply.

3.3.8 Thickness of laminated window with plies of different materials

The equivalent thickness t_{eq}, in mm, of laminates made of n plies of different materials, of thicknesses $t_{p,1}$, $t_{p,2}$, …, $t_{p,n}$ and of Young's modulus $E_{p,1}$, $E_{p,2}$, ..., $E_{p,n}$ is to comply with the following formula:

$$t_{eq} \geq t$$

where:

$$t_{eq} = \min[t_{eq,j}]$$

$$t_{eq,j} = \sqrt{\frac{\sum_{j=1}^{n} E_{p,j} t_{p,j}^3}{t_{p,j}}}$$

j : Ply index, ranging from 1 to n

t : Thickness, in mm, of a monolithic window, calculated according to [3.3.4] for the same material than the ply giving the minimum value of $t_{eq,j}$.

3.3.9 Thickness of double windows

Double windows are glass windows made of two plies of glass separated by an hermetically sealed spacebar.

The thickness of the ply exposed to the loads defined in [3.3.2] is to be calculated as per monolithic windows according to [3.3.4].

3.3.10 Thickness of glasses forming screen bulkheads or internal boundaries of deckhouses

The thickness of glasses forming screen bulkheads on the side of enclosed promenade spaces and that for rectangular windows in the internal boundaries of deckhouses which are protected by such screen bulkheads are considered by the Society on a case by case basis.

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

Sidescuttles to the following spaces are to be fitted with efficient, hinged inside deadlights:

- *spaces below the freeboard deck*
- *spaces within the first tier of enclosed superstructures*
- *first tier deckhouses on the freeboard deck protecting openings leading below or considered buoyant in stability calculations.*

Deadlights are to be capable of being closed and secured watertight if fitted below the freeboard deck and weathertight if fitted above.

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 sidescuttles except that, abaft one eighth of the ship's length from the forward perpendicular and above a line drawn parallel to the bulkhead deck at side and having its lowest point at a height of (3,7+0,025B) m above the deepest subdivision summer load line*, the deadlights may be portable in passenger accommodation, 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 sidescuttles they serve.*

3.4.3 Openings at the side shell in the second tier

Sidescuttles and windows at the side shell in the second tier, protecting direct access below or considered buoyant in the stability calculations, are to be provided with efficient, hinged inside deadlights capable of being effectively closed and secured weathertight.

3.4.4 Openings set inboard in the second tier

Sidescuttles and windows set inboard from the side shell in the second tier, protecting direct access below to spaces listed in [3.4.1], are to be provided with either efficient, hinged inside deadlights or, where they are accessible, permanently attached external storm covers of approved design and substantial construction capable of being effectively closed and secured weathertight.

Cabin bulkheads and doors in the second tier separating sidescuttles and windows from a direct access leading below may be accepted in place of fitted deadlights or storm covers.

Note 1: Deadlights in accordance with recognised standards are fitted to the inside of windows and sidescuttles, 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 quarterdeck or on a superstructure of less than standard height may be treated as being on the second tier as far as the provision of deadlights is concerned, provided the height of the raised quarterdeck or superstructure is not less than the standard quarterdeck 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 sidescuttles 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-chute, rubbish-chute, etc.

The inboard opening of each ash-chute, rubbish-chute, etc. is to be fitted with an efficient cover.

If the inboard opening is situated below the bulkhead deck for passenger ships or the freeboard deck for cargo ships, the cover is to be watertight, and in addition an automatic non-return valve is to be fitted in the chute in an easily accessible position above the deepest subdivision summer load line. When the chute 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 draught 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 freeboard deck of a passenger ship, or the waterline corresponding to the deepest draught after damage in a cargo 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 bulkhead 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 gate valve, 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* which replaces the lower gate valve.

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 gate valve controls and/or hinged cover 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 3.

Table 3 : Wall thickness of garbage chutes

External diameter d, in mm	Thickness, in mm
$d \le 80$	7,0
$80 < d < 180$	$7,0 + 0,03\ (d - 80)$
$180 \le d \le 220$	$10,0 + 0,063\ (d - 180)$
$d > 220$	12,5

5 Transducers

5.1 General

5.1.1 Transducers are not to be fitted inside compartments intended for fuel and hydrocarbons. They may only be fitted in adjacent cofferdams.

If transducers are fitted in hazardous areas, they are to be fitted inside a watertight box. In this case, transducers are to be sealed and the connecting cables are to be specially protected.

5.2 Protection of transducers in ballast and main compartment

5.2.1 Transducers may be fitted in compartments intended for ballast (double bottoms, deep tank, peak). In such a case, the instrument and its power cable are to be mechanically protected and the watertightness of the protecting device is to be such that the material and its cable may be considered as protected against external agents.

5.2.2 Where transducers are not fitted inside a small box or a little separate compartment within a double bottom but directly within a main compartment, it is necessary to provide for inspection of materials of every part which ensures structural and watertight integrity and to test them at works after completion. Besides, the complete set is to be tested under a hydraulic pressure at least equal to 1,5 times the service pressure, the latter being considered as equal to the depth of the ship.

If a transducer is fitted inside a single bottom ship, the tank of the transducer itself is to be considered as ensuring the structural integrity. Special attention is to be paid to welding and testing of the transducer bell.

5.3 Fitting of hull boss and transducer receiver

5.3.1 The hull boss is to be made of steel with the same grade and yield stress as the bottom plates to which it is fitted. Full penetration welding is to be performed with suitable electrodes.

When the transducer receiver, owing to the fitting arrangement, slightly projects beyond the external surface of the shell plates, the precise position of the installation is to be supplied to the Owner to enable him to take the necessary precautions in case of docking.

5.4 Fitting of transducer in heavily stressed areas

5.4.1 Where the transducer is fitted in the midship region or in heavily stressed areas, the openings are to be either elliptical (ratio 2/1, the major axis being parallel to the longitudinal axis of the ship) or truncated ellipse shaped at least for large ships. Moreover, a possible compensation is to be provided on the location of the cut.

6 Freeing ports

6.1 General provisions

6.1.1 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.

6.1.2 Freeing port areas

The minimum required freeing port areas in bulwarks on the freeboard deck, on each side of the ship, are specified in Tab 4.

6.1.3 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.

6.1.4 Freeing port positioning

The lower edge of freeing ports is to be as near the deck as practicable.

All the openings in the bulwark are to be protected by rails or bars spaced approximately 230 mm apart.

6.1.5 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.

In ships operating in areas where icing is likely to occur, no shutters are to be fitted in the feeing ports.

6.1.6 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.

Table 4 : 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 A	$0,33\ \ell_B\ h_B$	[6.5.2]
Type B-100	$0,33\ \ell_B\ h_B$	[6.5.2]
Type B-60	$0,25\ \ell_B\ h_B$	[6.5.1]
Ships fitted with a trunk included in freeboard calculation and/ or breadth ≥ 0,6 B	$0,33\ \ell_B\ h_B$	[6.3.1]
Ships fitted with a trunk not included in freeboard calculation and/ or continuous or substantially continuous hatch coamings	A_2	[6.3.1]
Ships fitted with non-continuous trunk and/ or hatch coamings	A_3	[6.3.2]
Ships fitted with open superstructure	A_S for superstructures A_W for wells	[6.4.2] [6.4.3]
Other ships	A_1	[6.2.1]

Note 1:
ℓ_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 ℓ_B.

6.2 Freeing port area in a well not adjacent to a trunk or hatchways

6.2.1 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 m², in Tab 5.

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.

6.2.2 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 5, where ℓ_B is to be taken equal to the actual length of the well considered.

6.2.3 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 [6.1.2].

Table 5 : Freeing port area in a well not adjacent to a trunk or hatchways

Location	Area A_1 of freeing ports, in m²	
	$\ell_B \le 20$	$\ell_B > 20$
Freeboard deck and raised quarterdecks	$0,7 + 0,035\ \ell_B + A_C$	$0,07\ \ell_B + A_C$
Superstructure decks	$0,35 + 0,0175\ \ell_B + 0,5\ A_C$	$0,035\ \ell_B + 0,5\ A_C$

Note 1:

ℓ_B : Length, in m, of bulwark in the well, to be taken not greater than 0,7 L_{LL}

A_C : Area, in m², to be taken, with its sign, equal to:

$$A_C = \frac{\ell_B}{25}(h_B - 1,2) \quad \text{for } h_B > 1,2$$

$$A_C = 0 \quad \text{for } 0,9 \le h_B \le 1,2$$

$$A_C = \frac{\ell_B}{25}(h_B - 0,9) \quad \text{for } h_B < 0,9$$

h_B : Mean height, in m, of the bulwark in a well of length ℓ_B.

6.3 Freeing port area in a well contiguous to a trunk or hatchways

6.3.1 Freeing port area for continuous trunk or continuous hatchway coaming

The freeing port area in the well contiguous to substantially continuous trunk/hatchway coaming is to be not less than:

- that obtained from Tab 6, where the trunk/hatchway coaming is not included in the freeboard calculation
- 33% of the bulwark area where the trunk/hatchway coaming meets the conditions of the International Convention on Load Lines in force and is included in the freeboard calculation.

6.3.2 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 7.

6.4 Freeing port area in an open space within superstructures

6.4.1 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.

Table 6 : 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, in m², of freeing ports
$B_H \le 0,4\ B$	$0,2\ \ell_B h_B\left(\frac{h_S}{2h_W}\right)$
$0,4\ B < B_H < 0,75\ B$	$\left[0,2 - 0,286\left(\frac{B_H}{B} - 0,4\right)\right]\ell_B h_B\left(\frac{h_S}{2h_W}\right)$
$B_H \ge 0,75\ B$	$0,1\ \ell_B h_B\left(\frac{h_S}{2h_W}\right)$

Note 1:

ℓ_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 ℓ_B

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, to be taken not less than 0,5 h_S.

Table 7 : Freeing port area in a well contiguous to a non-continuous trunk or hatchway

Free flow area f_P, in m^2	Freeing port area A_3, in m^2
$f_p \leq A_1$	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 m^2, to be obtained from Tab 5

A_2 : Area of freeing ports, in m^2, to be obtained from Tab 6.

6.4.2 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 m^2, from the following formula:

$$A_S = A_1 c_{SH}\left[1 - \left(\frac{\ell_W}{\ell_T}\right)^2\right]\left(\frac{b_0 h_S}{2\ell_T h_W}\right)$$

where:

- ℓ_T : Total well length, in m, to be taken equal to: $\ell_T = \ell_W + \ell_S$
- 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 m^2, required for an open well of length ℓ_T, in accordance with Tab 5, 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, h_W : As defined in Tab 6.

6.4.3 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 m^2, from the following formula:

$$A_W = A_1 c_{SH}\left(\frac{h_S}{2h_W}\right)$$

- A_1 : Freeing port area, in m^2, required for an open well of length ℓ_W, in accordance with Tab 5
- ℓ_W : Defined in [6.4.2].

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.

6.5 Freeing port area in bulwarks of the freeboard deck for ships of types A, B-100 and B-60

6.5.1 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.

6.5.2 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.

7 Machinery space openings

7.1 Engine room skylights

7.1.1 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.

7.2 Closing devices

7.2.1 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.

7.2.2 Machinery casings on Type A ships

Machinery casings on Type A ships are to be protected by an enclosed poop or bridge of at least standard height, or by a deckhouse of equal height and equivalent strength.

Machinery casings may, however, be exposed if there are no openings giving direct access from the freeboard deck to the machinery spaces.

However, a weathertight door is permitted in the machinery casing, provided that it leads to a space or passageway which is as strongly constructed as the casing and is separated from the stairway to the engine room by a second weathertight door of steel or other equivalent material.

7.2.3 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.

7.2.4 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.

7.2.5 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.

7.3 Coamings

7.3.1 *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 [9.1.2], 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 [9.1.2], may be permitted by the Society in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

8 Companionway

8.1 General

8.1.1 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.

8.1.2 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.

8.1.3 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 standard height of a superstructure.

8.2 Scantlings

8.2.1 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.

8.3 Closing devices

8.3.1 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 watertight.

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.

8.3.2 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 not provided from above, the height of the sills to doorways in a poop bridge or deckhouse on the freeboard deck is to be 600 mm.

Where access is provided to spaces inside a bridge or poop from the deck 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.

9 Ventilators

9.1 Closing appliances

9.1.1 General

Ventilator openings are to be provided with efficient weathertight closing appliances of steel or other equivalent material.

9.1.2 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.*

9.1.3 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.

9.1.4 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.

9.1.5 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 [9.1.2], i.e. their openings are to be so located that they do not require closing appliances.

Note 1: See also Pt C, Ch 4, Sec 2, [2.1] regarding closing appliances for ventilation systems.

9.1.6 Reduced height of ventilator coamings for machinery spaces and emergency generator room

Where, due to the ship's size and arrangement, the requirements in [9.1.5] 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 [9.1.1], [9.1.3] and [9.1.4] in combination with other suitable arrangements, such as separators fitted with drains, to ensure an uninterrupted, adequate supply of ventilation to these spaces.

9.1.7 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.

Table 8 : 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.

9.2 Coamings

9.2.1 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.

9.2.2 Scantlings

The scantlings of ventilator coamings exposed to the weather are to be not less than those obtained from Tab 8.

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.*

10 Tank cleaning openings

10.1 General

10.1.1 Ullage plugs, sighting ports and tank cleaning openings may not be arranged in enclosed spaces.

SECTION 11 HELICOPTER DECKS AND PLATFORMS

Symbols

W_H : Maximum weight of the helicopter, in t.

1 Application

1.1 General

1.1.1 The requirements of this Section apply to areas equipped for the landing and take-off of helicopters with landing gears or landing skids, and located on a deck or on a platform permanently connected to the hull structure.

1.1.2 Helicopter deck or platform intended for the landing of helicopters having landing devices other than wheels or skids are to be examined by the Society on a case by case basis.

2 Definition

2.1 Landing gear

2.1.1 A landing gear may consist of a single wheel or a group of wheels.

3 General arrangement

3.1 Landing area and approach sector

3.1.1 The main dimensions of the landing area, its location on board, the approach sector for landing and take-off are to comply with the applicable requirements from National or other Authorities.

3.1.2 The landing area and the approach sector are to be free of obstructions above the level of the helicopter deck or platform.

Note 1: The following items may exceed the height of the landing area, but not more than 100 mm:

- guttering or slightly raised kerb
- lightning equipment
- outboard edge of the safety net
- foam monitors
- those handrails and other items associated with the landing area which are incapable of complete retraction or lowering for helicopter operations.

3.2 Sheathing of the landing area

3.2.1 Within the landing area, a non-skid deck covering is recommended.

Where the helicopter deck or platform is wood sheathed, special attention is to be paid to the fire protection.

3.3 Safety net

3.3.1 It is recommended to provide a safety net at the sides of the helicopter deck or platform.

3.4 Drainage system

3.4.1 Gutterways of adequate height and a drainage system are recommended on the periphery of the helicopter deck or platform.

4 Design principle

4.1 General

4.1.1 Local deck strengthening is to be fitted at the connection of diagonals and pillars supporting platform.

4.2 Partial safety factors

4.2.1 The partial safety factors to be considered for checking helicopter decks and platforms structures are specified in Tab 1.

Table 1 : Helicopter decks and platforms Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors			
	Symbol	Plating	Ordinary stiffeners	Primary supporting members
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,20	1,10

5 Design loads

5.1 Emergency landing load

5.1.1 The emergency landing force F_{EL} transmitted through one landing gear or one extremity of skid to the helicopter deck or platform is to be obtained, in kN, from the following formula:

$$F_{EL} = 1,25\ g\ W_H$$

Table 2 : Helicopter platforms - Still water and inertial forces

Ship condition	Load case	Still water force F_S and inertial force F_W, in kN
Still water condition		$F_S = (W_H + W_P)\ g$
Upright condition	"a"	No inertial force
	"b"	$F_{W,X} = (W_H + W_P)\ a_{X1} + 1,2\ A_{HX}$ in x direction $F_{W,Z} = (W_H + W_P)\ a_{Z1}$ in z direction
Inclined condition (negative roll angle)	"c"	$F_{W,Y} = C_{FA}\ (W_H + W_P)\ a_{Y2} + 1,2\ A_{HY}$ in y direction
	"d"	$F_{W,Z} = C_{FA}\ (W_H + W_P)\ a_{Z2}$ in z direction

Note 1:

W_p : Structural weight of the helicopter platform, in t, to be evenly distributed, and to be taken not less than the value obtained from the following formula:
$W_p = 0,2\ A_H$

A_H : Area, in m², of the entire landing area

a_{X1}, a_{Z1} : Accelerations, in m/s², determined at the helicopter centre of gravity for the upright ship condition, and defined in Ch 5, Sec 3, [3.4]

a_{Y2}, a_{Z2} : Accelerations, in m/s², determined at the helicopter centre of gravity for the inclined ship condition, and defined in Ch 5, Sec 3, [3.4]

A_{HX}, A_{HY} : Vertical areas, in m², of the helicopter platform in x and y directions respectively. Unless otherwise specified, A_{HX} and A_{HY} may be taken equal to $A_H/3$

C_{FA} : Combination factor, to be taken equal to:
- $C_{FA} = 0,7$ for load case "c"
- $C_{FA} = 1,0$ for load case "d".

The point of application of the force F_{EL} is to be taken so as to produce the most severe stresses on the supporting structure.

5.2 Garage load

5.2.1 Where a garage zone is fitted in addition to the landing area, the still water and inertial forces transmitted trough each landing gear or each landing skid to the helicopter deck or platform are to be obtained, in kN, as specified in Ch 5, Sec 6, [6.1.2], where M is to be taken equal to:

- for helicopter with landing gears:

  M is the landing gear load, in t, to be specified by the Designer. If the landing gear load is not known, M is to be taken equal to:

  $$M = \frac{1,25}{n} W_H$$

  where n is the total number of landing gears
- for helicopter with landing skids:

  $M = 0,5\ W_H$

5.2.2 When helicopters are parked in an unprotected area, sea pressures on deck, as per Ch 5, Sec 5, [3.2.1], are to be considered simultaneously with the loads defined in [5.2.1].

5.3 Specific loads for helicopter platforms

5.3.1 The still water and inertial forces applied to an helicopter platform are to be determined, in kN, as specified in Tab 2.

6 Scantlings

6.1 General

6.1.1 The scantlings of the structure of an helicopter deck or platform are to be obtained according to [6.2], [6.3]and [6.4]. They are to be considered in addition to scantlings obtained from other applicable loads, in particular from sea pressures.

6.1.2 As specified in Ch 4, Sec 2, [1], 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 4, Sec 2, [1].

6.2 Plating

6.2.1 Load model

The following forces P_0 are to be considered independently:

- $P_0 = F_{EL}$

  where F_{EL} is the force corresponding to the emergency landing load, as defined in [5.1]
- $P_0 = \gamma_{s2}\ F_s + \gamma_{w2}\ F_{w,z}$

  where F_s and $F_{w,z}$ are the forces corresponding to the garage load, as defined in [5.2], if applicable.

6.2.2 Net thickness of plating

The net thickness of an helicopter deck or platform subjected to forces defined in [6.2.1] is not to be less than the value obtained according to Ch 7, Sec 1, [4.3.1], with:

A_T : Tyre or skid print area, in m^2.

For helicopter with skids in emergency landing case, only the extremity of skid of 0,3 m x 0,01 m is to be considered.

For other cases, where the print area A_T is not specified by the Designer, the following values are to be taken into account:

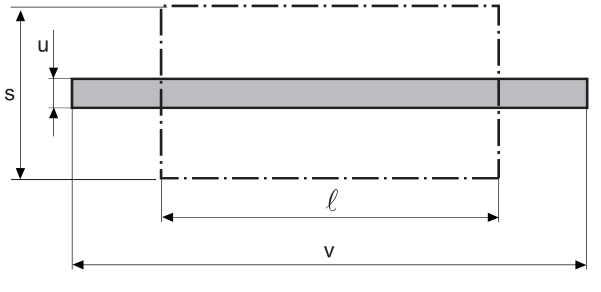
- for one tyre: 0,3 m x 0,3 m
- for one skid: 1 m x 0,01 m

λ : Coefficient defined in Ch 7, Sec 1, [4.3.1] and taken equal to 1 in the particular case of a platform.

6.2.3 Helicopter with skids

For helicopters with skids, in the particular case where $v > \ell$, v being equal to the skid length, the skid print outside of the plate panel is to be disregarded. The load and the print area to be considered are to be reduced accordingly. (see Fig 1).

Figure 1 : Skid print with v > ℓ



6.3 Ordinary stiffeners

6.3.1 Load model

The following forces P_0 are to be considered independently:

- $P_0 = F_{EL}$

  where F_{EL} is the force corresponding to the emergency landing load, as defined in [5.1]

- $P_0 = \gamma_{s2}\ F_s + \gamma_{w2}\ F_{w,z}$

  where F_s and $F_{w,z}$ are the forces corresponding to the garage load, as defined in [5.2], if applicable

- $P_0 = \gamma_{s2}\ F_s + \gamma_{w2}\ F_{w,z}$

  for an helicopter platform, where F_s and $F_{w,z}$ are the forces defined in [5.3].

6.3.2 Normal and shear stresses

The normal stress σ and the shear stress τ induced by forces defined in [6.3.1] in an ordinary stiffener of an helicopter deck or platform are to be obtained, in N/mm², according to:

$$\sigma = \frac{P_0 \ell}{mW} 10^3 + \sigma_{X1,\,Wh}$$

$$\tau = \frac{10 P_0}{A_{Sh}}$$

where:

m : Coefficient to be taken equal to:

- m = 6, in the case of an helicopter with wheels
- m = 10, in the case of an helicopter with landing skids.

In addition, in both cases of helicopter with wheels and helicopter with landing skids, the hull girder stresses $\sigma_{X1,Wh}$ are to be taken equal to 0 in the particular case of an helicopter platform.

6.3.3 Checking criteria

It is to be checked that the normal stress σ and the shear stress τ calculated according to [6.3.2] are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \ge \sigma$$

$$0.5 \frac{R_y}{\gamma_R \gamma_m} \ge \tau$$

where:

γ_m : Partial safety factor covering uncertainties on the material, to be taken equal to 1,02

γ_R : Partial safety factor covering uncertainties on the resistance, to be taken equal to:

- γ_R = 1,02 for garage load
- γ_R = 1,00 for emergency landing load.

6.4 Primary supporting members

6.4.1 Load model

The following loads are to be considered independently:

- emergency landing load, as defined in [5.1]
- garage load, as defined in [5.2], if applicable
- for an helicopter platform, specifics loads as defined in [5.3].

The most unfavorable case, i.e. where the maximum number of landing gears is located on the same primary supporting members, is to be considered.

6.4.2 Normal and shear stresses

In both cases of helicopter with wheels and helicopter with landing skids, the normal stress σ and the shear stress τ induced by loads defined in [6.4.1] in a primary supporting member of an helicopter deck or platform are to be obtained as follows:

- for analyses based on finite element models:

  $\sigma = \max(\sigma_1, \sigma_2)$ and $\tau = \tau_{12}$

  where σ_1, σ_2 and τ_{12} are to be obtained according to Ch 7, App 2, [5.2]

- for analyses based on beam models:

  $\sigma = \sigma_1$ and $\tau = \tau_{12}$

  where σ_1 and τ_{12} are to be obtained according to Ch 7, App 2, [5.3].

In addition, the hull girder stresses are to be taken equal to 0 in the particular case of an helicopter platform.

6.4.3 Checking criteria

It is to be checked that the normal stress σ and the shear stress τ calculated according to [6.4.2] are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0.5 \frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

where:

γ_m : Partial safety factor covering uncertainties on the material, to be taken equal to 1,02

γ_R : Partial safety factor covering uncertainties on the resistance, to be taken equal to:

- $\gamma_R = 1,02$ for garage load
- $\gamma_R = 1,00$ for emergency landing load.

SECTION 12 WATERTIGHT AND WEATHERTIGHT DOORS

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the scantling of shell doors not covered by Ch 8, Sec 6 and doors in bulkheads that are required to be watertight or weathertight.

1.2 Definitions

1.2.1 Watertightness

The various degrees of watertightness are defined in Ch 3, Sec 3, [3.3.2].

1.2.2 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges, or from sliding open.

1.2.3 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship's structure.

1.2.4 Locking device

A locking device is a device locking the securing device in the closed position.

2 Design loads

2.1 General

2.1.1 Doors are to be designed to offer equivalent strength compared to the adjacent bulkhead in which they are fitted. Therefore, they are to be assessed considering the same design loads, as per the examples given in the following requirements.

2.2 Side shell doors

2.2.1 Doors fitted in side shell are to be checked with the outside sea pressures defined in Ch 5, Sec 5, and whenever relevant, with the internal flooding pressure defined in Ch 5, Sec 6, [9].

2.3 Internal bulkheads doors

2.3.1 Doors fitted in watertight bulkheads are to be checked with the flooding pressures defined in Ch 5, Sec 6, [9] for spaces on both sides of the bulkhead.

2.4 Superstructure doors

2.4.1 Doors fitted in superstructure walls are to be checked with the loads defined in Ch 8, Sec 4, [2].

3 Door leaf scantling

3.1 Plating

3.1.1 The net thickness of watertight and weathertight doors is to be not less than that calculated according to Ch 7, Sec 1, [3.5] or to Ch 8, Sec 4, [3], as relevant.

3.2 Stiffeners

3.2.1 The net scantling of doors stiffeners is to be not less than that calculated according to Ch 7, Sec 2 or to Ch 8, Sec 4, [4], as relevant, considering that doors stiffeners are generally to be considered as simply supported at ends instead of clamped.

3.3 Glass

3.3.1 If permitted, when glazing is fitted in the door leaf, its thickness is to be in line with the requirements of Ch 8, Sec 10, [3.3].

4 Securing and supporting

4.1 General

4.1.1 Doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case by case basis.

In order to prevent damage to the packing material, the edges of the part of the door frame in contact with the seal should be rounded or chamfered.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

4.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [4.2].

The number and distribution of securing and supporting devices is to be set to achieve the scantling criteria in [4.2] and the required degree of watertightness.

4.2 Scantlings

4.2.1 Securing and supporting devices are to be adequately designed so that they can comply with the checking criteria defined in Ch 7, Sec 3, [3.6.1] for primary members, using general or flooding partial safety factors as relevant.

4.2.2 In addition to the requirements in [4.2.1], every element transmitting loads by means of direct contact must be checked against bearing. In that respect, the maximum normal compressive stress σ_c distributed over the contact area between the two elements is not to be higher than R_{eH}.

4.2.3 The distribution of the reaction forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the hull structure, the actual position of the supports and the design load pattern. In case of homogeneously distributed supports and uniform design pressure, the total force acting on the door may be considered as evenly divided amongst the supports.

4.2.4 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices. These elements include pins, support brackets and back-up brackets.

5 Inspection and testing

5.1 General

5.1.1 Watertight and semi-watertight doors which become immersed by an equilibrium or intermediate waterplane are to be subjected to a hydrostatic pressure test.

5.1.2 For large doors of more than 6 m² intended for use in the watertight subdivision boundaries of cargo spaces, structural analysis may be accepted in lieu of pressure testing. Where such doors utilize gasket seals, a prototype pressure test to confirm that the compression of the gasket material is capable of accommodating any deflection, revealed by the structural analysis, is to be carried out.

5.1.3 Watertight doors which are not immersed by an equilibrium or intermediate waterplane but become intermittently immersed at angles of heel in the required range of positive stability beyond the equilibrium position may be only hose tested (required only to be weathertight according to Ch 3, Sec 3, [3.3.2].

5.2 Hydrostatic pressure testing

5.2.1 The head of water used for the pressure test shall correspond at least to the head measured from the lower edge of the door opening, at the location in which the door is to be fitted in the vessel, to the bulkhead deck or freeboard deck, as applicable, or to the most unfavourable damage waterplane, if that be greater. Testing may be carried out at the factory or other shore based testing facility prior to installation in the ship. The duration of the test is to be at least 30 min.

5.2.2 *For cargo ships not covered by damage stability requirements, watertight doors are to be tested by water pressure]to a head of water measured from the lower edge of the opening to one metre above the freeboard deck.*

5.2.3 Leakage criteria for watertight doors

The following acceptable leakage criteria should apply:

- doors with gaskets: no leakage
- doors with metallic sealing: max leakage 1 litre/min.

Limited leakage may be accepted for pressure tests on large doors located in cargo spaces employing gasket seals or guillotine doors located in conveyor tunnels, in accordance with the following value, in litre/min:

$$\frac{(P + 4.572) \times h^3}{6568}$$

where:

P : Perimeter of door opening (m)

h : Test head of water (m).

However, in the case of doors where the water head taken for the determination of the scantling does not exceed 6,10 m, the leakage rate may be taken equal to 0,375 litre/min if this value is greater than that calculated by the above-mentioned formula.

5.2.4 Leakage criteria for semi-watertight doors

A leakage quantity of approximately 100 l/hour is to be considered as being acceptable for a 1,35 m² opening.

5.2.5 For doors on passenger ships which are normally open and used at sea or which become submerged by the equilibrium or intermediate waterplane, a prototype test shall be conducted, on each side of the door, to check the satisfactory closing of the door against a force equivalent to a water height of at least 1m above the sill on the centre line of the door.

5.3 Hose testing

5.3.1 All watertight, semi-watertight and weathertight doors shall be subject to a hose test after installation in a ship. Hose testing is to be carried out:

- from both sides of a watertight or semi-watertight door unless, for a specific application, exposure to floodwater is anticipated only from one side
- from both sides of internal bulkheads weathertight doors (fitted above bulkhead deck)
- from the exposed side of external weathertight doors (superstructures).

Where a hose test is not practicable because of possible damage to machinery, electrical equipment insulation or outfitting items, it may be replaced by means such as an ultrasonic leak test or an equivalent test.

6 Type approval procedure

6.1 General

6.1.1 Type approval certificates of doors may be issued to applicant manufacturers to certify that the design of the door has been assessed against a given strength level.

6.1.2 The documents and information listed in [6.2.1] must allow for the door strength to be checked against the applied design load.

6.1.3 In case a type approved door is fitted onboard a vessel, the hull supporting structure in way of the door is to be checked to have adequate strength according to [4].

6.1.4 A type approved door fitted onboard a vessel is to be selected to have a design load at least equivalent to the adjacent bulkhead in which it is fitted.

6.2 Documents and information to be submitted

6.2.1 Prior to issuance of type approval certificate, the following documents and information must be submitted to the Society for review, for each door model and variant:

- maximum considered design load
- tightness level (weathertight, semi-watertight or watertight)
- door dimensions
- structural drawings of the door, including securing devices
- material and mechanical properties of each part of the door
- test and inspection procedure (if relevant, see [6.3]).

6.3 Prototype test

6.3.1 *Where testing of individual doors is not carried out because of possible damage to insulation or outfitting items, testing of individual doors may be replaced by a prototype pressure test of each type and size of door with a test pressure corresponding at least to the head required for the individual location. The prototype test is to be carried out before the door is fitted. The installation method and procedure for fitting the door on board is to correspond to that of the prototype test. When fitted on board, each door is to be checked for proper seating between the bulkhead, the frame and the door.*

The related test reports are then annexed to the type approval certificate.

6.3.2 In such a case, the test procedure is to be submitted to the Society for review and shall be in line with the relevant requirements in [5].

Part B
Hull and Stability

Chapter 9
HULL OUTFITTING

SECTION 1 RUDDERS

Symbols

V_{AV} : Maximum ahead service speed, in knots, with the ship on summer load waterline; if V_{AV} is less than 10 knots, the maximum service speed is to be taken not less than the value obtained from the following formula:

$$V_{MIN} = \frac{V_{AV} + 20}{3}$$

V_{AD} : Maximum astern speed, in knots, to be taken not less than 0,5 V_{AV}

A : Total area of the rudder blade, in m^2, bounded by the blade external contour, including the mainpiece and the part forward of the centreline of the rudder pintles, if any

k_1 : Material factor, defined in [1.4.3]

k : Material factor, defined in Ch 4, Sec 1, [2.3] (see also [1.4.5])

C_R : Rudder force, in N, acting on the rudder blade, defined in [2.1.2]

M_{TR} : Rudder torque, in N.m, acting on the rudder blade, defined in [2.1.3] and [2.2.3]

M_B : Bending moment, in N.m, in the rudder stock, to be calculated according to Ch 9, App 1, [1.4], for each type of rudder listed in Tab 4.

1 General

1.1 Application

1.1.1 Ordinary profile rudders

The requirements of this Section apply to ordinary profile rudders, without any special arrangement for increasing the rudder force, whose maximum orientation at maximum ship speed is limited to 35° on each side.

In general, an orientation greater than 35° is accepted for manoeuvres or navigation at very low speed.

1.1.2 High efficiency rudders

The requirements of this Section also apply to rudders fitted with flaps to increase rudder efficiency. For these rudder types, an orientation at maximum speed different from 35° may be accepted. In these cases, the rudder forces are to be calculated by the Designer for the most severe combinations between orientation angle and ship speed. These calculations are to be considered by the Society on a case-by-case basis.

The rudder scantlings are to be designed so as to be able to sustain possible failures of the orientation control system, or, alternatively, redundancy of the system itself may be required.

1.1.3 Steering nozzles

The requirements for steering nozzles are given in [10].

1.1.4 Special rudder types

Rudders others than those in [1.1.1], [1.1.2] and [1.1.3] are to be considered by the Society on a case-by-case basis.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangements

1.3.1 Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by means of 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.

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

In addition, structural rudder stops of suitable strength are to be provided, except where the steering gear is provided with its own rudder stopping devices, as detailed in Pt C, Ch 1, Sec 11.

1.3.3 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.

1.4 Materials

1.4.1 Rudder stocks, pintles, coupling bolts, keys and cast parts of rudders are to be made of rolled steel, steel forgings or steel castings according to the applicable requirements in NR216 Materials and Welding, Chapter 2.

1.4.2 The material used for rudder stocks, pintles, keys and bolts is to have a minimum yield stress not less than 200 N/mm^2.

1.4.3 The requirements relevant to the determination of scantlings contained in this Section apply to steels having a minimum yield stress equal to 235 N/mm².

Where the material used for rudder stocks, pintles, coupling bolts, keys and cast parts of rudders has a yield stress different from 235 N/mm², the scantlings calculated with the formulae contained in the requirements of this Section are to be modified, as indicated, depending on the material factor k_1, to be obtained from the following formula:

$$k_1 = \left(\frac{235}{R_{eH}}\right)^n$$

where:

R_{eH} : Minimum yield stress, in N/mm², of the specified steel, and not exceeding the lower of 0,7 R_m and 450 N/mm²

R_m : Minimum ultimate tensile strength, in N/mm², of the steel used

n : Coefficient to be taken equal to:

- n = 0,75 for $R_{eH} > 235$ N/mm²
- n = 1,00 for $R_{eH} \leq 235$ N/mm².

1.4.4 Significant reductions in rudder stock diameter due to the application of steels with yield stresses greater than 235 N/mm² may be accepted by the Society subject to the results of a check calculation of the rudder stock deformations (refer to [4.2.1]).

1.4.5 Welded parts of rudders are to be made of approved rolled hull materials. For these members, the material factor k defined in Ch 4, Sec 1, [2.3] is to be used.

2 Force and torque acting on the rudder

2.1 Rudder blade without cut-outs

2.1.1 Rudder blade description

A rudder blade without cut-outs may have trapezoidal or rectangular contour.

2.1.2 Rudder force

The rudder force C_R is to be obtained, in N, from the following formula:

$C_R = 132\ n_R\ A\ V^2\ r_1\ r_2\ r_3$

where:

n_R : Navigation coefficient, defined in Tab 1

V : V_{AV} or V_{AD}, depending on the condition under consideration (for high lift profiles see [1.1.2])

r_1 : Shape factor, to be taken equal to:

$$r_1 = \frac{\lambda + 2}{3}$$

λ : Coefficient, to be taken equal to:

$$\lambda = \frac{h^2}{A_T}$$

and not greater than 2

h : Mean height, in m, of the rudder area to be taken equal to (see Fig 1):

$$h = \frac{z_3 + z_4 - z_2}{2}$$

A_T : Area, in m², to be calculated by adding the rudder blade area A to the area of the rudder post or rudder horn, if any, up to the height h

r_2 : Coefficient to be obtained from Tab 2

r_3 : Coefficient to be taken equal to:

- $r_3 = 0,8$ for rudders outside the propeller jet (centre rudders on twin screw ships, or similar cases)
- $r_3 = 1,15$ for rudders behind a fixed propeller nozzle
- $r_3 = 1,0$ in other cases.

Table 1 : Navigation coefficient

Navigation notation	Navigation coefficient n_R
Unrestricted navigation	1,00
Summer zone	0,95
Tropical zone	0,85
Coastal area	0,85
Sheltered area	0,75

Table 2 : Values of coefficient r_2

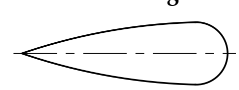
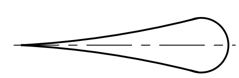
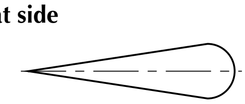
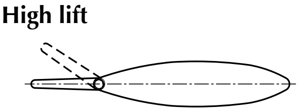
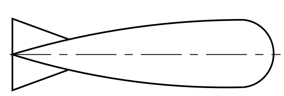
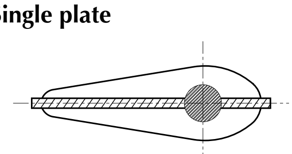
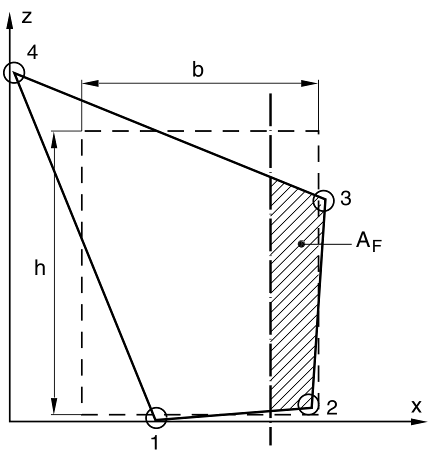
Rudder profile type	r_2 for ahead condition	r_2 for astern condition
NACA 00 - Goettingen 	1,10	0,80
Hollow 	1,35	0,90
Flat side 	1,10	0,90
High lift 	1,70	1,30
Fish tail 	1,40	0,80
Single plate 	1,00	1,00
Mixed profiles (e.g. HSVA)	1,21	0,90

Figure 1 : Geometry of rudder blade without cut-outs



2.1.3 Rudder torque

The rudder torque M_{TR}, for both ahead and astern conditions, is to be obtained, in N.m, from the following formula:

$M_{TR} = C_R\, r$

where:

r : Lever of the force C_R, in m, equal to:

$$r = b\left(\alpha - \frac{A_F}{A}\right)$$

and to be taken not less than 0,1 b for the ahead condition

b : Mean breadth, in m, of rudder area to be taken equal to (see Fig 1):

$$b = \frac{x_2 + x_3 - x_1}{2}$$

α : Coefficient to be taken equal to:

- $\alpha = 0{,}33$ for ahead condition
- $\alpha = 0{,}66$ for astern condition

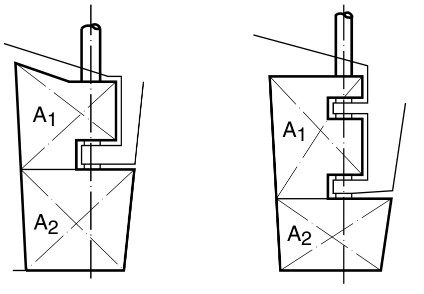
A_F : Area, in m², of the rudder blade portion afore the centreline of rudder stock (see Fig 1).

2.2 Rudder blade with cut-outs (semi-spade rudders)

2.2.1 Rudder blade description

A rudder blade with cut-outs may have trapezoidal or rectangular contour, as indicated in Fig 2.

Figure 2 : Rudder blades with cut-outs



Trapezoidal rudder blade Semi-spade rudder with rudder horn - 2 bearings

Trapezoidal rudder blade Semi-spade rudder with rudder horn - 3 bearings

2.2.2 Rudder force

The rudder force C_R, in N, acting on the blade is to be calculated in accordance with [2.1.2].

2.2.3 Rudder torque

The rudder torque M_{TR}, in N.m, is to be calculated in accordance with the following procedure.

The rudder blade area A is to be divided into two rectangular or trapezoidal parts having areas A_1 and A_2, defined in Fig 2, so that:

$A = A_1 + A_2$

The rudder forces C_{R1} and C_{R2}, acting on each part A_1 and A_2 of the rudder blade, respectively, are to be obtained, in N, from the following formulae:

$$C_{R1} = C_R\frac{A_1}{A}$$

$$C_{R2} = C_R\frac{A_2}{A}$$

The levers r_1 and r_2 of the forces C_{R1} and C_{R2}, respectively, are to be obtained, in m, from the following formulae:

$$r_1 = b_1\left(\alpha - \frac{A_{1F}}{A_1}\right)$$

$$r_2 = b_2\left(\alpha - \frac{A_{2F}}{A_2}\right)$$

where:

b_1, b_2 : Mean breadths of the rudder blade parts having areas A_1 and A_2, respectively, to be determined according to [2.1.3]

A_{1F}, A_{2F} : Areas, in m², of the rudder blade parts, defined in Fig 3

α : Coefficient to be taken equal to:

- $\alpha = 0{,}33$ for ahead condition
- $\alpha = 0{,}66$ for astern condition

For rudder parts located behind a fixed structure such as a rudder horn, α is to be taken equal to:

- $\alpha = 0{,}25$ for ahead condition
- $\alpha = 0{,}55$ for astern condition.

The torques M_{TR1} and M_{TR2}, relevant to the rudder blade parts A_1 and A_2 respectively, are to be obtained, in N.m, from the following formulae:

$M_{TR1} = C_{R1}\, r_1$

$M_{TR2} = C_{R2}\, r_2$

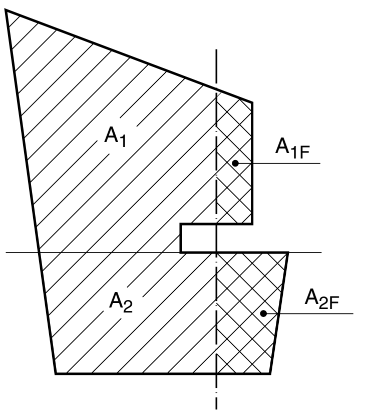
The total torque M_{TR} acting on the rudder stock, for both ahead and astern conditions, is to be obtained, in N.m, from the following formula:

$M_{TR} = M_{TR1} + M_{TR2}$

For the ahead condition only, M_{TR} is to be taken not less than the value obtained, in N.m, from the following formula:

$$M_{TR,MIN} = 0{,}1\,C_R\frac{A_1 b_1 + A_2 b_2}{A}$$

Figure 3 : Geometry of rudder blade with cut-outs



3 Rudder types and relevant loads acting on the rudder structure

3.1 General

3.1.1 Loads per rudder category - basic assumptions

Depending on the shape of the rudder blade and arrangement of the rudder, twelve types of rudders are considered. Tab 4 summarizes these rudder types.

The force and torque acting on the rudder, defined in [2], may induce in the rudder structure the following loads:

- bending moment and torque in the rudder stock
- support forces at pintle and rudder stock bearings
- bending moment, shear force and torque in the rudder body
- bending moment, shear force and torque in rudder horns and solepieces.

Support forces, bending moments and shear forces are to be obtained according to Ch 9, App 1, [1.4], depending on the rudder type.

3.1.2 Loads for the scantlings and assembling of rudder parts

The loads to be considered for the scantlings of rudder parts and some assembling parts are indicated in Tab 3.

4 Rudder stock scantlings

4.1 Rudder stock diameter

4.1.1 Basic formulation

The scantling of the rudder stock diameter is based on the Von Mises equivalent stress criterion, written for a state of stress induced by a combined torque, M_{TR}, and a bending moment, M_B, acting on the rudder stock. The Von Mises equivalent stress, σ_E, calculated for this state of stress, has to be in compliance with the following formula:

$\sigma_E \le \sigma_{E,ALL}$

where:

σ_E : Equivalent stress, in N/mm², to be obtained from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3\tau_T^2}$$

σ_B : Bending stress, in N/mm², to be obtained from the following formula:

$$\sigma_B = \frac{10,2 M_B}{d_S^3} \cdot 10^3$$

τ_T : Torsional stress, in N/mm², to be obtained from the following formula:

$$\tau_T = \frac{5,1 M_{TR}}{d_S^3} \cdot 10^3$$

d_S : Stock diameter, in mm

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm², equal to:

$\sigma_{E,ALL} = 118 / k_1$

For this purpose, the rudder stock diameter is to be not less than the value obtained, in mm, from the following formula:

$$d_{TFi} = 4,2(M_{TR}k_1)^{1/3}\left[1 + \frac{4}{3}\left(\frac{M_{Bi}}{M_{TR}}\right)^2\right]^{1/6}$$

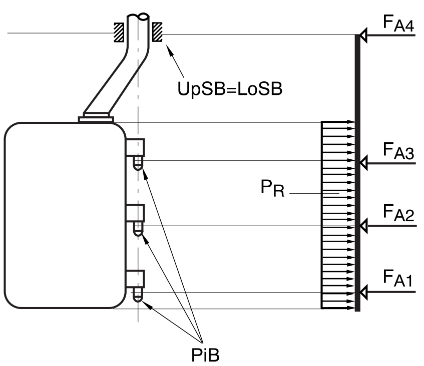
where M_{Bi} is to be obtained according to Ch 9, App 1, [1.1.1], for each type of rudder listed in Tab 4.

Table 3 : Scantling of parts, rudder stock couplings and relevant loads

Item identification	Relevant loads
Rudder stock scantlings	• either torque only, or • both, torque and bending moment See [4]
Rudder stock couplings	• either torque only, or • both, torque and bending moment See [5]
Rudder stock bearings	Horizontal reaction forces, F_{Ai}, See [6.2]
Pintle bearings	Horizontal reaction forces, F_{Ai}, See [6.3]
Scantling of pintles	Horizontal reaction forces, F_{Ai}, See [6.4]
Rudder blade scantlings	Bending moment and shear force See [7]
Rudder horn scantlings	Bending moment, shear force and torque See [8.1] and [8.2]
Solepiece scantlings	Bending moment and shear force See [8.3]

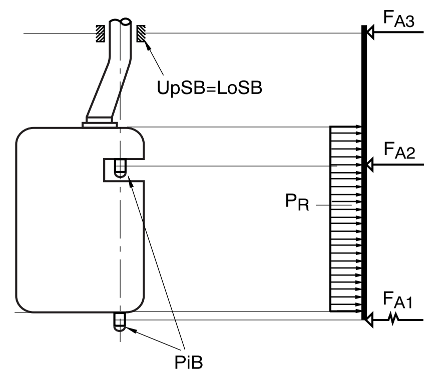
Table 4 : Types of rudders and load diagram

Type 1



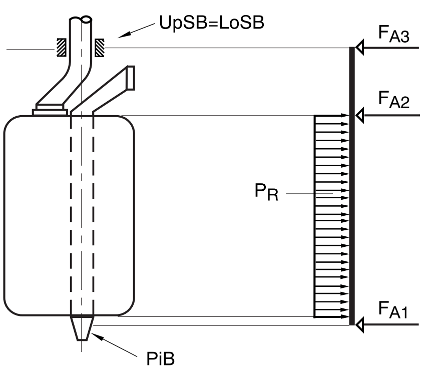
General description: 4-bearing rudder, including 3 pintle bearings and 1 rudder-stock bearing.
See Ch 9, App 1, [1.4.1].

Type 2



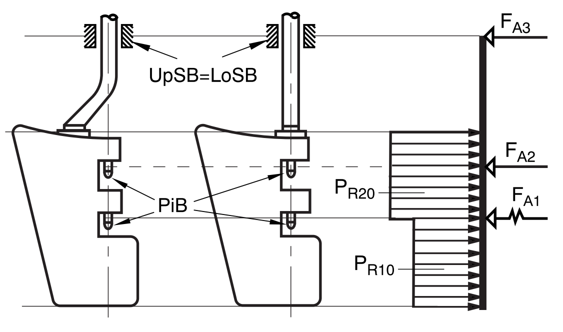
General description: 3-bearing rudder, including 2 pintle bearings and 1 rudder-stock bearing (the lower pintle bearing is represented by 1-elastic support).
See Ch 9, App 1, [1.4.2].

Type 3



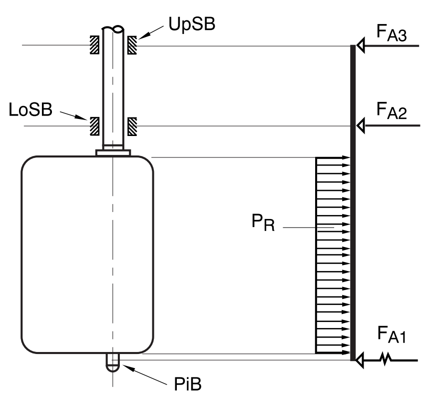
General description: 3-bearing rudder, including 2 bearings associated to the simplex rudder shaft and 1 rudder-stock bearing.
See Ch 9, App 1, [1.4.3].

Type 4



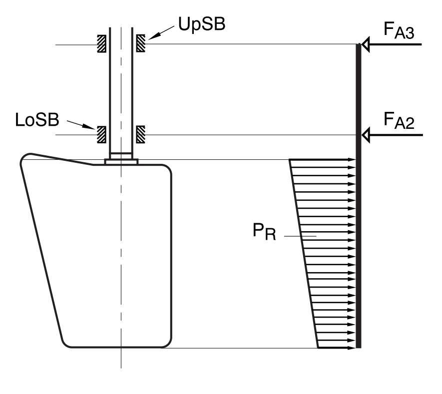
General description: 3-bearing semi-spade rudder, including 2 pintle bearings and 1 rudder-stock bearing (the lower pintle bearing is represented by 1-elastic support).
See Ch 9, App 1, [1.4.4].

Type 5



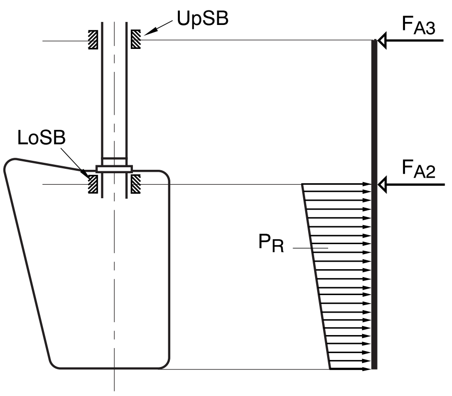
General description: 3-bearing rudder, including 1-elastic pintle bearing and 2 rudder-stock bearings.
See Ch 9, App 1, [1.4.5].

Type 6a



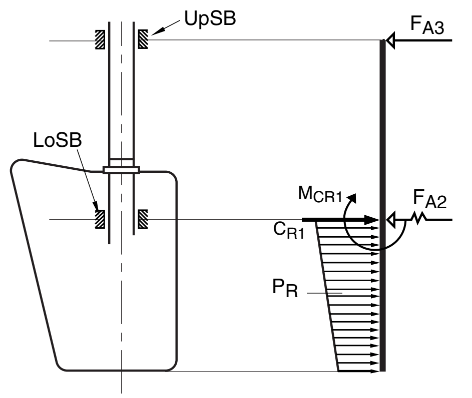
General description: 2-bearing spade rudder, including 2 rudder-stock bearings, both of them located out of the rudder blade area.
See Ch 9, App 1, [1.4.6].

Type 6b



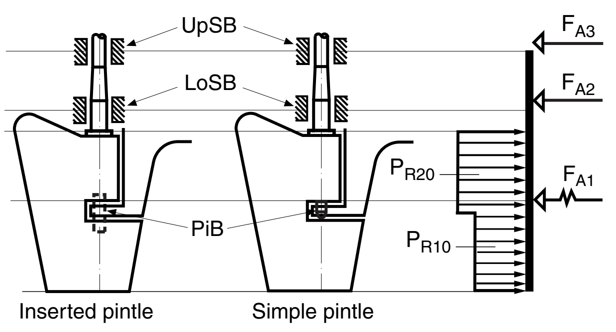
General description: 2-bearing spade rudder, including 2 rudder-stock bearings, the lowest one located inside of the rudder blade area and close to its upper edge. See Ch 9, App 1, [1.4.7].

Type 6c



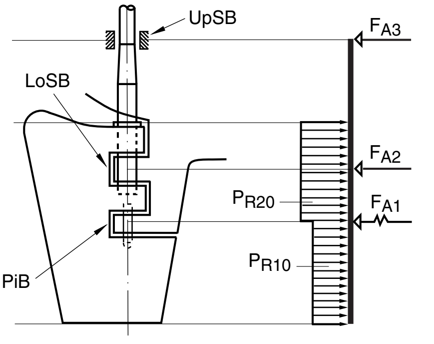
General description: 2-bearing spade rudder, including 2 rudder-stock bearings, the lowest one located inside of the rudder blade area. See Ch 9, App 1, [1.4.8].

Type 7



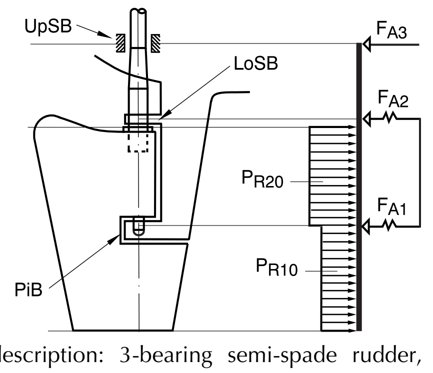
General description: 3-bearing semi-spade rudder, including 1-elastic pintle bearing and 2 rudder-stock bearings.
See Ch 9, App 1, [1.4.9].

Type 8



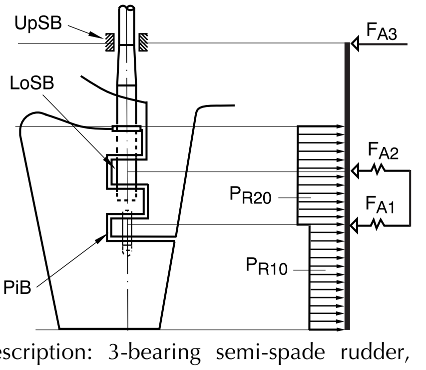
General description: 3-bearing semi-spade rudder, including 1-elastic pintle bearing and 2 rudder-stock bearings (with 1 rudder-stock bearing inside of the rudder blade area).
See Ch 9, App 1, [1.4.10].

Type 9



General description: 3-bearing semi-spade rudder, including 1 pintle bearing and 2 rudder-stock bearings (lower pintle and stock bearings represented by 2-conjugate elastic supports).
See Ch 9, App 1, [1.4.11].

Type 10



General description: 3-bearing semi-spade rudder, including 1 pintle bearing and 2 rudder-stock bearings (lower pintle and stock bearings represented by 2-conjugate elastic supports, located inside of the rudder blade area).
See Ch 9, App 1, [1.4.12].

Note 1: Bending moment and shear forces need to be calculated at any generic horizontal section of the rudder blade, to make possible strength checks prescribed under [7.2].

Note 2:

UpSB : Upper rudder-stock bearing
LoSB : Lower rudder-stock bearing
PiB : Position of pintle bearing(s).

Note 3: Steering nozzle rudders are not included in this table (refer to [10] for more details).

4.1.2 Rule rudder stock diameter

The rudder stock diameter, at the lower part, is to be not less than the value obtained, in mm, from the following formula:

$$d_{TF} = 4,2(M_{TR}\,k_1)^{1/3}\left[1+\frac{4}{3}\left(\frac{M_B}{M_{TR}}\right)^2\right]^{1/6}$$

with:

M_B : Maximum absolute value of bending moment M_{Bi} over the rudder stock length, to be obtained according to Ch 9, App 1, [1.4], for each type of rudder listed in Tab 4.

If not otherwise specified, the notation d_1 used in this Section is equivalent to d_{TF}.

4.1.3 Rudder stock cross sections with null bending moment

The diameter, in mm, of a rudder stock cross section subjected to torque only is not to be less than the diameter d_T obtained from [4.1.2], taking M_B equal to zero:

$d_T = 4,2\ (M_{TR}\ k_1)^{1/3}$

This is equivalent to check that the torsional shear stress τ_T, in N/mm², induced by the torque only, is in compliance with the following formula:

$\tau_T \le \tau_{ALL}$

where:

τ_{ALL} : Allowable torsional shear stress, in N/mm²:

$\tau_{ALL} = 68 / k_1$

τ_T : Torsional stress, in N/mm², defined in [4.1.1].

4.1.4 Rule rudder stock diameter in way of the tiller

In general, the diameter of a rudder stock subjected to torque and bending may be gradually tapered above the lower stock bearing so as to reach, from d_{TF} value, the value of d_T in way of the quadrant or the tiller.

4.2 Deformation criterion

4.2.1 Rudder stock slope in way of bearings

Large rudder stock deformations are to be avoided in order to avoid excessive edge pressures in way of bearings.

The Society may require an additional check of the rudder stock diameter to make sure that the rudder stock slopes in way of bearings are acceptable, by relating them to bearing lengths (see [6.2.3]) and bearing clearances (see [6.2.4]).

4.3 Service notations - Navigation in ice

4.3.1 Service notations

For specific service notations, increase in rudder stock diameter is required according to the relevant requirements in Part D or Part E.

4.3.2 Navigation in ice

For ships having an additional **ICE CLASS** notation, refer to applicable requirements in Pt F, Ch 8, Sec 2.

5 Rudder stock couplings

5.1 Horizontal flange couplings

5.1.1 General

In general, the coupling flange and the rudder stock are to be forged from a solid piece. A shoulder radius as large as practicable is to be provided for between the rudder stock and the coupling flange. This radius is to be not less than 0,15 d_1, where d_1 is defined in [4.1.2].

5.1.2 Welding

Where the rudder stock diameter does not exceed 350 mm, the coupling flange may be welded onto the stock, provided that its thickness is increased by 10% and that the weld extends through the full thickness of the coupling flange and that the assembly obtained is subjected to heat treatment. This heat treatment is not required if the diameter of the rudder stock is less than 75 mm.

Where the coupling flange is welded, the grade of the steel used is to be of weldable quality, with a carbon content not exceeding 0,23% on ladle analysis or a carbon equivalent CEQ not exceeding 0,41%. The welding conditions (preparation before welding, choice of electrodes, pre- and post-heating, inspection after welding) are to be defined to the satisfaction of the Society. The throat weld at the top of the flange is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius:

- is to be not less than 0,15d_1 , where d_1 is defined in [4.1.2]
- may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld
- 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.

The inspection is to include full non destructive tests at weld location (dye penetrant or magnetic particle test and ultrasonic test).

5.1.3 Bolts

Horizontal flange couplings are to be connected by fitted bolts having a diameter not less than the value obtained, in mm, from the following formula:

$$d_B = 0,62\sqrt{\frac{d_1^3 k_{1B}}{n_B e_M k_{1S}}}$$

where:

d_1 : Rudder stock diameter, in mm, defined in [4.1.2]

k_{1S} : Material factor k_1 for the steel used for the rudder stock

k_{1B} : Material factor k_1 for the steel used for the bolts

e_M : Mean distance, in mm, of the bolt axes from the centre of the bolt system

n_B : Total number of bolts, which is to be not less than 6.

Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted having a section of ($0,25d_T$ x $0,10d_T$) mm^2 and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

The distance from the bolt axes to the external edge of the coupling flange is to be not less than 1,2 d_B.

5.1.4 Coupling flange

The thickness of the coupling flange is to be not less than the value obtained, in mm, from the following formulae, whichever is the greater:

- $t_P = d_B \sqrt{\frac{k_{1F}}{k_{1B}}}$
- $t_p = 0,9\ d_B$

where:

d_B : Bolt diameter, in mm, calculated in accordance with [5.1.3], where the number of bolts n_B is to be taken not greater than 8

k_{1F} : Material factor k_1 for the steel used for the flange

k_{1B} : Material factor k_1 for the steel used for the bolts.

d_1 : Rudder stock diameter, in mm, defined in [4.1.2].

5.1.5 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

5.2 Couplings between rudder stocks and tillers

5.2.1 Application

The requirements of this sub-article apply in addition to those specified in Pt C, Ch 1, Sec 11.

The requirements specified in [5.2.3] and [5.2.4] apply to solid rudder stocks in steel and to tiller bosses, either in steel or in SG iron, with constant external diameter. Solid rudder stocks others than those above will be considered by the Society on a case-by-case basis, provided that the relevant calculations, to be based on the following criteria, are submitted to the Society:

- Young's modulus:
  - $E = 2,06.10^5$ N/mm^2 for steel
  - $E = 1,67.10^5$ N/mm^2 for SG iron
- Poisson's ratio:
  - $\nu = 0,30$ for steel
  - $\nu = 0,28$ for SG iron
- Frictional coefficient:
  - $\mu = 0,15$ for contact steel/steel
  - $\mu = 0,13$ for contact steel/SG iron
- Torque C_T transmissible through friction:

  $C_T \geq \eta\ M_{TR}$

  where η is defined in [5.2.3]
- Combined stress in the boss:

  $\sqrt{\sigma_R^2 + \sigma_T^2 - \sigma_R\sigma_T} \leq (0,5 + 0,2\ \eta) R_{eH}$

  where:

  σ_R , σ_T : Algebraic values of, respectively, the radial compression stress and the tangent tensile stress, in N/mm^2, induced by the grip pressure and calculated at the bore surface ($\sigma_R = p_F$, where p_F is the grip pressure in the considered horizontal cross-section of the boss)
- Where the rudder stock is hollow, the following strength criterion is to be complied with, at any point of the rudder stock cross-section:

  $\sqrt{\sigma_R^2 + \sigma_T^2 - \sigma_R\sigma_T + 3\tau^2} \leq 0,7\ R_{eH}$

  where:

  σ_R , σ_T : Algebraic values of, respectively, the radial and the tangent compressive stresses, in N/mm^2, induced by the grip pressure

  τ : Shear stress, in N/mm^2, induced by the torque M_{TR} .

5.2.2 General

The entrance edge of the tiller bore and that of the rudder stock cone are to be rounded or bevelled.

The right fit of the tapered bearing is to be checked before final fit up, to ascertain that the actual bearing is evenly distributed and at least equal to 80% of the theoretical bearing area; push-up length is measured from the relative positioning of the two parts corresponding to this case.

The required push-up length is to be checked after releasing of hydraulic pressures applied in the hydraulic nut and in the assembly.

5.2.3 Push-up length of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push-up length Δ_E , in mm, of the rudder stock tapered part into the tiller boss is in compliance with the following formula:

$\Delta_0 \leq \Delta_E \leq \Delta_1$

where:

$$\Delta_0 = 6,2 \frac{M_{TR}\eta\gamma}{c d_M t_S \mu_A \beta} 10^{-3}$$

$$\Delta_1 = \frac{2\eta + 5}{1,8} \cdot \frac{\gamma d_0 R_{eH}}{c} 10^{-6}$$

η : Coefficient to be taken equal to:
- $\eta = 1$ for keyed connections
- $\eta = 2$ for keyless connections

c : Taper of conical coupling measured on diameter, to be obtained from the following formula:

$c = (d_U - d_0) / t_S$

t_S, d_U, d_0 : Geometrical parameters of the coupling, defined in Fig 4

β : Coefficient to be taken equal to:

$$\beta = 1 - \left(\frac{d_M}{d_E}\right)^2$$

d_M : Mean diameter, in mm, of the conical bore, to be obtained from the following formula:

$d_M = d_U - 0,5\ c\ t_S$

d_E : External boss diameter, in mm

μ_A : Coefficient to be taken equal to:

$$\mu_A = \sqrt{\mu^2 - 0,25c^2}$$

μ, γ : Coefficients to be taken equal to:

- for rudder stocks and bosses made of steel:

  $\mu = 0,15$

  $\gamma = 1$

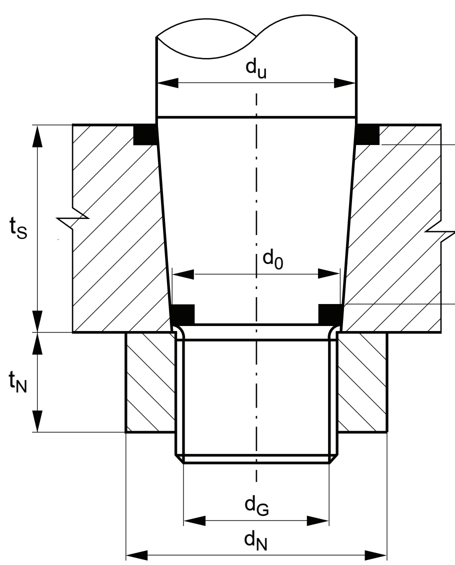
- for rudder stocks made of steel and bosses made of SG iron:

  $\mu = 0,13$

  $\gamma = 1,24 - 0,1\ \beta$

R_{eH} : Defined in [1.4.3].

Figure 4 : Geometry of cone coupling



5.2.4 Boss of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

The scantlings of the boss are to comply with the following formula:

$$\frac{1,8}{2\eta + 5} \cdot \frac{\Delta_E c}{\gamma d_0} 10^6 \le R_{eH}$$

where:

Δ_E : Push-up length adopted, in mm

c, η, γ : Defined in [5.2.3]

d_0 : Defined in Fig 4

R_{eH} : Defined in [1.4.3].

5.2.5 Cylindrical couplings by shrink fit

It is to be checked that the diametral shrinkage allowance δ_E, in mm, is in compliance with the following formula:

$$\delta_0 \le \delta_E \le \delta_1$$

where:

$$\delta_0 = 6,2 \cdot \frac{M_{TR}\eta\gamma}{d_U t_S \mu \beta_1} 10^{-3}$$

$$\delta_1 = \frac{2\eta + 5}{1,8} \cdot \gamma d_U R_{eH} 10^{-6}$$

η, μ, γ, c : Defined in [5.2.3]

d_U : Defined in Fig 4

β_1 : Coefficient to be taken equal to:

$$\beta_1 = 1 - \left(\frac{d_U}{d_E}\right)^2$$

R_{eH} : Defined in [1.4.3].

5.2.6 Keyless couplings through special devices

The use of special devices for frictional connections, such as expansible rings, may be accepted by the Society on a case-by-case basis provided that the following conditions are complied with:

- evidence that the device is efficient (theoretical calculations and results of experimental tests, references of behaviour during service, etc.) are to be submitted to the Society
- the torque transmissible by friction is to be not less than $2\ M_{TR}$
- design conditions and strength criteria are to comply with [5.2.1]
- instructions provided by the manufacturer are to be complied with, notably concerning the pre-stressing of the tightening screws.

5.3 Cone couplings between rudder stocks and rudder blades

5.3.1 Taper on diameter

The taper on diameter of the cone couplings is to be in compliance with the following formulae:

- for cone couplings without hydraulic arrangements for assembling and disassembling the coupling:

$$\frac{1}{12} \le \frac{d_U - d_0}{t_S} \le \frac{1}{8}$$

- for cone couplings with hydraulic arrangements for assembling and disassembling the coupling (assembling with oil injection and hydraulic nut):

$$\frac{1}{20} \le \frac{d_U - d_0}{t_S} \le \frac{1}{12}$$

where:

d_U, t_S, d_0 : Geometrical parameters of the coupling, defined in Fig 4.

5.3.2 Push-up pressure of cone coupling with hydraulic arrangements for assembling and disassembling the coupling

The push-up pressure, in N/mm², is not to be less than the greater of the two following values:

$$p_{req1} = \frac{2Q_F}{d_M^2 t_i \pi \mu_0} 10^3$$

$$p_{req2} = \frac{6M_{Bc}}{t_i^2 d_M} 10^3$$

where:

Q_F : Design yield moment of rudder stock, in N.m, defined in [5.3.6]

d_M : Mean diameter, in mm, of the conical bore defined in [5.2.3]

t_i : Geometrical parameter of the coupling defined in Fig 4

μ_0 : Frictional coefficient, taken equal to 0,15

M_{Bc} : Bending moment at mid-height of the cone coupling, in N.m, to be deduced from the calculation of the bending moment in the rudder stock, M_B, as defined in Ch 9, App 1.

It has to be demonstrated by the designer that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure, in N/mm², is to be determined by the following formula:

$$p_{perm} = \frac{0.95 R_{eH}(1-\alpha^2)}{\sqrt{3+\alpha^4}} - p_b$$

where:

p_b : Pressure due to rudder bending, to be taken as follows:

$$p_b = \frac{3.5 M_{Bc}}{t_i^2 d_M} 10^3$$

R_{eH} : Minimum yield stress for the steel used for the gudgeon

α : d_M/d_E

d_E : Outer diameter of the gudgeon, in mm.

The outer diameter of the gudgeon is to be not less than 1.25 d_U, with d_U the rudder stock diameter, in mm, as defined in Fig 4.

5.3.3 Push-up length of cone coupling with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push-up length Δ_E, in mm, of the rudder stock tapered part into the boss is in compliance with the following formula:

$$\Delta_0 \le \Delta_E \le \Delta_1$$

where:

$$\Delta_0 = \frac{p_{req} d_M}{E\left(\frac{1-\alpha^2}{2}\right)c} + \frac{0.8 R_{tm}}{c}$$

$$\Delta_1 = \frac{p_{perm} d_M}{E\left(\frac{1-\alpha^2}{2}\right)c} + \frac{0.8 R_{tm}}{c}$$

R_{tm} : Mean roughness, in mm, taken equal to 0,01

c : Taper on conical coupling defined in [5.2.3].

Note 1: In case of hydraulic pressure connections, the required push-up force P_e, in N, may be determined by the following formula:

$$P_e = p_{req} d_M \pi t_i \left(\frac{c}{2} + 0,02\right)$$

5.3.4 Lower rudder stock end

The lower rudder stock end is to be fitted with a threaded part having a core diameter, d_G, in mm, not less than (see Fig 4):

$d_G = 0,65\ d_U$

where:

d_U : Rudder stock diameter, in mm, as defined in Fig 4.

This threaded part is to be fitted with an adequate slogging nut efficiently locked in rotation.

The contact length t_i, in mm, of the rudder stock coupling cone inserted in the massive part (see Fig 4), deduction made of the chamfers and sealing ring grooves (oil grooves may be disregarded), is to be such that:

$$t_i \ge 1,5 d_U \sqrt{k_1}$$

where:

k_1 : Material factor of the massive part.

When the foreseen contact surface ratio between the rudder stock and the massive part is greater than 70%, a lower t_i/d_U ratio may be accepted, on a case-by-case basis, provided that the contact percentage is proportionally higher, without however being taken less than 1,2.

The dimensions of the slogging nut are recommended to be as follows (see Fig 4:

- outer diameter: $d_N \ge$ Max (1,2 d_0 ; 1,5 d_G)
- thickness: $t_N \ge 0,60\ d_G$

where:

d_0 : As defined in Fig 4.

These dimensions and the core diameter d_G of the lower rudder stock end are given for guidance only, the determination of the adequate scantlings being left to the Designer.

5.3.5 Washer

For cone couplings with hydraulic arrangements for assembling and disassembling the coupling, a washer is to be fitted between the nut and the rudder gudgeon, having a thickness not less than 0,09 d_G and an outer diameter not less than 1,3 d_0 or 1,6 d_G, whichever is the greater.

The washer is not needed if the seat-surface of the nut is flat and, at least, identical to the contact surface calculated for a washer with the required diameter.

5.3.6 Couplings with key

For cone couplings without hydraulic arrangements for assembling and disassembling the coupling, a key is to be fitted and keyways in both the tapered part and the rudder gudgeon.

The key is to be machined and located on the fore or aft part of the rudder. The key is to be inserted at half-thickness into stock and into the solid part of the rudder.

The key shear area a_S, in cm², is to be not less than:

$$a_S = \frac{17,55 Q_F}{d_k R_{eH1}}$$

where:

Q_F : Design yield moment of rudder stock, in N.m, obtained from the following formula:

$$Q_F = 0,02664\frac{d_1^{\,3}}{k_{1S}}$$

Where the actual stock diameter is greater than the calculated diameter d_1, the actual diameter is to be used, without being taken greater than 1,145 d_1.

d_1 : Rudder stock diameter, in mm, taken equal to d_T, as defined in [4.1.3]

k_{1S} : Material factor k_1 for the steel used for the rudder stock

d_k : Mean diameter of the conical part of the rudder stock at the key, in mm

R_{eH1} : Minimum yield stress R_{eH} for the steel used for key.

The effective surface area a_k, in cm², of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than:

$$a_k = \frac{5Q_F}{d_k R_{eH2}}$$

where:

R_{eH2} : Minimum yield stress R_{eH} of the key, stock or coupling material, whichever is less.

It is to be proved that 50% of the design yield moment Q_F is solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure p_{req} and push-up length Δ_E according to [5.3.2] and [5.3.3] for a torsional moment Q'_F equal to 0,5 Q_F.

In the specific case where the key is considered to transmit the entire rudder torque to the couplings, the scantlings of the key, as well as the push-up force and push-up length, are to be at the discretion of the Society.

5.3.7 Instructions

All necessary instructions for hydraulic assembly and disassembly of the nut, including indication of the values of all relevant parameters, are to be available on board.

5.4 Vertical flange couplings

5.4.1 Vertical flange couplings are to be connected by fitted bolts having a diameter, in mm, not less than the value obtained, in mm, from the following formula:

$$d_B = \frac{0,81\,d_1}{\sqrt{n_B}}\sqrt{\frac{k_{1B}}{k_{1S}}}$$

where:

d_1 : Rudder stock diameter, in mm, defined in [4.1.2]

k_{1S}, k_{1B} : Material factors, defined in [5.1.3]

n_B : Total number of bolts, which is to be not less than 8.

5.4.2 The first moment of area of the sectional area of bolts about the vertical axis through the centre of the coupling is to be not less than the value obtained, in cm³, from the following formula:

$M_S = 0,00043\ d_1^{\,3}$

where:

d_1 : Rudder stock diameter, in mm, defined in [4.1.2].

5.4.3 The thickness of the coupling flange, in mm, is to be not less than d_B, defined in [5.4.1].

5.4.4 The distance, in mm, from the bolt axes to the external edge of the coupling flange is to be not less than 1,2 d_B, where d_B is defined in [5.4.1].

5.4.5 A suitable locking device is to be provided to prevent the accidental loosening of nuts.

5.5 Couplings by continuous rudder stock welded to the rudder blade

5.5.1 When the rudder stock extends through the upper plate of the rudder blade and is welded to it, the thickness of this plate in the vicinity of the rudder stock is to be not less than 0,20 d_1, where d_1 is defined in [4.1.2].

5.5.2 The welding of the upper plate of the rudder blade with the rudder stock is to be made with a full penetration weld and is to be subjected to non-destructive inspection through dye penetrant or magnetic particle test and ultrasonic test.

The throat weld at the top of the rudder upper plate is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius:

- is to be not less than 0,15 d_1, where d_1 is defined in [4.1.2]
- may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld
- 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.

5.6 Rudder trunks

5.6.1 In case where the rudder stock is fitted with a rudder trunk welded in such a way the rudder trunk is loaded by the pressure induced on the rudder blade, as given in [2.1.2], the bending and shear stresses in the rudder trunk, in N/mm², are to be in compliance with the following formulae:

$\sigma \leq 80 / k$

$\tau \leq 48 / k$

where k is not to be taken less than 0,7.

For the calculation of the bending and shear stresses, refer to Ch 9, App 1, [1.8].

5.6.2 The steel grade used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0,23% on ladle analysis and a carbon equivalent CEQ not exceeding 0,41.

5.6.3 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:

$r = 0,1\ d_1$

where d_1 is defined in [4.1.2],

without being less than:

$r = 60$ mm when $\sigma \geq 40 / k$ N/mm²

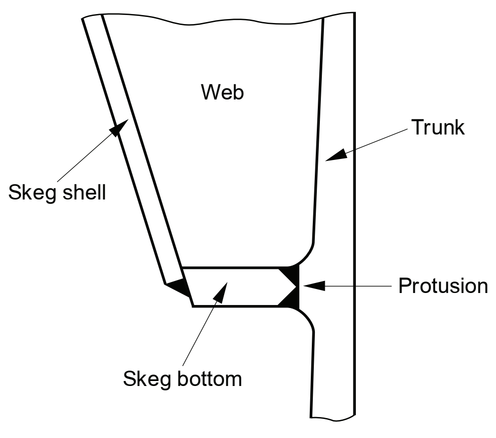
$r = 30$ mm when $\sigma < 40 / k$ N/mm².

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.

5.6.4 In case of type 6c rudders, the trunk tube is to be made with a protrusion at connection with skeg bottom, and scallops in webs are to be avoided at connection between the bottom of the skeg and the trunk or the shell, as shown in Fig 5.

Figure 5 : Typical trunk/skeg connection on type 6c rudders



5.6.5 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 NR216 Materials and Welding, Ch 5, Sec 4.

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.

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.

5.6.6 Rudder trunks in materials other than steel are to be specially considered by the Society.

5.6.7 The thickness of the shell or of the bottom plate is to be compatible with the trunk thickness.

6 Rudder stock and pintle bearings

6.1 Forces on rudder stock and pintle bearings

6.1.1 Support forces F_{Ai} , for i = 1, 2, 3, 4, as described in Tab 4, are to be obtained according to Ch 9, App 1, depending on the rudder type.

6.2 Rudder stock bearing

6.2.1 The mean bearing pressure acting on the rudder stock bearing is to be in compliance with the following formula:

$p_F \leq p_{F,ALL}$

where:

p_F : Mean bearing pressure acting on the rudder stock bearings, in N/mm², equal to:

$$p_F = \frac{F_{Ai}}{d_m h_m}$$

F_{Ai} : Support force acting on the rudder stock bearing, in N

d_m : Actual inner diameter, in mm, of the rudder stock bearings (contact diameter)

h_m : Bearing length, in mm (see [6.2.3])

$p_{F,ALL}$: Allowable bearing pressure, in N/mm², defined in Tab 5.

Values greater than those given in Tab 5 may be accepted by the Society on the basis of specific tests.

Table 5 : Allowable bearing pressure

Bearing material	$p_{F,ALL}$, in N/mm²
Lignum vitae	2,5
White metal, oil lubricated	4,5
Synthetic material with hardness between 60 and 70 Shore D **(1)**	5,5
Steel, bronze and hot-pressed bronze-graphite materials **(2)**	7,0

(1) Indentation hardness test at 23°C and with 50% moisture to be performed according to a recognised standard. Type of synthetic bearing materials is to be approved by the Society.
(2) Stainless and wear-resistant steel in combination with stock liner approved by the Society.

6.2.2 An adequate lubrication of the bearing surface is to be ensured.

6.2.3 The length/diameter ratio of the bearing surface is not to be greater than 1,2.

6.2.4 The manufacturing clearance t_0 on the diameter of metallic supports is to be not less than the value obtained, in mm, from the following formula:

$$t_0 = \frac{d_m}{1000} + 1$$

In the case of non-metallic supports, the clearances are to be carefully evaluated on the basis of the thermal and distortion properties of the materials employed. In any case, for non metallic supports, the clearance on support diameter is to be not less than 1,5 mm unless a smaller clearance is supported by the manufacturer's recommendation and there is documented evidence of satisfactory service history with a reduced clearance.

6.2.5 Liners and bushes are to be fitted in way of the bearings. Their minimum thickness is to be equal to:

- 8 mm for metallic and synthetic materials
- 22 mm for lignum vitae material.

6.3 Pintle bearings

6.3.1 The mean bearing pressure acting on the gudgeons is to be in compliance with the following formula:

$p_F \leq p_{F,ALL}$

where:

p_F : Mean bearing pressure acting on the gudgeons, in N/mm², equal to:

$$p_F = \frac{F_{Ai}}{d_{AC} h_L}$$

F_{Ai} : Support force acting on the pintle, in N

d_{AC} : Actual diameter, in mm, of the rudder pintles (contact diameter)

h_L : Bearing length, in mm (see [6.3.3])

$p_{F,ALL}$: Allowable bearing pressure, in N/mm², defined in Tab 5.

Values greater than those given in Tab 5 may be accepted by the Society on the basis of specific tests.

6.3.2 An adequate lubrication of the bearing surface is to be ensured.

6.3.3 The length/diameter ratio of the bearing surface is not to be less than 1 and not to be greater than 1,2.

6.3.4 The manufacturing clearance t_0 on the diameter of metallic supports is to be not less than the value obtained, in mm, from the following formula:

$$t_0 = \frac{d_{AC}}{1000} + 1$$

In the case of non-metallic supports, the clearances are to be carefully evaluated on the basis of the thermal and distortion properties of the materials employed. In any case, for non-metallic supports, the clearance on support diameter is to be not less than 1,5 mm.

6.3.5 The thickness of any liner or bush, in mm, is to be not less than the greater of:

- $0,01\sqrt{F_{Ai}}$
- the minimum thickness defined in [6.2.5].

6.4 Pintles

6.4.1 Rudder pintles are to have a diameter not less than the value obtained, in mm, from the following formula:

$$d_A = \frac{0,38 V_{AV}}{V_{AV} + 3}\sqrt{F_{Ai} k_1} + f_C$$

where:

d_A : corresponds to d_U value shown in Fig 4

F_{Ai} : Force, in N, acting on the pintle, as specified in Tab 4

f_C : Coefficient depending on corrosion, whose value may generally be obtained from the following formula:

$$f_C = 30\sqrt{k_1}$$

The Society may accept lower values of f_C, considering the ship's dimensions and satisfactory service experience of corrosion control systems adopted.

6.4.2 Provision is to be made for a suitable locking device to prevent the accidental loosening of pintles.

6.4.3 The pintles are to have a conical coupling with a taper on diameter in accordance with [5.3.1].

The conical coupling is to be secured by a nut. The dimensions of the massive part and slogging nut are to be in accordance with the following formulae:

$d_E \geq d_M + 0,6\, d_A$

$t_N \geq 0,60\, d_G$

$d_N \geq 1,2\, d_0$ and, in any case, $d_N \geq 1,5\, d_G$

where:

d_A : Pintle diameter defined in [6.4.1]

d_E : External diameter, in mm, of the massive part of Fig 4, having the thickness t_S

d_M : Mean diameter, in mm, of the conical bore, as defined in [5.2.3]

t_S, d_G, t_N, d_N, d_0 : Geometrical parameters of the coupling, defined in Fig 4.

The above minimum dimensions of the locking nut are only given for guidance, the determination of adequate scantlings being left to the Designer.

6.4.4 The length of the pintle housing in the gudgeon, which corresponds to t_i in Fig 4, is to be not less than the greater of the values obtained, in mm, from the following formulae:

$$h_L = 0,35\sqrt{F_{Ai} k_1}$$

$h_L = d_A$

where:

F_{Ai} : Force, in N, acting on the pintle, as specified in Tab 4.

The thickness of pintle housing in the gudgeon, in mm, is to be not less than 0,25 d_A, where d_A is defined in [6.4.1].

6.4.5 The required push-up pressure for pintle, in N/mm², is to be determined by the following formula:

$$p_{req} = 0.4\frac{F_{Ai}d_A}{d_M^2 t_i}$$

where:

d_M : Mean diameter, in mm, of the conical bore defined in [5.2.3]

t_i : Geometrical parameter of the coupling defined in Fig 4.

The push-up length is to be calculated according to [5.3.3] using required push-up pressure and pintle properties.

7 Rudder blade scantlings

7.1 General

7.1.1 Application

The requirements in [7.1] to [7.6] apply to streamlined rudders and, when applicable, to rudder blades of single plate rudders.

7.1.2 Rudder blade structure

The structure of the rudder blade is to be such that stresses are correctly transmitted to the rudder stock and pintles. To this end, horizontal and vertical web plates are to be provided.

Horizontal and vertical webs acting as main bending girders of the rudder blade are to be suitably reinforced.

7.1.3 Access openings

Streamlined rudders, including those filled with pitch, cork or foam, are to be fitted with plug-holes and the necessary devices to allow their mounting and dismounting.

Access openings to the pintles are to be provided. If necessary, the rudder blade plating is to be strengthened in way of these openings.

The corners of openings intended for the passage of the rudder horn heel and for the dismantling of pintle or stock nuts are to be rounded off with a radius as large as practicable.

Where the access to the rudder stock nut is closed with a welded plate, a full penetration weld is to be provided.

7.1.4 Connection of the rudder blade to the trailing edge for rudder blade area greater than 6 m²

Where the rudder blade area is greater than 6 m², the connection of the rudder blade plating to the trailing edge is to be made by means of a forged or cast steel fashion piece, a flat or a round bar.

7.2 Strength checks

7.2.1 Bending stresses

For the generic horizontal section of the rudder blade it is to be checked that the bending stress σ, in N/mm², induced by the loads defined in [3.1], is in compliance with the following formula:

$$\sigma \le \sigma_{ALL}$$

where:

σ_{ALL} : Allowable bending stress, in N/mm², specified in Tab 6.

7.2.2 Shear stresses

For the generic horizontal section of the rudder blade it is to be checked that the shear stress τ, in N/mm², induced by the loads defined in [3.1], is in compliance with the following formula:

$$\tau \le \tau_{ALL}$$

where:

τ_{ALL} : Allowable shear stress, in N/mm², specified in Tab 6.

Table 6 : Allowable stresses for rudder blade scantlings

Type of rudder blade	Allowable bending stress σ_{ALL} in N/mm²	Allowable shear stress τ_{ALL} in N/mm²	Allowable equivalent stress $\sigma_{E,ALL}$ in N/mm²
General	110 / k	50 / k	120 / k
In way of the recess for rudder horn pintle on semi-spade rudders **(1) (2)**	75	50	100

(1) No benefit is given for high tensile steel in this case.
(2) Applicable in way of rudder recess sections in general.

7.2.3 Combined bending and shear stresses

For the generic horizontal section of the rudder blade it is to be checked that the equivalent stress σ_E is in compliance with the following formula:

$$\sigma_E \le \sigma_{E,ALL}$$

where:

σ_E : Equivalent stress induced by the loads defined in [3.1], to be obtained, in N/mm², from the following formula:

$$\sigma_E = \sqrt{\sigma^2 + 3\tau^2}$$

σ : Bending stress, in N/mm²

τ : Shear stress, in N/mm²

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm², specified in Tab 6.

7.3 Rudder blade plating

7.3.1 Plate thickness

The thickness of each rudder blade plate panel is to be not less than the value obtained, in mm, from the following formula:

$$t_F = 5{,}5 s\beta\sqrt{k\left(T + \frac{C_R 10^{-4}}{A}\right)} + 2{,}5$$

where:

β : Coefficient equal to:

$$\beta = \sqrt{1{,}1 - 0{,}5\left(\frac{s}{b_L}\right)^2}$$

to be taken not greater than 1,0 if $b_L/s > 2{,}5$

s : Length, in m, of the shorter side of the plate panel

b_L : Length, in m, of the longer side of the plate panel.

7.3.2 Thickness of the top and bottom plates of the rudder blade

The thickness of the top and bottom plates of the rudder blade is to be taken as the maximum of:

- the thickness t_F defined in [7.3.1], by considering the relevant values of s and b_L, for both the top and bottom plates
- 1,2 times the thicknesses obtained for the attached side platings around the top and bottom plates, respectively, calculated according to [7.3.1], by considering the relevant values of s and b_L

Where the rudder is connected to the rudder stock with a coupling flange, the thickness of the top plate which is welded in extension of the rudder flange is to be not less than 1,1 times the thickness calculated above.

7.3.3 Web spacing

The spacing between horizontal web plates is to be not greater than 1,20 m.

Vertical webs are to have spacing not greater than twice that of horizontal webs.

7.3.4 Web thickness

Web thickness is to be at least 70% of that required for rudder plating and in no case is it to be less than 8 mm, except for the upper and lower horizontal webs. The thickness of each of these webs is to be uniform and not less than that of the web panel having the greatest thickness t_F, as calculated in [7.3.1]. In any case it is not required that the thickness is increased by more than 20% in respect of normal webs.

When the design of the rudder does not incorporate a mainpiece, this is to be replaced by two vertical webs closely spaced, having thickness not less than that obtained from Tab 7. In rudders having area less than 6 m^2, one vertical web only may be accepted provided its thickness is at least twice that of normal webs.

7.3.5 Thickness of side plating and vertical web plates welded to solid part or to rudder flange

The thickness, in mm, of the vertical web plates welded to the solid part where the rudder stock is housed, or welded to the rudder flange, as well as the thickness of the rudder side plating under this solid part, or under the rudder coupling flange, is to be not less than the value obtained, in mm, from Tab 7.

7.3.6 Reinforced strake of semi-spade rudders

A reinforced strake is to be provided in the lower pintle zone of semi-spade rudders. Its thickness is to be not less than 1,6 t_F, where t_F is defined in [7.3.1]. This strake is to be extended forward of the main vertical web plate (see Fig 6).

7.3.7 Main vertical webs of semi-spade rudders

The thickness of the main vertical web plate in the area between the rudder blade upper part and the pintle housing of semi-spade rudders is to be not less than 2,6 t_F, where t_F is defined in [7.3.1].

Under the pintle housing the thickness of this web is to be not less than the value obtained from Tab 7.

Where two main vertical webs are fitted, the thicknesses of these webs are to be not less than the values obtained from Tab 7 depending on whether the web is fitted in a rudder blade area without opening or if the web is along the recess cut in the rudder for the passage of the rudder horn heel.

Figure 6 : Reinforced strake extension for semi-spade rudders

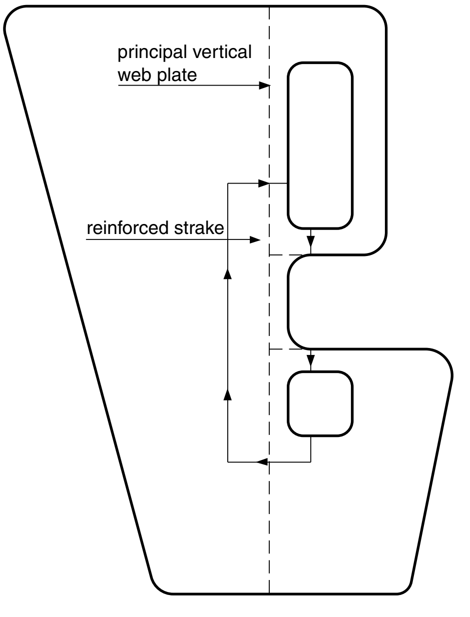


Table 7 : Thickness of the vertical webs and rudder side plating welded to solid part or to rudder flange

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 types 1, 2, 3 and 4 (see Tab 4)	t_F	1,3 t_F	t_F	1,2 t_F
Rudder type 5 (see Tab 4)	1,2 t_F	1,6 t_F	1,2 t_F	1,4 t_F
Rudder types 6, 7, 8, 9 and 10 (see Tab 4)	1,4 t_F	2,0 t_F	1,3 t_F	1,6 t_F

Note 1:
t_F : Defined in [7.3.1].

7.3.8 Welding

The welded connections of blade plating to vertical and horizontal webs are to be in compliance with the applicable requirements of NR216 Materials and Welding.

Where the welds of the rudder blade are accessible only from outside of the rudder, slots on a flat bar welded to the webs are to be provided to support the weld root, to be cut on one side of the rudder only.

7.3.9 Rudder nose plate thickness

Rudder nose plates are to have a thickness not less than:

- 1,25 t_F without exceeding 22 mm, for $t_F < 22$ mm
- t_F, for $t_F \geq 22$ mm

where t_F is defined in [7.3.1].

The rudder nose plate thickness may be increased on a case by case basis to be considered by the Society.

7.4 Connections of rudder blade structure with solid parts in forged or cast steel

7.4.1 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.

7.4.2 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 cm³, 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 [4.1.2]

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 in [1.4], for the rudder blade plating and the rudder stock, respectively.

7.4.3 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 7)

H_X : Distance defined in [7.4.2]

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 according to [7.1.3], they are to be deducted (see Fig 7).

7.4.4 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:

$t_H = 1{,}2\ t_F$

$$t_H = 0{,}045\frac{d_S^2}{s_H}$$

where:

t_F : Defined in [7.3.1]

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

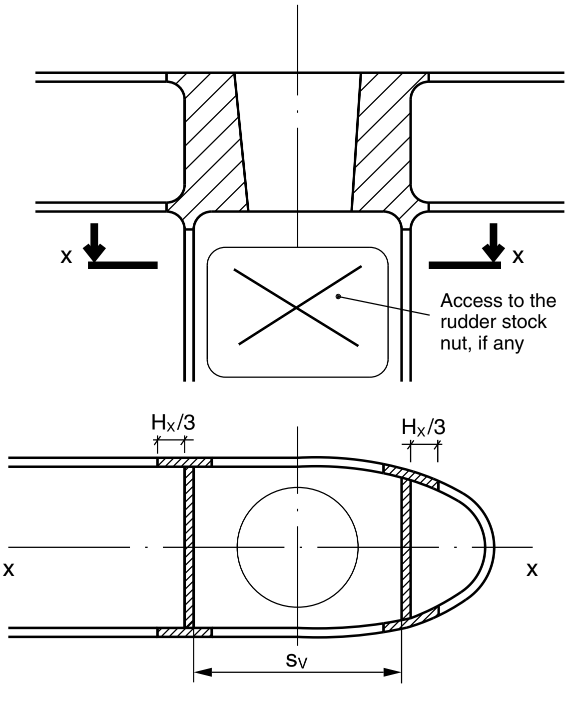
d_1 : Rudder stock diameter, in mm, defined in [4.1.2]

d_A : Pintle diameter, in mm, defined in [6.4.1]

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 7 : Cross-section of the connection between rudder blade structure and rudder stock housing



7.4.5 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 7.

7.4.6 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.

7.5 Connection of the rudder blade with the rudder stock by means of horizontal flanges

7.5.1 Minimum section modulus of the connection

The section modulus of the cross-section of the structure of the rudder blade which is directly connected with the flange, which is made by vertical web plates and rudder blade plating, is to be not less than the value obtained, in cm^3, from the following formula:

$$w_S = 1{,}3\ d_1^3\ 10^{-4}$$

where d_1 is the rudder stock diameter d_{TF}, in mm, to be calculated in compliance with [4.1.2], taking k_1 equal to 1.

7.5.2 Actual section modulus of the connection

The section modulus of the cross-section of the structure of the rudder blade which is directly connected with the flange is to be calculated with respect to the symmetrical axis of the rudder.

For the calculation of this actual section modulus, the length of the rudder cross-section equal to the length of the rudder flange is to be considered.

Where the rudder plating is provided with an opening under the rudder flange, the actual section modulus of the rudder blade is to be calculated in compliance with [7.4.3].

7.5.3 Welding of the rudder blade structure to the rudder blade flange

The welds between the rudder blade structure and the rudder blade flange are to be full penetrated (or of equivalent strength) and are to be 100% inspected by means of non-destructive tests.

Where the full penetration welds of the rudder blade are accessible only from outside of the rudder, a backing flat bar is to be provided to support the weld root.

The external fillet welds between the rudder blade plating and the rudder flange are to be of concave shape and their throat thickness is to be at least equal to 0,5 times the rudder blade thickness.

Moreover, the rudder flange is to be checked before welding by non-destructive inspection for lamination and inclusion detection in order to reduce the risk of lamellar tearing.

7.5.4 Thickness of side plating and vertical web plates welded to the rudder flange

The thickness of the vertical web plates directly welded to the rudder flange as well as the plating thickness of the rudder blade upper strake in the area of the connection with the rudder flange are to be not less than the values obtained, in mm, from Tab 7.

7.6 Single plate rudders

7.6.1 Mainpiece diameter

The mainpiece diameter is to be obtained from the formulae in [4.1.2] or [4.1.3].

In any case, the mainpiece diameter is to be not less than the stock diameter.

For spade rudders the lower third may taper down to 0,75 times the stock diameter.

7.6.2 Blade thickness

The blade thickness is to be not less than the value obtained, in mm, from the following formula:

$$t_B = 1{,}5 s V_{AV} \sqrt{k} + 2{,}5$$

where:

s : Spacing of stiffening arms, in m, to be taken not greater than 1 m (see Fig 8).

7.6.3 Arms

The thickness of the arms is to be not less than the blade thickness.

The section modulus of the generic section is to be not less than the value obtained, in cm^3, from the following formula:

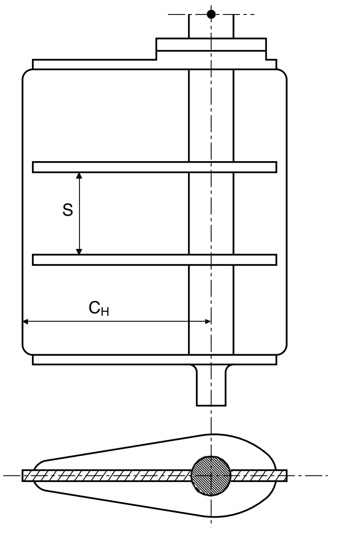
$Z_A = 0{,}5\ s\ C_H^2\ V_{AV}^2\ k$

where:

C_H : Horizontal distance, in m, from the aft edge of the rudder to the centreline of the rudder stock (see Fig 8)

s : Defined in [7.6.2].

Figure 8 : Single plate rudder



8 Rudder horn and solepiece scantlings

8.1 General

8.1.1 The weight of the rudder is normally supported by a carrier bearing inside the rudder trunk.

In the case of unbalanced rudders having more than one pintle, the weight of the rudder may be supported by a suitable disc fitted in the solepiece gudgeon.

Robust and effective structural rudder stops are to be fitted, except where adequate positive stopping arrangements are provided in the steering gear, in compliance with the applicable requirements of Pt C, Ch 1, Sec 11.

8.2 Rudder horn

8.2.1 General

When the connection between the rudder horn and the hull structure is designed as a curved transition into the hull plating, special consideration is to be paid to the effectiveness of the rudder horn plate in bending and to the stresses in the transverse web plates.

8.2.2 Loads

The following loads acting on the generic section of the rudder horn are to be considered:

- bending moment
- shear force
- torque.

Bending moment, shear forces and torque are to be calculated according to Ch 9, App 1, [1.6], or Ch 9, App 1, [1.7], depending on the relevant type of rudder.

8.2.3 Shear stress check

For the generic section of the rudder horn, it is to be checked that:

$\tau_S \le \tau_{ALL}$

where:

τ_S : Shear stress, in N/mm^2, to be obtained according to, either Ch 9, App 1, [1.6] or Ch 9, App 1, [1.7]

τ_{ALL} : Allowable shear stress, in N/mm^2:

$\tau_{ALL} = 48 / k_1$

8.2.4 Combined stress strength check

For the generic section of the rudder horn, it is to be checked that:

$\sigma_E \le \sigma_{E,ALL}$

$\sigma_B \le \sigma_{B,ALL}$

where:

σ_E : Equivalent stress to be obtained, in N/mm^2, from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3(\tau_S^2 + \tau_T^2)}$$

σ_B : Bending stress, in N/mm^2, to be obtained from, either Ch 9, App 1, [1.6] or Ch 9, App 1, [1.7], depending on the rudder type

τ_S , τ_T : Shear and torsional stresses, in N/mm^2, to be obtained according to, either Ch 9, App 1, [1.6] or Ch 9, App 1, [1.7]

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm^2, equal to:

$\sigma_{E,ALL} = 120 / k_1$

$\sigma_{B,ALL}$: Allowable bending stress, in N/mm^2, equal to:

$\sigma_{B,ALL} = 67 / k_1$.

8.3 Solepieces

8.3.1 Strength checks

For the generic section of the solepiece, it is to be checked that:

$\sigma_B \le \sigma_{B,ALL}$

$\tau \le \tau_{ALL}$

where:

σ_B : Bending stress, in N/mm^2, to be obtained according to Ch 9, App 1, [1.5.2]

τ : Shear stress, in N/mm^2, to be obtained according to Ch 9, App 1, [1.5.2]

$\sigma_{B,ALL}$: Allowable bending stress, in N/mm², equal to:

$\sigma_{B,ALL} = 80 / k_1$

τ_{ALL} : Allowable shear stress, in N/mm², equal to:

$\tau_{ALL} = 48 / k_1$.

8.3.2 Minimum section modulus around the horizontal axis

The section modulus around the horizontal axis Y (see Ch 9, App 1, Fig 11) is to be not less than the value obtained, in cm³, from the following formula:

$W_Y = 0,5\ W_Z$

where:

W_Z : Section modulus, in cm³, around the vertical axis Z (see Ch 9, App 1, Fig 11).

9 Simplex rudder shaft

9.1 Scantlings

9.1.1 Diameter of the rudder shaft

The rudder shaft diameter is to be not less than the value obtained, in mm, from the following formula:

$$d = 17,9\left(\frac{\alpha A(V_{AV} + 2)^2}{\ell}\right)^{1/3}$$

where:

α : Coefficient equal to:

- $\alpha = b\ (\ell - b + a)$ if $a \le b$
- $\alpha = a\ (\ell - a + b)$ if $a > b$

a, b, ℓ : Geometrical parameters, in m, defined in Fig 9.

9.1.2 Sectional area of rudder shaft

The overall sectional area of the rudder shaft is to be not less than the greater of the following values:

- 70% of the sectional area for the propeller post defined in Ch 8, Sec 2, [6.3]
- value of the sectional area of the pintle supporting half the rudder blade, whose diameter is to be calculated from the formula in [6.4.1].

If the latter value is the greater, it is to be applied only where the rudder bears on the rudder shaft; in such case, it is recommended that an overthickness or a bush is provided in way of the bearing areas.

9.1.3 Bearings

The bearing length of the rudder shaft is to be not less than 1,2 d, where d is the shaft diameter defined in [9.1.1].

The mean pressure acting on the bearings is not to exceed the relevant allowable values, defined in Tab 5.

9.1.4 The manufacturing clearance t_0 on the diameter of metallic supports is to be not less than the value obtained, in mm, from the following formula:

$$t_0 = \frac{d_A}{1000} + 1$$

where:

d_A : Actual inner diameter, in mm, of the rudder shaft bearing (contact diameter).

In the case of non-metallic supports, the clearances are to be carefully evaluated on the basis of the thermal and distortion properties of the materials employed.

In any case, for non-metallic supports, the clearance on support diameter is to be not less than 1,5 mm.

9.2 Connections

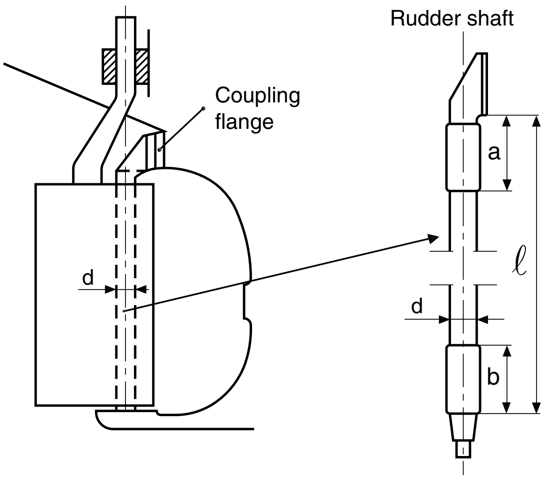
9.2.1 Connection with the hull

The shaft is to be connected with the hull by means of a vertical coupling flange having thickness at least equal to d/4, where d is the shaft diameter, obtained from the formula in [9.1.1] (see Fig 9).

The coupling flange is to be secured by means of six fitted bolts. The shank diameter of the bolts is to be not less than the coupling flange thickness defined above.

The distance from the bolt centre lines to the coupling flange edge is to be not less than 1,17 times the bolt diameter defined above.

Figure 9 : Simplex rudder shaft geometry



9.2.2 Connection with the solepiece

The rudder shaft is to be connected with the solepiece by means of a cone coupling, having a taper on the radius equal to about 1/10 and housing length not less than 1,1 d, where d is obtained from the formula in [9.1.1] (See Fig 9).

The mean pressure exerted by the rudder shaft on the bearing is to be not greater than the relevant allowable bearing pressure, defined in Tab 5 assuming a rudder with two pintles.

10 Steering nozzles

10.1 General

10.1.1 The requirements of this Article apply to scantling steering nozzles for which the power transmitted to the propeller is less than the value obtained, in kW, from the following formula:

$$P = \frac{16900}{d_M}$$

where:

d_M : Inner diameter of the nozzle, in m.

Nozzles for which the power transmitted is greater than the value obtained from the above formula are considered on a case-by-case basis.

The following requirements may apply also to fixed nozzle scantlings.

10.1.2 Nozzles normally consist of a double skin cylindrical structure stiffened by ring webs and other longitudinal webs placed perpendicular to the nozzle.

One of the ring webs is to be fitted in way of the axis of rotation of the nozzle.

10.1.3 The section modulus W_N, in cm^3, of the nozzle double skin profile (half nozzle cross section) around its neutral axis parallel to the center line, is not to be less than:

$W_N = n\, d^2\, b\, V_{AV}^2$

where:

d : Inner diameter of nozzle, in m

b : Length of nozzle, in m

n : Coefficient taken equal to:

- 1,0 for steering nozzles
- 0,7 for fixed nozzles.

10.1.4 Care is to be taken in the manufacture of the nozzle to ensure the welded connection between plating and webs.

10.1.5 The internal part of the nozzle is to be adequately protected against corrosion.

10.2 Nozzle plating and internal diaphragms

10.2.1 The thickness of the inner plating of the nozzle is to be not less than the value obtained, in mm, from the following formulae:

$$t_F = (0{,}085\sqrt{P d_M} + 9{,}65)\sqrt{k} \qquad \text{for} \quad P \le \frac{6100}{d_M}$$

$$t_F = (0{,}085\sqrt{P d_M} + 11{,}65)\sqrt{k} \qquad \text{for} \quad P > \frac{6100}{d_M}$$

where:

P, d_M : Defined in [10.1.1].

The thickness t_F is to be extended to a length, across the transverse section containing the propeller blade tips, equal to one fourth of the total nozzle length.

Outside this length, the thickness of the inner plating is to be not less than (t_F – 7) mm and, in any case, not less than 7 mm.

10.2.2 The thickness of the outer plating of the nozzle is to be not less than (t_F – 9) mm, where t_F is defined in [10.2.1] and, in any case, not less than 7 mm.

10.2.3 The thicknesses of ring webs and longitudinal webs are to be not less than (t_F – 7) mm, where t_F is defined in [10.2.1], and, in any case, not less than 7 mm.

However, the thickness of the ring web, in way of the headbox and pintle support structure, is to be not less than t_F.

The Society may consider reduced thicknesses where an approved stainless steel is used, in relation to its type.

10.3 Nozzle stock

10.3.1 The diameter of the nozzle stock is to be not less than the value obtained, in mm, from the following formula:

$d_{NTF} = 6{,}42\,(M_T\, k_1)^{1/3}$

where:

M_T : Torque, to be taken as the greater of those obtained, in N.m, from the following formulae:

- $M_{TAV} = 0{,}3\, S_{AV}\, a$
- $M_{TAD} = S_{AD}\, b$

S_{AV} : Force, in N, equal to:
$S_{AV} = 150\, V_{AV}^2\, A_N$

S_{AD} : Force, in N, equal to:
$S_{AD} = 200\, V_{AD}^2\, A_N$

A_N : Area, in m^2, equal to:
$A_N = 1{,}35\, A_{1N} + A_{2N}$

A_{1N} : Area, in m^2, equal to:
$A_{1N} = L_M\, d_M$

A_{2N} : Area, in m^2, equal to:
$A_{2N} = L_1\, H_1$

a, b, L_M, d_M, L_1, H_1 : Geometrical parameters of the nozzle, in m, defined in Fig 10.

The diameter of the nozzle stock may be gradually tapered above the upper stock bearing so as to reach, in way of the tiller or quadrant, the value obtained, in mm, from the following formula:

$d_{NT} = 0{,}75\, d_{NTF}$

10.4 Pintles

10.4.1 The diameter of the pintles is to be not less than the value obtained, in mm, from the following formula:

$$d_A = \left(\frac{0{,}35 V_{AV}}{V_{AV} + 3}\sqrt{S_{AV}} + 30\right)\sqrt{k_1}$$

where:

S_{AV} : Defined in [10.3.1].

10.4.2 The length/diameter ratio of the pintle is not to be less than 1 and not to be greater than 1,2.

Smaller values of h_A may be accepted provided that the pressure on the gudgeon bearing p_F is in compliance with the following formula:

$p_F \le p_{F,ALL}$

where:

p_F : Mean bearing pressure acting on the gudgeon, to be obtained in N/mm^2, from the following formula:

$$p_F = \frac{0{,}6S'}{d'_A h'_A}$$

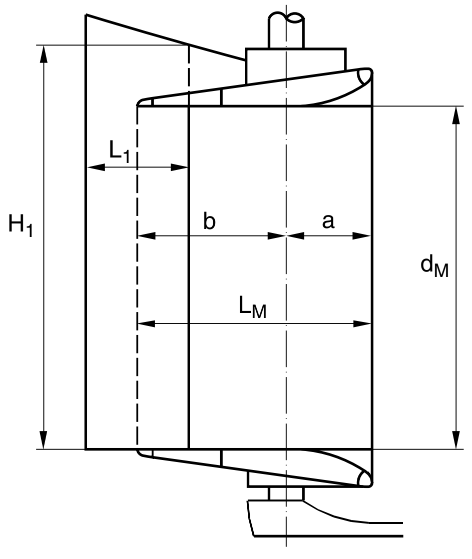
S′ : The greater of the values S_{AV} and S_{AD}, in N, defined in [10.3.1]

d'_A : Actual pintle diameter, in mm

h'_A : Actual bearing length of pintle, in mm

$p_{F,ALL}$: Allowable bearing pressure, in N/mm^2, defined in Tab 5.

Figure 10 : Geometrical parameters of the nozzle



10.5 Nozzle coupling

10.5.1 Diameter of coupling bolts

The diameter of the coupling bolts is to be not less than the value obtained, in mm, from the following formula:

$$d_B = 0{,}62\sqrt{\frac{d_{NTF}^3 k_{1B}}{n_B e_M k_{1S}}}$$

where:

- d_{NTF} : Diameter of the nozzle stock, in mm, defined in [10.3.1]
- k_{1S} : Material factor k_1 for the steel used for the stock
- k_{1B} : Material factor k_1 for the steel used for the bolts
- e_M : Mean distance, in mm, from the bolt axes to the longitudinal axis through the coupling centre (i.e. the centre of the bolt system)
- n_B : Total number of bolts, which is to be not less than:
  - 4 if $d_{NTF} \le 75$ mm
  - 6 if $d_{NTF} > 75$ mm.

Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted having a section of ($0{,}25d_{NT}$ x $0{,}10d_{NT}$) mm^2, where d_{NT} is defined in [10.3.1], and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

The distance from the bolt axes to the external edge of the coupling flange is to be not less than 1,2 d_B.

10.5.2 Thickness of coupling flange

The thickness of the coupling flange is to be not less than the value obtained, in mm, from the following formula:

$$t_P = d_B\sqrt{\frac{k_{1F}}{k_{1B}}}$$

where:

- d_B : Diameter of the coupling bolts, in mm, defined in [10.5.1]
- k_{1B}, : Material factor k_1 for the steel used for the bolts
- k_{1F} : Material factor k_1 for the steel used for the coupling flange.

10.5.3 Push-up length of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push-up length Δ_E of the nozzle stock tapered part into the boss is in compliance with the following formula:

$$\Delta_0 \le \Delta_E \le \Delta_1$$

where:

Δ_0 : The greater of:

- $6,2 \cdot \dfrac{M_{TR}\eta\gamma}{c d_M t_S \mu_A \beta}$
- $16 \cdot \dfrac{M_{TR}\eta\gamma}{c t_S^2 \beta} \cdot \sqrt{\dfrac{d_{NTF}^6 - d_{NT}^6}{d_{NT}^6}}$

$$\Delta_1 = \frac{2\eta + 5}{1,8} \cdot \frac{\gamma d_0 R_{eH}}{10^6 c(1+\rho_1)}$$

$$\rho_1 = \frac{80\sqrt{d_{NTF}^6 - d_{NT}^6}}{R_{eH} d_M t_S^2\left[1 - \left(\dfrac{d_0}{d_E}\right)^2\right]}$$

- d_{NTF}, d_{NT} : Nozzle stock diameters, in mm, to be obtained from [10.3.1], considering $k_1 = 1$
- η, c, β, d_M, d_E, μ_A, μ, γ:Defined in [5.2.3]
- t_S, d_0 : Defined in Fig 4
- R_{eH} : Defined in [1.4.3].

10.5.4 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

11 Azimuth propulsion system

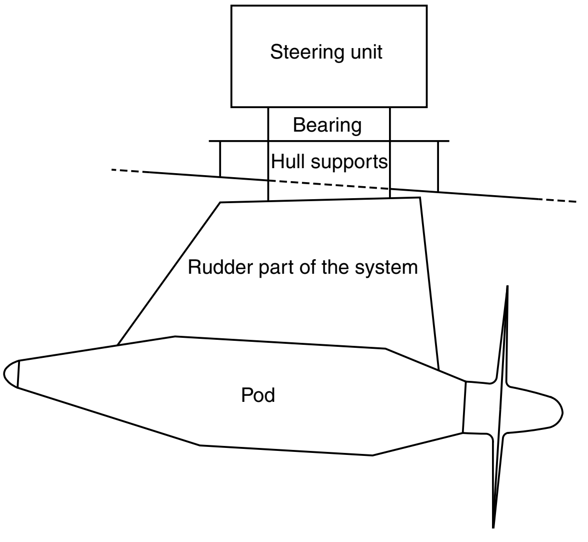
11.1 General

11.1.1 Arrangement

The azimuth propulsion system is constituted by the following sub-systems (see Fig 11):

- 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 11 : 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 requirements in Pt C, Ch 1, Sec 11 and Pt C, Ch 1, Sec 12, respectively.

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 [7.3.1], 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 7, Sec 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 [7.3.4], 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 7, 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 angle at 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 σ_{VM} in primary supporting members, calculated, in N/mm², for the load cases defined in [11.6.2], is in compliance with the following formula:

$\sigma_{VM} \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable stress, in N/mm², to be taken equal to $0,55\ R_{eH}$

R_{eH} : Minimum yield stress, in N/mm², of the specified steel. R_{eH} is not to exceed the lower of $0,7\ R_m$ and 450 N/mm²

R_m : Minimum ultimate tensile strength, in N/mm², of the steel used.

When the loads are calculated for crash stop of the ship, the criteria given in [11.6.4] are to be complied with.

When fine mesh finite element analysis is used for the calculation of stresses, then the criteria in Ch 7, Sec 3, [4.4.3] and Ch 7, Sec 3, [4.4.4] is to be applied, with:

$\sigma_{MASTER} = \sigma_{ALL}$

11.6.4 Strength check for crash stop of the ship

When the loads are calculated for crash stop of the ship, the Von Mises equivalent stress σ_{VM} in primary supporting members, calculated, in N/mm², is to be checked with the following formula:

$\sigma_{VM} \leq \sigma_{CRASH}$

where:

$\sigma_{CRASH} = 1,25\ \sigma_{ALL}$

σ_{ALL} : Allowable stress as defined in [11.6.3].

When fine mesh finite element analysis is used for the calculation of stresses, then the criteria in Ch 7, Sec 3, [4.4.3] and Ch 7, Sec 3, [4.4.4] is to be applied, with:

$\sigma_{MASTER} = \sigma_{CRASH}$

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 σ_{VM} in hull supports, in N/mm², calculated for the load cases defined in [11.6.2], is in compliance with the following formula:

$\sigma_{VM} \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable stress, in N/mm², equal to:

$\sigma_{ALL} = 65 / k$

k : Material factor, defined in Ch 4, Sec 1, [2.3].

When the loads are calculated for crash stop of the ship, the criteria given in [11.7.4] is to be complied with.

Values of σ_{VM} greater than σ_{ALL} may be accepted by the Society on a case-by-case basis, depending on the localisation of σ_{VM} and on the type of direct calculation analysis.

When fine mesh finite element analysis is used for the calculation of stresses, then the criteria in Ch 7, Sec 3, [4.4.3] and Ch 7, Sec 3, [4.4.4] is to be applied, with:

$\sigma_{MASTER} = \sigma_{ALL}$

11.7.4 Strength check for crash stop of the ship

When the loads are calculated for crash stop of the ship, the Von Mises equivalent stress σ_{VM} in primary supporting members, calculated, in N/mm², is to be checked with the following formula:

$\sigma_{VM} \leq \sigma_{CRASH}$

where:

$\sigma_{CRASH} = 1,25\ \sigma_{ALL}$

σ_{ALL} : Allowable stress as defined in [11.7.3].

When fine mesh finite element analysis is used for the calculation of stresses, then the criteria in Ch 7, Sec 3, [4.4.3] and Ch 7, Sec 3, [4.4.4] is to be applied, with:

$\sigma_{MASTER} = \sigma_{CRASH}$

11.7.5 Buckling check

A local buckling check is to be carried out, for plate panels which constitute hull supports of the azimuth propulsion system, according to Ch 7, Sec 1, [5], calculating the stresses in the plaet panels according to [11.7.1] and [11.7.2].

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 all exposed decks.

1.2 General

1.2.1 Efficient bulwarks or guard rails are to be fitted around all exposed decks.

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 A and 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 8, Sec 10, [6.5.2] 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 8, Sec 10, [6.3.1] 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 8, Sec 10, [6].

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 A, 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 thickness of bulwarks on the freeboard deck not exceeding 1100 mm in height is to be not less than:

- 5,5 mm for $L \leq 30$ m
- 6,0 mm for $30 \text{ m} < L \leq 120$ m
- 6,5 mm for $120 \text{ m} < L \leq 150$ 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 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:

$$Z = 40\, s\, (1 + 0{,}01\, L)\, h_B^2$$

where:

- L : Length of ship, in m, to be assumed not greater than 100 m
- 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 width not exceeding 600 mm may also be included in the calculation of the actual 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 [3.1.3].

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.

2.2.7 Bulwarks located in the bow flare area as defined in Ch 8, Sec 1, [4.1.2] are to be reinforced according to Ch 8, Sec 1, [4], considering the stays as cantilever primary supporting members.

3 Guard rails

3.1 General

3.1.1 Where guard rails are provided, the upper edge of sheerstrake is to be kept as low as possible.

3.1.2 Guard rails fitted on superstructure and freeboard decks shall have at least three courses. In other locations, guardrails with at least two courses shall be fitted.

3.1.3 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.

3.1.4 In the case of ships with rounded gunwales or sheerstrake, the stanchions are to be placed on the flat part of the deck.

3.1.5 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.

In lieu of at least every third stanchion supported by a stay, three other alternatives may be accepted:

- at least every third stanchion is of increased breadth: $k\, b_s = 2{,}9\, b_s$
- at least every second stanchion is of increased breadth: $k\, b_s = 2{,}4\, b_s$
- every stanchion is of increased breadth: $k\, b_s = 1{,}9\, b_s$

where:

- b_s : breadth of normal stanchion according to the design standard

Flat steel stanchions of increased breadth (see Fig 1) are to be aligned with member below deck. A minimum flat bar 100 x 12 is to be welded to deck by double continuous fillet welds with leg size of minimum 7 mm or as specified by the design standard.

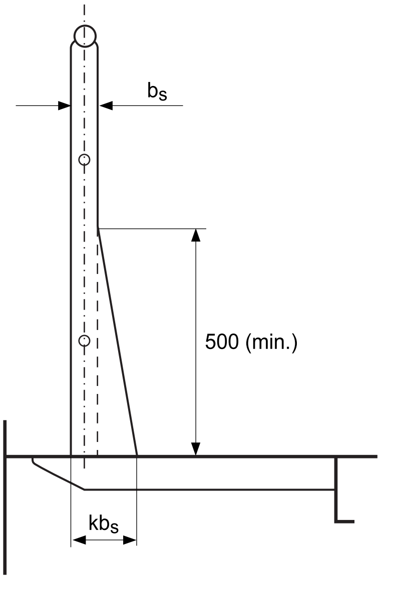
The stanchions with increased breadth need not be aligned with under deck structure for deck plating exceeding 20 mm.

Removable or hinged stanchions are to be capable of being locked in the upright position.

3.1.6 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.

3.1.7 Chains may only be accepted in short lengths in lieu of guard rails if they are fitted between two fixed stanchions and/or bulwarks.

Figure 1 : Guardrail stanchion of increased breadth



SECTION 3 PROPELLER SHAFT BRACKETS

Symbols

F_C : Force, in kN, taken equal to:

$$F_C = \left(\frac{2\pi N}{60}\right)^2 R_P P$$

P : Mass of a propeller blade, in t

N : Number of revolutions per minute of the propeller

R_P : Distance, in m, of the centre of gravity of a blade in relation to the rotation axis of the propeller

σ_{ALL} : Allowable stress, in N/mm²:

$\sigma_{ALL} = 70 / K$

where:

K : Material factor, as defined in Ch 4, Sec 1, [2.3]

w_A : Section modulus, in cm³, of the arm at the level of the connection to the hull with respect to a transversal axis

w_B : Section modulus, in cm³, of the arm at the level of the connection to the hull with respect to a longitudinal axis

A : Sectional area, in cm², of the arm

A_S : Shear sectional area, in cm², of the arm

d_P : Propeller shaft diameter, in mm, measured inside the liner, if any.

1 Propeller shaft brackets

1.1 General

1.1.1 Propeller shafting is either enclosed in bossing or independent of the main hull and supported by shaft brackets.

1.2 Double arm propeller shaft brackets

1.2.1 General

This type of propeller shaft bracket consists of two arms arranged, as far as practicable, at right angles and converging in the propeller shaft bossing.

Exceptions to this will be considered by the Society on a case by case basis.

1.2.2 Scantlings of arms

The moment in the arm, in kN.m, is to be obtained from the following formula:

$$M = \frac{F_C}{\sin\alpha}\left(\frac{L}{\ell} d_1 \cos\beta + L - \ell\right)$$

where:

α : Angle between the two arms

β : Angle defined in Fig 1

d_1 : Distance, in m, defined in Fig 1

L, ℓ : Lengths, in m, defined in Fig 2.

Figure 1 : Angle β and length d_1

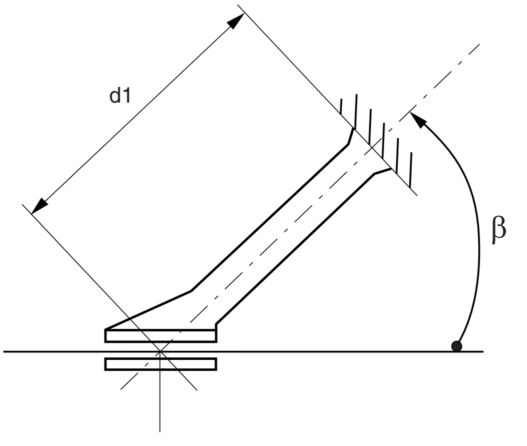
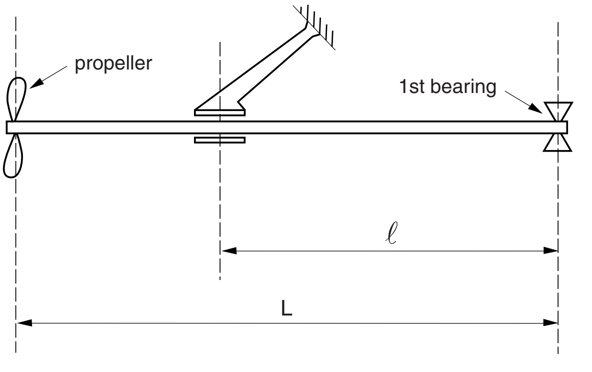


Figure 2 : Lengths L and ℓ



It is to be checked that the bending stress σ_F, the compressive stress σ_N and the shear stress τ are in compliance with the following formula:

$$\sqrt{(\sigma_F + \sigma_N)^2 + 3\tau^2} \leq \sigma_{ALL}$$

where:

$$\sigma_F = \frac{M}{w_A} 10^3$$

$$\sigma_N = 10 F_C \frac{L \sin\beta}{A \ell \sin\alpha}$$

$$\tau = 10 F_C \frac{L \cos\beta}{A_S \ell \sin\alpha}$$

1.2.3 Scantlings of propeller shaft bossing

The length of the propeller shaft bossing is to be not less than the length of the aft sterntube bearing bushes (see Pt C, Ch 1, Sec 7, [2.4]).

The thickness of the propeller shaft bossing is to be not less than 0,33 d_P.

1.2.4 Bracket arm attachments

In way of bracket arms attachments, the thickness of deep floors or girders is to be suitably increased. Moreover, the shell plating is to be increased in thickness and suitably stiffened.

The securing of the arms to the hull structure is to prevent any displacement of the brackets with respect to the hull.

1.3 Single arm propeller shaft brackets

1.3.1 General

This type of propeller shaft bracket consists of one arm and may be used only on ships less than 65 m in length.

1.3.2 Scantlings of arms

The moment in case of a single arm, in kN.m, is to be obtained from the following formula:

$$M = d_2 0,75 F_C \frac{L}{\ell}$$

where:

d_2 : Length of the arm, in m, measured between the propeller shaft axis and the hull

L, ℓ : Lengths, in m, defined in Fig 2.

It is to be checked that the bending stress σ_F and the shear stress τ are in compliance with the following formula:

$$\sqrt{\sigma_F^2 + 3\tau^2} \le \sigma_{ALL}$$

where:

$$\sigma_F = \frac{M}{w_B} 10^3$$

$$\tau = 10 F_C \frac{L}{A_S \ell}$$

1.3.3 Scantlings of propeller shaft bossing

The length of the propeller shaft bossing is to be not less than the length of the aft sterntube bearing bushes (see Pt C, Ch 1, Sec 7, [2.4]).

The thickness of the propeller shaft bossing is to be not less than 0,33 d_P.

1.3.4 Bracket arm attachments

In way of bracket arms attachments, the thickness of deep floors or girders is to be suitably increased. Moreover, the shell plating is to be increased in thickness and suitably stiffened.

The securing of the arm to the hull structure is to prevent any displacement of the bracket with respect to the hull.

1.4 Bossed propeller shaft brackets

1.4.1 General

Where bossed propeller shaft brackets are fitted, their scantlings are to be considered by the Society on a case by case basis.

1.4.2 Scantling of the boss

The length of the boss is to be not less than the length of the aft sterntube bearing bushes (see Pt C, Ch 1, Sec 7, [2.4]).

The thickness of the boss, in mm, is to be not less than 0,33 d_P.

The aft end of the bossing is to be adequately supported.

1.4.3 Scantling of the end supports

The scantlings of end supports are to be specially considered. Supports are to be adequately designed to transmit the loads to the main structure.

End supports are to be connected to at least two deep floors of increased thickness or connected to each other within the ship.

1.4.4 Stiffening of the boss plating

Stiffening of the boss plating is to be specially considered. At the aft end, transverse diaphragms are to be fitted at every frame and connected to floors of increased scantlings.

At the fore end, web frames spaced not more than four frames apart are to be fitted.

SECTION 4 EQUIPMENT

Symbols

EN : Equipment Number defined in [1.2]

σ_{ALL} : Allowable stress, in N/mm², used for the yielding check in [3.9.7], [3.10.7], [3.11.2] and [3.11.3], to be taken as the lesser of:
- $\sigma_{ALL} = 0,67\ R_{eH}$
- $\sigma_{ALL} = 0,40\ R_m$

R_{eH} : Minimum yield stress, in N/mm², of the material, defined in Ch 4, Sec 1, [2]

R_m : Tensile strength, in N/mm², of the material, defined in Ch 4, Sec 1, [2].

1 General

1.1 Application

1.1.1 The requirements of the present Article and Article [2] apply to temporary mooring of a ship within a harbour or sheltered area when the ship is awaiting a berth, the tide, etc.

Therefore, the equipment complying with these requirements:
- is not intended for holding a ship off fully exposed coasts in rough weather or for stopping a ship which is moving or drifting.
- 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.

1.1.2 The required anchoring equipment in [1.2] is given considering the following environmental conditions:
- maximum current speed of 5 knots (2,5 m/s)
- maximum wind speed of 50 knots (25 m/s)
- no waves
- minimum scope of chain cable of 6, the scope being the ratio between length of chain paid out and water depth.

1.1.3 As guidance for the limitations of the anchoring equipment used in semi-sheltered anchorages, the required anchoring equipment as defined in [1.2] can also be considered applicable for ships with the length L_E as defined in [1.2.2] greater than 135 m to the following environmental conditions including waves:
- maximum current speed of 3 knots (1,54 m/s)
- maximum wind speed of 21 knots (11 m/s)
- waves with maximum significant height of 2 m
- minimum scope of chain cable of 6, the scope being the ratio between length of chain paid out and water depth.

1.1.4 For ships intended to anchor in deep and unsheltered water and assigned with the additional class notation **UNSHELTERED ANCHORING** according to Pt A, Ch 1, Sec 2, [6.14.43] refer to additional applicable requirements in Pt F, Ch 11, Sec 23.

1.1.5 It is assumed that under normal circumstances a ship uses only one bow anchor and chain cable at a time.

1.2 Equipment number

1.2.1 General

All ships are to be provided with equipment in anchors and chain cables (or ropes according to [2.2.5]), to be obtained from Tab 1, based on their Equipment Number EN.

For ships having the navigation notation **coastal area** or **sheltered area**, the equipment in anchors and chain cables may be reduced. The reduction consists of entering in Tab 1 one line higher for ships having the navigation notation **coastal area** and two lines higher for ships having the navigation notation **sheltered area**, based on their Equipment Number EN.

1.2.2 Equipment Number formulae

The Equipment Number EN is to be obtained from the following formula:

$$EN = \Delta^{2/3} + 2\ h\ B + 0,1\ A$$

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:

$h = a + \Sigma h_n$

When calculating h, sheer and trim are to be disregarded

a : Freeboard amidships from the summer load waterline to the upper deck, in m

h_n : 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

For the lowest tier, h is to be measured at centreline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck, see Fig 1.

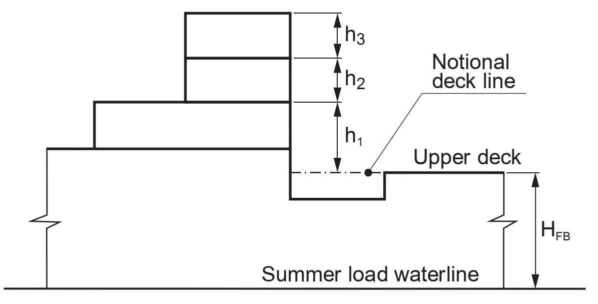
A : Side projected area, in m^2, of the hull, superstructures and houses above the summer load waterline which are within the length L_E and also have a breadth greater than B/4

L_E : 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, fixed picture windows 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 2 is to be included. In case of non butt-jointed picture windows, only the efficient closed areas are 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.

Figure 1 : Effective height h



1.2.3 Specific cases

For ships of special design or ships engaged in special services or on special voyages, the Society may consider equipment other than that in Tab 1 on a case-by-case basis.

The Society may accept ships with low equipment number ($30 \le EN < 50$) or with high equipment number ($EN \ge 16000$). The determination of the equipment will be considered on a case-by-case basis.

For $30 \le EN < 50$, anchors and stud link chain cables are to be fitted according to the values in Tab 2.

However, the design of such equipment is to comply with the present section and the requirements in NR216 Materials and Welding, Ch 4, Sec 1.

2 Anchoring equipment

2.1 Anchors

2.1.1 General

The anchors are to be of an approved type and satisfy the testing conditions laid down in NR216 Rules for Materials and Welding.

The scantlings of anchors are to be in compliance with [2.1.2] to [2.1.7].

In general, stockless anchors are to be adopted.

Anchors are to be constructed and tested in compliance with approved plans.

2.1.2 Ordinary anchors

The required mass for each bower 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.

2.1.3 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 NR216 Materials and Welding, Ch 4, Sec 1, [1], 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 bower anchors in Tab 1.

The mass of VHHP anchors is to be, in general, less than or equal to 1500 kg.

2.1.4 Installation of chain cables and anchors on board

The bower anchors are to be connected to their own chain cables and positioned on board ready for use.

To hold the anchor tight in against the hull or the anchor pocket, respectively, it is recommended to fit anchor lashings, e.g., a ‘devil’s claw’.

Anchor lashings should be designed to resist a load at least corresponding to twice the anchor mass plus 10 m of cable without exceeding 40% of the yield strength of the material.

2.1.5 Tests for high holding power anchors approval

For approval of a HHP anchor, comparative full scale tests are to be performed 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 as HHP anchors 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.

Figure 2 : Effective area of bulwarks or fixed screen to be included in the Equipment Number

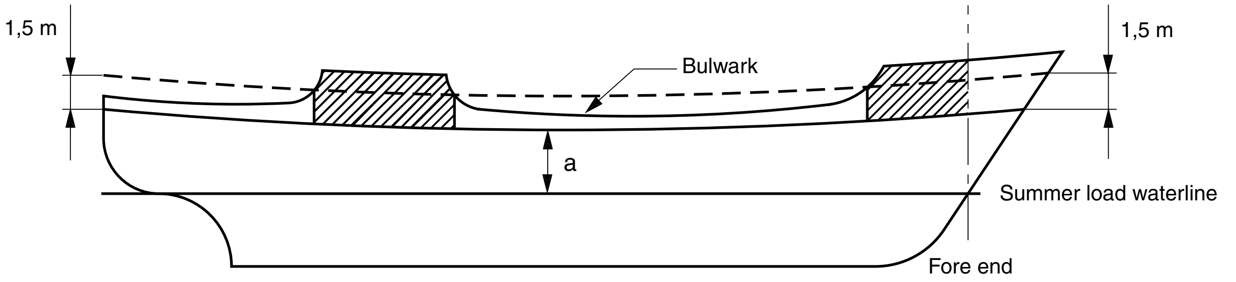


Table 1 : Equipment

Equipment number EN A ≤ EN < B		Stockless bower anchors		Stud link chain cables for bower anchors			
		Number of anchors	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	2	660	302,5	26,0	22,0	20,5
240	280	2	780	330,0	28,0	24,0	22,0
280	320	2	900	357,5	30,0	26,0	24,0
320	360	2	1020	357,5	32,0	28,0	24,0
360	400	2	1140	385,0	34,0	30,0	26,0
400	450	2	1290	385,0	36,0	32,0	28,0
450	500	2	1440	412,5	38,0	34,0	30,0
500	550	2	1590	412,5	40,0	34,0	30,0
550	600	2	1740	440,0	42,0	36,0	32,0
600	660	2	1920	440,0	44,0	38,0	34,0
660	720	2	2100	440,0	46,0	40,0	36,0
720	780	2	2280	467,5	48,0	42,0	36,0
780	840	2	2460	467,5	50,0	44,0	38,0
840	910	2	2640	467,5	52,0	46,0	40,0
910	980	2	2850	495,0	54,0	48,0	42,0
980	1060	2	3060	495,0	56,0	50,0	44,0
1060	1140	2	3300	495,0	58,0	50,0	46,0
1140	1220	2	3540	522,5	60,0	52,0	46,0
1220	1300	2	3780	522,5	62,0	54,0	48,0
1300	1390	2	4050	522,5	64,0	56,0	50,0
1390	1480	2	4320	550,0	66,0	58,0	50,0
1480	1570	2	4590	550,0	68,0	60,0	52,0
1570	1670	2	4890	550,0	70,0	62,0	54,0
1670	1790	2	5250	577,5	73,0	64,0	56,0
1790	1930	2	5610	577,5	76,0	66,0	58,0

Equipment number EN A ≤ EN < B		Stockless bower anchors		Stud link chain cables for bower anchors			
		Number of anchors	Mass per anchor, in kg	Total length in m	Diameter, in mm		
A	B				Q1	Q2	Q3
1930	2080	2	6000	577,5	78,0	68,0	60,0
2080	2230	2	6450	605,0	81,0	70,0	62,0
2230	2380	2	6900	605,0	84,0	73,0	64,0
2380	2530	2	7350	605,0	87,0	76,0	66,0
2530	2700	2	7800	632,5	90,0	78,0	68,0
2700	2870	2	8300	632,5	92,0	81,0	70,0
2870	3040	2	8700	632,5	95,0	84,0	73,0
3040	3210	2	9300	660,0	97,0	84,0	76,0
3210	3400	2	9900	660,0	100,0	87,0	78,0
3400	3600	2	10500	660,0	102,0	90,0	78,0
3600	3800	2	11100	687,5	105,0	92,0	81,0
3800	4000	2	11700	687,5	107,0	95,0	84,0
4000	4200	2	12300	687,5	111,0	97,0	87,0
4200	4400	2	12900	715,0	114,0	100,0	87,0
4400	4600	2	13500	715,0	117,0	102,0	90,0
4600	4800	2	14100	715,0	120,0	105,0	92,0
4800	5000	2	14700	742,5	122,0	107,0	95,0
5000	5200	2	15400	742,5	124,0	111,0	97,0
5200	5500	2	16100	742,5	127,0	111,0	97,0
5500	5800	2	16900	742,5	130,0	114,0	100,0
5800	6100	2	17800	742,5	132,0	117,0	102,0
6100	6500	2	18800	742,5		120,0	107,0
6500	6900	2	20000	770,0		124,0	111,0
6900	7400	2	21500	770,0		127,0	114,0
7400	7900	2	23000	770,0		132,0	117,0
7900	8400	2	24500	770,0		137,0	122,0
8400	8900	2	26000	770,0		142,0	127,0
8900	9400	2	27500	770,0		147,0	132,0
9400	10000	2	29000	770,0		152,0	132,0
10000	10700	2	31000	770,0			137,0
10700	11500	2	33000	770,0			142,0
11500	12400	2	35500	770,0			147,0
12400	13400	2	38500	770,0			152,0
13400	14600	2	42000	770,0			157,0
14600	16000	2	46000	770,0			162,0

Table 2 : Equipment for 30 ≤ EN < 50

Stockless bower anchors		Stud link chain cables for bower anchors		
N	Mass per anchor, in kg	Total length, in m	Diameter, in mm	
			Q1	Q2
2	120	192,5	12,5	11

2.1.6 Tests for very high holding power anchors approval

For approval of a VHHP anchor, comparative full scale tests are to be performed 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.

For approval as VHHP anchors 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, indicative of the bottom, middle and top of the mass range.

2.1.7 Specification for tests on high holding power and very high holding power anchors

Full scale tests are to be performed on various types of sea bottom: soft mud or silt, sand or gravel and hard clay or similar compounded material.

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.

The holding power test load is to be less than or equal to the proof load of the anchor, specified in NR216 Materials and Welding, Ch 4, Sec 1, [1.5.2].

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 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, without being less than 6.

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.

2.2 Chain cables for bower anchors

2.2.1 Material

The anchor 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 NR216 Materials and Welding, Ch 4, Sec 1.

Chain cables made of grade Q1 may not be used with high holding power and very high holding power anchors.

2.2.2 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 NR216 Materials and Welding, Ch 4, Sec 1.

The diameter of stud link chain cables is to be not less than the value in Tab 1.

2.2.3 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 NR216 Materials and Welding, Ch 4, Sec 1, [3], and that the steel grade of the studless chain is equivalent to the steel grade of the stud chains it replaces, as defined in [2.2.1].

2.2.4 Anchor chain cable arrangement

Anchor 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.

2.2.5 Wire ropes

Wire ropes may be used in place of anchor chain cables on ships with less than 40 m in length and subject to the following conditions:

- the wire ropes 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 [2.2.2])
- 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
- all surfaces being in contact with the wire need to be rounded with a radius of not less than 10 times the wire rope diameter (including stem).

2.3 Attachment pieces

2.3.1 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 [2.3.2], 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.

2.3.2 Scantlings

The diameters of the attachment pieces, in mm, are to be not less than the values indicated in Tab 3.

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 3 : 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.	

2.3.3 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 NR216 Materials and Welding, Ch 4, Sec 1.

2.4 Hawse pipes

2.4.1 Hawse pipes are to be of substantial construction. Their position and slope are to be arranged so as to facilitate housing and dropping of the anchors and avoid damage to the hull during these operations. The parts on which the chains bear are to be rounded to a suitable radius.

2.4.2 All mooring units and accessories, such as timbler, riding and trip stoppers are to be securely fastened, to the Surveyor's satisfaction.

2.5 Windlass

2.5.1 General

The Rule Note NR626 Anchor Windlass is to be applied, considering the windlass brake capacity defined in [2.5.2].

2.5.2 Brake capacity

Based on mooring line arrangements with brakes engaged and cable lifter disengaged, the capacity HL (Holding Load), in kN, of the windlass brake is to be sufficient to withstand the following loads without any permanent deformation of the stressed parts and without brake slip:

- 0,8 times the breaking load BL of the chain, if not combined with a chain stopper
- 0,45 times the breaking load BL of the chain, if combined with a chain stopper.

2.6 Chain stopper

2.6.1 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.

2.6.2 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.

2.7 Chain locker

2.7.1 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.

2.7.2 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.

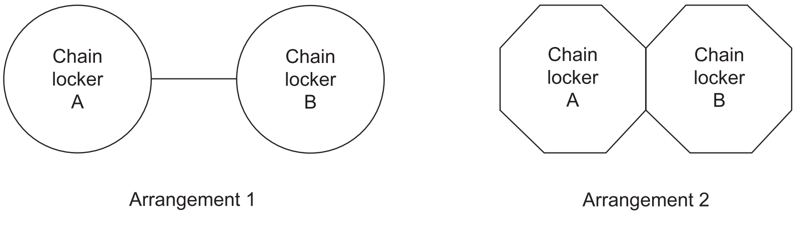
2.7.3 The inboard ends of chain cables are to be secured to suitably reinforced attachments in the structure by means of end shackles, whether or not associated with attachment pieces.

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.

2.7.4 The chain locker boundaries and access openings are to be watertight. Provisions are to be made to minimise the probability of the chain locker being flooded in bad weather. Adequate drainage facilities for the chain locker are to be provided.

Figure 3 : Chain locker arrangement



2.7.5 Spurling pipes and chain lockers are to be watertight up to the weather deck.

Bulkheads between separate chain lockers (see Fig 3, Arrangement 1) or which form a common boundary of chain lockers (see Fig 3, Arrangement 2), need not however be watertight.

2.7.6 Where means of access is provided, it is to be closed by a substantial cover and secured by closely spaced bolts.

2.7.7 Where a means of access to spurling pipes or cable lockers is located below the weather deck, the access cover and its securing arrangements are to be in accordance with recognized standards or equivalent for watertight manhole covers. Butterfly nuts and/or hinged bolts are prohibited as the securing mechanism for the access cover.

2.7.8 Spurling pipes through which anchor cables are led are to be provided with permanently attached closing appliances, to minimize water ingress.

Examples of arrangements for permanently attached closing appliances are such as steel plates with cut-outs to accommodate chain links or canvas hoods with a lashing arrangement that maintains the cover in the secured position.

3 Emergency towing arrangement

3.1 Definitions

3.1.1 Deadweight

Deadweight is the difference, in t, between the displacement of a ship in water of a specific gravity of 1,025 t/m³ at the summer load line *corresponding to the assigned summer freeboard and the lightweight of the ship.*

3.2 Application

3.2.1 The requirements of this Article apply to equipment arrangement for towing ships out of danger in emergencies such as complete mechanical breakdowns, loss of power or loss of steering capability.

The concerned ships are:

- the ships as defined in [3.2.2]
- all ships when the additional class notation **ETA** is assigned (see Pt A, Ch 1, Sec 2, [6.15.3]).

3.2.2 An emergency towing arrangement is to be fitted at both ends on board of ships of 20000 t deadweight and above with one of the following service notations:

- **combination carrier ESP**
- **oil tanker ESP**
- **FLS tanker**
- **chemical tanker ESP**
- **liquefied gas carrier**.
- **LNG bunkering ship**

3.3 Documentation

3.3.1 Documentation for approval

In addition to the documents in Ch 1, Sec 3, the following documentation is to be submitted to the Society for approval:

- general layout of the bow and stern towing arrangements and associated equipment
- operation manual for the bow and stern towing arrangements
- construction drawings of the bow and stern strongpoints (towing brackets or chain cable stoppers) and fairleads (towing chocks), together with material specifications and relevant calculations
- drawings of the local ship structures supporting the loads applied by strongpoints, fairleads and roller pedestals.

3.3.2 Documentation for information

The following documentation is to be submitted to the Society for information (see Ch 1, Sec 3):

- specifications of chafing gears, towing pennants, pick-up gears and roller fairleads
- height, in m, of the lightest seagoing ballast freeboard measured at stern towing fairlead
- deadweight, in t, of the ship at summer load line.

3.4 General

3.4.1 Scope

The emergency towing arrangements are to be so designed as to facilitate salvage and emergency towing operations on the concerned ship, primarily to reduce the risk of pollution.

3.4.2 Main characteristics

The emergency towing arrangements are, at all times, to be capable of rapid deployment in the absence of main power on the ship to be towed and easy connection to the towing ship.

To demonstrate such rapid and easy deployment, the emergency towing arrangements are to comply with the requirements in [3.12].

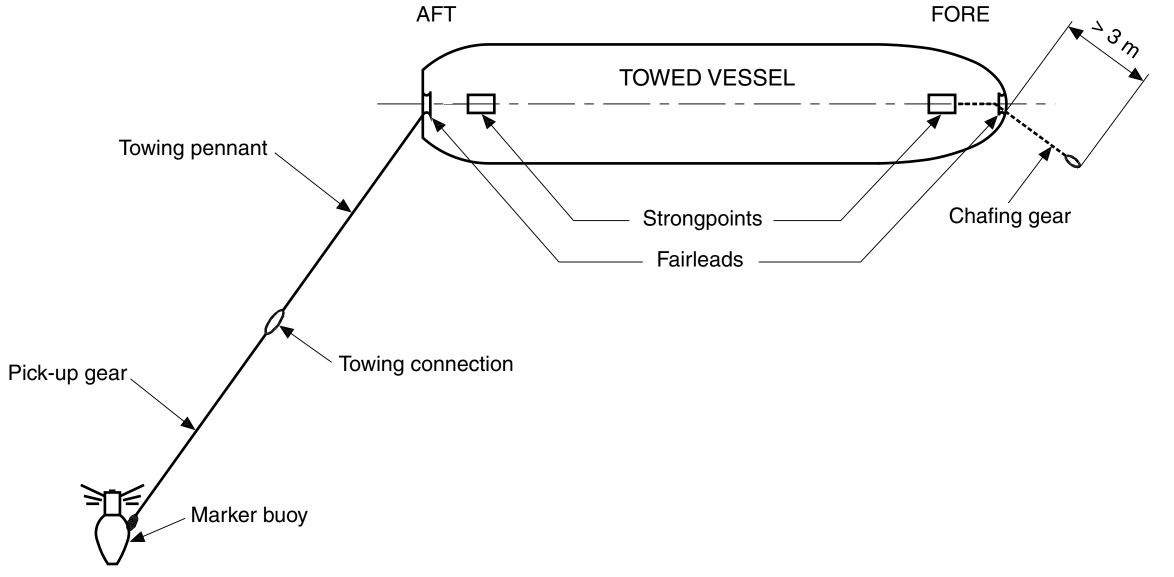
3.4.3 Typical layout

Fig 4 shows an emergency towing arrangement which may be used as reference.

3.4.4 List of major components

The major components of the towing arrangements, their position on board and the requirements of this Article which they are to comply with are defined in Tab 4.

Figure 4 : Typical emergency towing arrangement



3.4.5 Inspection and maintenance

All the emergency towing arrangement components are to be inspected by ship personnel at regular intervals and maintained in good working order.

3.5 Emergency towing arrangement approval

3.5.1 General

Emergency towing arrangements of ships are to comply with the following requirements:

- they are to comply with the requirements of this item
- they are to be type approved according to the requirements in [3.13]
- Certificates of inspection of materials and equipment are to be provided according to [3.13.2]
- fitting on board of the emergency towing arrangements is to be witnessed by a Surveyor of the Society and a relevant Certificate is to be issued
- demonstration of the rapid deployment according to the criteria in [3.12] is to be effected for each ship and this is to be reported in the above Certificate.

3.5.2 Alternative to testing the rapid deployment for each ship

At the request of the Owner, the testing of the rapid deployment for each ship according to [3.5.1] may be waived provided that:

- the design of emergency towing arrangements of the considered ship is identical to the type approved arrangements and this is confirmed by the on board inspection required in [3.5.1]
- the strongpoints (chain stoppers, towing brackets or equivalent fittings) are type approved (prototype tested).

In this case, an exemption certificate is to be issued.

In general, such dispensation may be granted to subsequent ships of a series of identical new buildings fitted with identical arrangements.

Table 4 : Major components of the emergency towing arrangement

Towing component	Non pre-rigged	Pre-rigged	Reference of applicable requirements
Towing pennant	Optional	Required	[3.7]
Fairlead	Required	Required	[3.9]
Strongpoint (inboard end fastening of the towing gear)	Required	Required	[3.10]
Pick-up gear	Optional	Required	No requirement
Pedestal roller fairlead	Required	Depending on design	No requirement

Towing component	Forward	Afterward	Reference of applicable requirements
Chafing gear	Required	Depending on design	[3.8]

3.6 Safe working load (SWL) of towing pennants, chafing gears, fairleads and strongpoints

3.6.1 Safe working load

The safe working load (defined as one half of the ultimate strength) of towing pennants, chafing gear, fairleads and strongpoints is to be not less than that obtained, in kN, from Tab 5.

The strength of towing pennants, chafing gear, fairleads and strongpoints is to be sufficient for all pulling angles of the towline, i.e. up to 90° from the ship's centreline to port and starboard and 30° vertical downwards.

The safe working load of other components is to be sufficient to withstand the load to which such components may be subjected during the towing operation.

Table 5 : Safe working load

Ship deadweight DWT, in t	Safe working load, in kN
20000 ≤ DWT < 50000	1000
DWT ≥ 50000	2000

3.7 Towing pennant

3.7.1 Material

The towing pennant may be made of steel wire rope or synthetic fibre rope, which is to comply with the applicable requirements in NR216 Materials and Welding, Ch 4, Sec 1.

3.7.2 Length of towing pennant

The length ℓ_P of the towing pennant is to be not less than that obtained, in m, from the following formula:

$\ell_P = 2\,H + 50$

where:

H : Lightest seagoing ballast freeboard measured, in m, at the fairlead.

3.7.3 Minimum breaking strength of towing pennants when separate chafing gear is used

Where a separate chafing gear is used, the minimum breaking strength MBS_p of towing pennants, including their terminations, is to be not less than that obtained from the following formula:

$MBS_P = 2\ SWL$

Where:

SWL : Safe working load of the towing pennants, defined in [2.6.1].

3.7.4 Minimum breaking strength of towing pennants when no separate chafing gear is used

Where no separate chafing gear is used (i.e. where the towing pennant may chafe against the fairlead during towing operation), the minimum breaking strength of the towing pennants MBS_{PC} is to be not less than that obtained, in kN, from the following formula:

$MBS_{PC} = \varphi\ MBS_P$

where:

MBS_P : Minimum breaking strength, in kN, defined in [3.7.3]

φ : Coefficient to be taken equal to:

$$\varphi = \frac{2\sqrt{\rho}}{2\sqrt{\rho} - 1}$$

φ may be taken equal to 1,0 if tests carried out under a test load equal to twice the safe working load defined in [3.6.1] demonstrate that the strength of the towing pennants is satisfactory

ρ : Bending ratio (ratio between the minimum bearing surface diameter of the fairlead and the towing pennant diameter), to be taken not less than 7.

3.7.5 Towing pennant termination

For towing connection, the towing pennant is to have a hard eye-formed termination allowing connection to a standard shackle.

Socketed or ferrule-secured eye terminations of the towing pennant are to be type tested in order to demonstrate that their minimum breaking strength is not less than twice the safe working load defined in [3.6.1].

3.8 Chafing gear

3.8.1 General

Different solutions for the design of chafing gear may be used.

If a chafing chain is to be used, it is to have the characteristics defined in the following requirements.

3.8.2 Type

Chafing chains are to be stud link chains.

3.8.3 Material

In general, grade Q3 chain cables and associated accessories complying with the applicable requirements in NR216 Materials and Welding, Ch 4, Sec 1 are to be used.

3.8.4 Chafing chain length

The chafing chain is to be long enough to ensure that the towing pennant, or the towline, remains outside the fairlead during the towing operation. A chain extending from the strongpoint to a point at least 3 m beyond the fairlead complies with this requirement.

3.8.5 Minimum breaking strength

The minimum breaking strength of the stud link chafing chain and the associated links is to be not less than twice the safe working load defined in [3.6.1].

3.8.6 Diameter of the common links

The diameter of the common links of stud link chain cables is to be not less than:

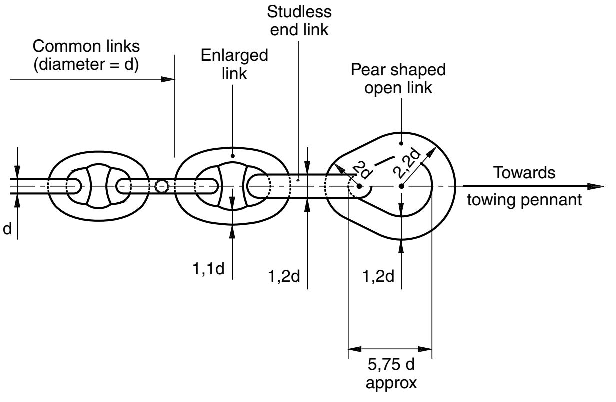
- 52 mm for a safe working load, defined in [3.6.1], equal to 1000 kN
- 76 mm for a safe working load, defined in [3.6.1], equal to 2000 kN.

3.8.7 Chafing chain ends

One end of the chafing chain is to be suitable for connection to the strongpoint. Where a chain stopper is used, the inboard end of the chafing chain is to be efficiently secured in order to prevent any inadvertent loss of the chafing chain when operating the stopping device. Where the chafing chain is connected to a towing bracket, the corresponding chain end may be constructed as shown in Fig 5, but the inner dimension of the pear link may be taken as 5,30 d (instead of 5,75 d).

The other end of the chafing chain is to be fitted with a standard pear-shaped open link allowing connection to a standard bow shackle. A typical arrangement of this chain end is shown in Fig 5. Arrangements different than that shown in Fig 5 are considered by the Society on a case-by-case basis.

Figure 5 : Typical outboard chafing chain end



3.8.8 Storing

The chafing chain is to be stored and stowed in such a way that it can be rapidly connected to the strongpoint.

3.9 Fairleads

3.9.1 General

Fairleads are normally to be of a closed type (such as Panama chocks).

Fairleads are to have an opening large enough to pass the largest portion of the chafing gear, towing pennant or towline. The corners of the opening are to be suitably rounded.

Where the fairleads are designed to pass chafing chains, the openings are to be not less than 600mm in width and 450mm in height.

3.9.2 Material

Fairleads are to be made of fabricated steel plates or other ductile materials such as weldable forged or cast steel complying with the applicable requirements of NR216 Materials and Welding, Chapter 2.

3.9.3 Operating condition

The fairleads are to give adequate support for the towing pennant during towing operation, which means bending 90° to port and starboard side and 30° vertical downwards.

3.9.4 Positioning

The fairleads are to be located so as to facilitate towing from either side of the bow or stern and minimise the stress on the towing system.

The fairleads are to be located as close as possible to the deck and, in any case, in such a position that the chafing chain is approximately parallel to the deck when it is under strain between the strongpoint and the fairlead.

Furthermore, the bow and stern fairleads are normally to be located on the ship's centreline. Where it is practically impossible to fit the towing fairleads exactly on the ship's centreline, it may be acceptable to have them slightly shifted from the centreline.

3.9.5 Bending ratio

The bending ratio (ratio between the towing pennant bearing surface diameter and the towing pennant diameter) is to be not less than 7.

3.9.6 Fairlead lips

The lips of the fairlead are to be suitably faired in order to prevent the chafing chain from fouling on the lower lip when deployed or during towing.

3.9.7 Yielding check

The equivalent Von Mises stress σ_E, in N/mm^2, induced in the fairlead by a load equal to the safe working load defined in [3.6.1], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

Areas subjected to stress concentrations are considered by the Society on a case-by-case basis.

Where the fairleads are analysed through standard mesh finite element models, the allowable stress may be taken as 1,1 σ_{ALL}.

3.9.8 Alternative to the yielding check

The above yielding check may be waived provided that fairleads are tested with a test load equal to twice the safe working load defined in [3.6.1] and this test is witnessed by a Surveyor of the Society. In this case, the Designer is responsible for ensuring that the fairlead scantlings are sufficient to withstand such a test load.

Unless otherwise agreed by the Society, components subjected to this test load are considered as prototype items and are to be discarded.

3.10 Strongpoint

3.10.1 General

The strongpoint (inboard end fastening of the towing gear) is to be a chain cable *stopper or a towing bracket or other fitting of equivalent strength* and ease of connection. *The strongpoint can be designed integral with the fairlead.*

The strongpoint is to be type approved according to [3.13] and is to be clearly marked with its SWL.

3.10.2 Materials

The strongpoint is to be made of fabricated steel or other ductile materials such as forged or cast steel complying with the applicable requirements of NR216 Materials and Welding, Chapter 2.

Use of spheroidal graphite cast iron (SG iron) may be accepted for the main framing of the strongpoint provided that:

- the part concerned is not intended to be a component part of a welded assembly
- the SG iron is of ferritic structure with an elongation not less than 12%
- the yield stress at 0,2% is measured and certified
- the internal structure of the component is inspected by suitable non-destructive means.

The material used for the stopping device (pawl or hinged bar) of chain stoppers and for the connecting pin of towing brackets is to have mechanical properties not less than those of grade Q3 chain cables, defined in NR216 Materials and Welding, Ch 4, Sec 1.

3.10.3 Typical strongpoint arrangement

Typical arrangements of chain stoppers and towing brackets are shown in Fig 6, which may be used as reference.

Chain stoppers may be of the hinged bar type or pawl (tongue) type or of other equivalent design.

3.10.4 Position and operating condition

The operating conditions and the positions of the strongpoints are to comply with those defined in [3.9.3] and [3.9.4], respectively, for the fairleads.

3.10.5 Stopping device

The stopping device (chain engaging pawl or bar) is to be arranged, when in closed position, to prevent the chain stopper from working in the open position, in order to avoid chain cable release and allow it to pay out.

Stopping devices are to be easy and safe to operate and, in the open position, are to be properly secured.

3.10.6 Connecting pin of the towing bracket

The scantlings of the connecting pin of the towing bracket are to be not less than those of a pin of a grade Q3 end shackle, as shown in Fig 6, provided that clearance between the two side lugs of the bracket does not exceed 2,0d, where d is the chain diameter specified in [3.8.6] (see also Fig 5).

3.10.7 Yielding check

The equivalent Von Mises stress σ_E , in N/mm^2, induced in the strongpoint by a load equal to the safe working load defined in [3.6.1], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

Areas subjected to stress concentrations are considered by the Society on a case-by-case basis.

Where the strongpoints are analysed through standard mesh finite element models, the allowable stress may be taken as 1,1 σ_{ALL}.

3.10.8 Alternative to the yielding check

The above yielding check may be waived provided that strongpoints are tested with a test load equal to twice the safe working load defined in [3.6.1] and this test is witnessed by a Surveyor. In this case, the Designer is responsible for ensuring that the fairlead scantlings are sufficient to withstand such a test load.

Unless otherwise agreed by the Society, components subjected to this test load are considered as prototype items and are to be discarded.

3.10.9 Bolted connection

Where a chain stopper or a towing bracket is bolted to a seating welded to the deck, the bolts are to be relieved from shear force by means of efficient thrust chocks capable of withstanding a horizontal force equal to 1,3 times the safe working load defined in [3.6.1] within the allowable stress defined in [3.10.7].

The steel quality of bolts is to be not less than grade 8.8 as defined by ISO standard No. 898/1.

Bolts are to be pre-stressed in compliance with appropriate standards and their tightening is to be suitably checked.

3.11 Hull structures in way of fairleads or strongpoints

3.11.1 Materials and welding

The materials used for the reinforcement of the hull structure in way of the fairleads or the strongpoints are to comply with the applicable requirements of NR216 Materials and Welding.

Main welds of the strongpoints with the hull structure are to be 100% inspected by adequate non-destructive tests.

3.11.2 Yielding check of bulwark and stays

The equivalent Von Mises stress σ_E , in N/mm^2, induced in the bulwark plating and stays in way of the fairleads by a load equal to the safe working load defined in [3.6.1], for the operating condition of the fairleads defined in [3.9.3], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

3.11.3 Yielding check of deck structures

The equivalent Von Mises stress σ_E , in N/mm^2, induced in the deck structures in way of chain stoppers or towing brackets, including deck seatings and deck connections, by a horizontal load equal to 1,3 times the safe working load defined in [3.6.1], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

3.11.4 Minimum gross thickness of deck plating

The gross thickness of the deck is to be not less than:

- 12 mm for a safe working load, defined in [3.6.1], equal to 1000 kN
- 15 mm for a safe working load, defined in [3.6.1], equal to 2000 kN.

3.12 Rapid deployment of towing arrangement

3.12.1 General

To facilitate approval of towing arrangements and to ensure rapid deployment, emergency towing arrangements are to comply with the requirements of this item.

3.12.2 Marking

All components, including control devices, of the emergency towing arrangements are to be clearly marked to facilitate safe and effective use even in darkness and poor visibility.

3.12.3 Aft arrangement

The aft emergency towing arrangement is to be pre-rigged and be capable of being deployed in a controlled manner in harbour conditions in not more than 15 minutes.

The pick-up gear for the aft towing pennant is to be designed at least for manual operation by one person taking into account the absence of power and the potential for adverse environmental conditions that may prevail during such emergency towing operations.

The pick-up gear is to be protected against the weather and other adverse conditions that may prevail.

3.12.4 Forward

The forward emergency towing arrangement is to be capable of being deployed in harbour conditions in not more than 1 hour.

The forward emergency towing arrangement is to be designed at least with a means of securing a tow line to the chafing gear using a suitably positioned pedestal roller to facilitate connection of the towing pennant.

Forward emergency towing arrangements which comply with the requirements for aft emergency towing arrangements may be accepted.

Figure 6 : Typical strongpoint arrangement

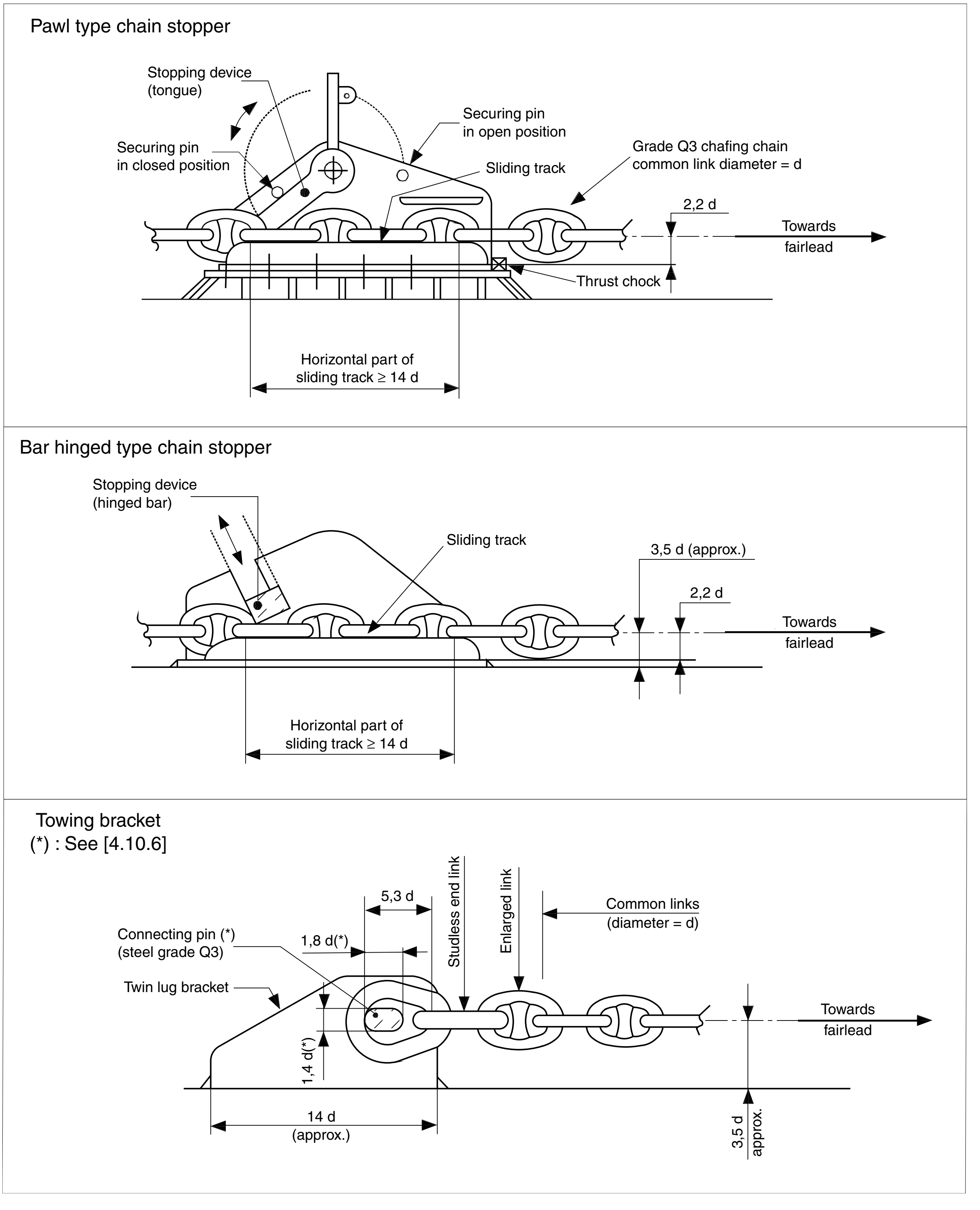


Table 6 : Material and equipment certification status

Component	Material		Equipment	
	Certificate	Reference of applicable requirements	Certificate	Reference of applicable requirements
Towing pennant	Not applicable	[3.7.1]	COI **(1)**	[3.7]
Chafing chain and associated accessories	COI **(2)**	[3.8.3]	COI **(1)**	[3.8]
Fairleads	CW	[3.9.2]	COI	[3.9]
Strongpoint:			COI **(3)**	[3.10]
• main framing	COI **(2)**	[3.10.2]		
• stopping device	COI **(2)**	[3.10.2]		
Pick-up gear:				No requirement
• rope	Not applicable	–	CW	
• buoy	Not applicable	–	Not required **(4)**	
• line-throwing appliance	Not applicable	–	Not required **(4)**	
Pedestal roller fairlead	CW	–	Not required **(4)**	No requirement

(1) According to NR216 Materials and Welding, Ch 4, Sec 1.
(2) According to NR216 Materials and Welding, Chapter 1.
(3) To be type approved.
(4) May be type approved.
Note 1:
COI : Certificate of inspection,
CW : Works' certificate 3.1.B according to EN 10204.

3.13 Type approval

3.13.1 Type approval procedure

Emergency towing arrangements are to be type approved according to the following procedure:

- the arrangement design is to comply with the requirements of this Section
- each component of the towing arrangement is to be tested and its manufacturing is to be witnessed and certified by a Surveyor according to [3.13.2]
- prototype tests are to be carried out in compliance with [3.13.3].

3.13.2 Inspection and certification

The materials and equipment are to be inspected and certified as specified in Tab 6.

3.13.3 Prototype tests

Prototype tests are to be witnessed by a Surveyor and are to include the following:

- demonstration of the rapid deployment according to the criteria in [3.12]
- load test of the strongpoints (chain stoppers, towing brackets or equivalent fittings) under a proof load equal to 1,3 times the safe working load defined in [3.6.1].

A comprehensive test report duly endorsed by the Surveyor is to be submitted to the Society for review.

4 Towing and mooring arrangement

4.1 General

4.1.1 Condition of classification

The towing and mooring arrangement as defined in Ch 9, App 2, [1] and the towing and mooring lines as defined in Ch 9, App 2, [2] are given as a guidance but are not required as a condition of classification.

4.2 Shipboard fittings and supporting hull structures associated with towing and mooring

4.2.1 Definitions

"Normal towing" means towing operations necessary for manoeuvring in ports and sheltered waters associated with the normal operations of the ship.

"Escort towing" means towing operations required in specific estuaries, in particular, for laden oil tankers or LNG carriers. Its main purpose is to control the ship in case of failures of the propulsion or steering system.

"Other towing" means towing operations necessary for towing the ship by another ship or a tug, e.g. such as to assist the ship in case of emergency, for ships not assigned with the additional class notation **ETA**.

"Emergency towing" means towing operations to assist the ship in case of emergency, for ships assigned with the additional class notation **ETA**.

"Canal transit towing" means towing operations for ships transiting canals, e.g. the Panama Canal.

"Shipboard fittings" means the components limited to the following: bollards and bitts, fairleads, stand rollers, chocks used for mooring and similar components used for normal, escort and other towing operations. Other components such as capstans, winches, etc. are not covered by the present sub-article. Any weld or bolt or equivalent device connecting the shipboard fitting to the supporting structure is part of the shipboard fitting and if selected from an recognised standard subject to that standard.

"Supporting hull structure" means the part of the ship structure on/in which the shipboard fitting is placed and which is directly submitted to the forces exerted on the shipboard fitting. The supporting hull structure of capstans, winches, etc. used for mooring and for normal, escort and other towing operations is also subject to the present sub-article.

4.2.2 Application

Requirements under the present sub-article apply to:

- conventional ships, i.e. displacement-type ships of 500 GT and above, excluding special purpose ships as defined in the IMO resolution MSC.266(84)
- shipboard fittings used for mooring and for normal, escort and other towing operations
- supporting hull structure under shipboard fittings used for mooring and for normal, escort and other towing operations
- supporting hull structure under winches and capstans used for mooring operations.

Requirements under the present sub-article do not apply for following towing operations:

- emergency towing: refer to Article [3]
- canal transit towing: it should be referred to local canal transit requirements.

4.2.3 Arrangement

The strength of shipboard fittings used for mooring and for normal, escort and other towing operations at bow, sides and stern, and of their supporting hull structures are to comply with the present sub-article.

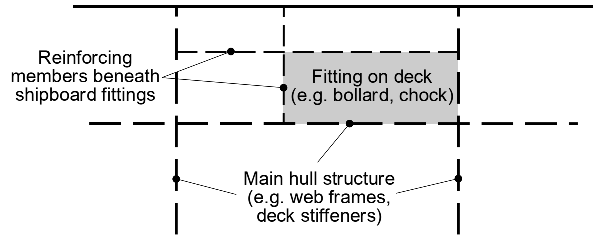
The strength of supporting hull structures of winches and capstans used for mooring are to comply with the present sub-article as well.

Shipboard fittings, winches and capstans are to be located on stiffeners and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the towing and mooring loads.

The reinforced members beneath shipboard fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the mooring and towing forces acting upon the shipboard fittings, see Fig 7 for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be ensured.

Other arrangements may be accepted (for chocks in bulwarks, etc.) provided the strength is confirmed adequate for the intended service.

Figure 7 : Reinforced members beneath shipboard fittings



4.2.4 Selection of shipboard fittings

Shipboard fittings may be selected from a recognised standard accepted by the Society (ISO standard for example) and at least based on the following loads:

a) normal towing operations: the intended maximum towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangements plan

b) escort or other towing operations: the minimum breaking load of the tow line as defined in Ch 9, App 2

c) For fittings intended to be used for, both, normal and escort or other towing operations, the greater of the loads according to a) and b)

d) Mooring operations: the minimum breaking load of the mooring line as defined in Ch 9, App 2

Towing bitts (double bollards) may be chosen for the towing line attached with eye splice if the recognised standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment, see Fig 9.

Mooring bitts (double bollards) are to be chosen for the mooring line attached in figure-of-eight fashion if the recognised standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment, see Fig 10.

When the shipboard fitting is not selected from an accepted standard:

- The design load used to assess its strength and its attachment to the ship is to be in accordance with [4.2.5].
- Towing bitts (double bollards) are required to resist the loads caused by the towing line attached with eye splice
- Mooring bitts (double bollards) are required to resist the loads caused by the mooring line attached in figure-of-eight fashion.
- At the discretion of the Society, load tests may be accepted as alternative to strength assessment by calculations.

Note 1: With the line attached to a mooring bitt in the usual way (figure-of-eight fashion), either of the two posts of the mooring bitt can be subjected to a force twice as large as that acting on the mooring line.

4.2.5 Design load

The design load is to be applied to fittings in all directions that may occur by taking into account the arrangement shown on the mooring and towing arrangements plan. Where the mooring or towing line takes a turn at a fitting the total design load applied to the fitting is equal to the resultant of the design loads acting on the line, see Fig 8.

Figure 8 : Design load on fitting

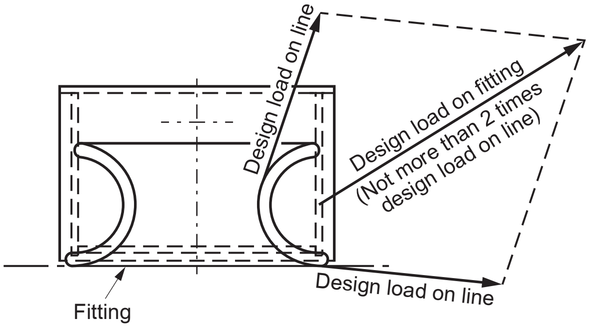
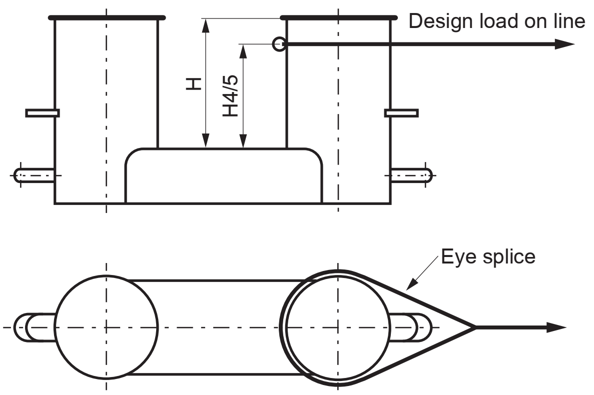


Figure 9 : Attachment point of the towing line on bollard and bitts



However, in no case does the design load applied to the fitting need to be greater than twice the design load on the line.

The acting point of the force on shipboard fittings is to be taken at the attachment point of the mooring or towing line or at a change in its direction. For bollards and bitts the attachment point of the line is to be taken not less than 4/5 of the tube height above the base, see Fig 9 and Fig 10.

However, if fins are fitted to the bollard tubes to keep the mooring line as low as possible, the attachment point of the mooring line may be taken at the location of the fins, see b) in Fig 10.

The design load to be applied to supporting hull structures and to shipboard fittings not selected from a recognised standard, in kN, is to be taken equal to:

a) Normal towing operations:

   1,25 times the greater of the intended maximum towing load (e.g. static bollard pull) and the safe towing load TOW requested by the applicant, see [4.2.8]

b) Escort or other towing operations:

   the greater of the breaking load of the tow line as defined in Ch 9, App 2 and 1.25 times the safe towing load TOW requested by the applicant, see [4.2.8]

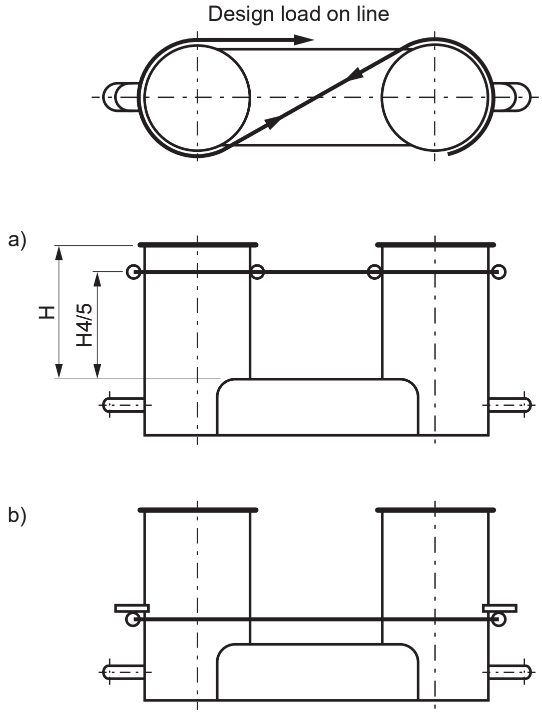
c) For fittings intended to be used for, both, normal and escort or other towing operations:

   the greater of the design loads according to a) and b).

d) Mooring operations:

   1,15 times the greater of the breaking load of the mooring line as defined in Ch 9, App 2 and the SWL of the shipboard fitting requested by the applicant, see [4.2.9].

Figure 10 : Attachment point of the mooring line on bollard and bitts



The design load to be applied to supporting hull structure of winches and capstans used for mooring operations, in kN, is to be taken equal to:

- Supporting hull structure of winches:

  1,25 times the intended maximum brake holding load, see notes below.

- Supporting hull structure of capstans:

  1,25 times the maximum hauling-in force.

Note 1: The maximum brake holding load of winches used for mooring operations is to be assumed not less than 80% of the breaking load of the mooring line as defined in Ch 9, App 2, [2].

Note 2: The breaking loads of tow and mooring lines taken in Ch 9, App 2, Tab 1 are to be based on an Equipment Number calculated according to [1.2.2] with a side projected area A including deck cargoes as given by the loading manual.

Note 3: The increase of the breaking loads of tow and mooring lines for synthetic ropes as required in Ch 9, App 2, [2.5] needs not to be taken into account for the loads applied to shipboard fittings and supporting hull structure.

4.2.6 Allowable stresses

Allowable stresses under the design load conditions as specified in [4.2.5] are as follows:

a) For strength assessment with beam theory or grillage analysis:

   - normal stress: 100% of the minimum yield stress R_{eH}
   - shear stress: 60% of the minimum yield stress R_{eH}

b) For strength assessment with finite element analysis:

   - equivalent stress: 100% of minimum yield stress R_{eH}

Note 1: Normal stress is to be considered as the sum of bending stress and axial stress, with the corresponding shearing stress acting perpendicular to the normal stress. No stress concentration factors being taken into account.

Note 2: For strength calculations by means of finite elements, the geometry is to be idealized as realistically as possible. The ratio of element length to width is not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs must not exceed one-third of the web height. In way of small openings in girder webs the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled by using shell, plane stress, or beam elements. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element.

4.2.7 Corrosion additions

The scantlings obtained by applying the allowable stresses as specified in [4.2.6] are net scantlings excluding any addition for corrosion.

The total corrosion addition t_c is not to be less than the following values:

- for the supporting hull structure, according to Ch 4, Sec 2, [3] for the surrounding structure (e.g. deck structures, bulwark structures).
- for pedestals and foundations on deck which are not part of a fitting according to a recognised standard, 2.0 mm.
- for shipboard fittings not selected from a recognised standard, 2.0 mm.

Note 1: In addition to the corrosion addition t_c given above, a wear down allowance t_w not less than 1.0 mm is to be included for shipboard fittings not selected from an recognised standard. This wear allowance is to be added to surfaces which are intended to regularly contact the line.

4.2.8 Safe Towing Load (TOW)

The safe towing load (TOW) is the load limit for towing purpose.

Unless a greater TOW is requested by the applicant, the TOW is not to exceed:

a) Normal towing operations: the intended maximum towing load (e.g. static bollard pull)

b) Escort or other towing operations: 80% of the breaking load of the tow line as defined in Ch 9, App 2

c) For fittings intended to be used for, both, normal and escort or other towing operations: the greater of the design loads according to a) and b).

TOW, in t, of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for towing.

For fittings intended to be used for, both, towing and mooring, SWL, in t, according to [4.2.9] is to be marked in addition to TOW.

Note 1: The above requirements on TOW apply for the use with no more than one line. If not otherwise chosen, for towing bitts (double bollards) TOW is the load limit for a towing line attached with eye-splice.

4.2.9 Safe Working Load (SWL)

The safe working load (SWL) is the load limit for mooring purpose.

Unless a greater SWL is requested by the applicant, the SWL is not to exceed the breaking load of the mooring line as defined in Ch 9, App 2, Tab 1.

SWL, in t, of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for mooring.

For fittings intended to be used for, both, mooring and towing, TOW, in t, according to [4.2.8] is to be marked in addition to SWL.

Note 1: The above requirements on SWL apply for the use with no more than one mooring line.

4.2.10 Towing and mooring arrangements plan

A plan showing the towing and mooring arrangement is to be submitted to the Society for information. This plan is to define the method of using the towing and mooring lines and is to include the following information for each shipboard fitting:

a) location on the ship

b) fitting type

c) SWL/TOW

d) purpose (mooring, harbour towing, escort towing, other towing)

e) manner of applying towing and mooring lines (including line load, line angles, etc.).

Item c) with respect to items d) and e), is subject to approval by the Society.

Furthermore, following information is to be clearly indicated on the plan:

- the arrangement of mooring lines showing the number of lines
- the breaking load of each mooring line
- the acceptable environmental conditions as given in Ch 9, App 2, [2.7.3] for the breaking load of mooring lines for ships with Equipment Number EN > 2000:

  - 30 second mean wind speed from any direction (v_w or v_w^* according to Ch 9, App 2, [2.7.3])

  - maximum current speed acting on bow or stern (±10°)

Note 1: The SWL and TOW for the intended use for each shipboard fitting is to be noted in the towing and mooring arrangements plan available on board for the guidance of the Master. It is to be noted that TOW is the load limit for towing purpose and SWL that for mooring purpose. If not otherwise chosen, for towing bitts it is to be noted that TOW is the load limit for a towing line attached with eye-splice.

Note 2: The information as listed above is to be incorporated into the pilot card in order to provide the pilot proper information on harbour, escort and other towing operations.

APPENDIX 1 CRITERIA FOR DIRECT CALCULATION OF RUDDER LOADS

Symbols

ℓ_{10}, ℓ_{20}, ℓ_{30}, ℓ_{40} : Lengths, in m, of the individual girders of the rudder system

ℓ_{50} : Length, in m, of the solepiece

ℓ_{TRU} : Length, in m, of the trunk

J_{10}, J_{20}, J_{30}, J_{40} : Moments of inertia about the x axis, in cm^4, of the individual girders of the rudder system having lengths ℓ_{10}, ℓ_{20}, ℓ_{30}, ℓ_{40} . For rudders supported by a solepiece only, J_{20} indicates the moment of inertia of the pintle in the sole piece

J_{50} : Moment of inertia about the z axis, in cm^4, of the solepiece

J_{TRU} : Moment of inertia about the x axis, in cm^4, of the trunk

C_R : Rudder force, in N, acting on the rudder blade, defined in Ch 9, Sec 1, [2.1.1]

C_{R1}, C_{R2} : Rudder forces, in N, defined in Ch 9, Sec 1, [2.2.3]

E : Young's modulus, in N/m^2:

$E = 2{,}06 \cdot 10^{11}\ N/m^2$

G : Shear elasticity modulus, in N/m^2:

$G = 7{,}85 \cdot 10^{10}\ N/m^2$.

1 Criteria for direct calculation of the loads acting on the rudder structure

1.1 General

1.1.1 Application

The requirements of this Appendix apply to all types of rudders listed under Ch 9, Sec 1, Tab 4.

The requirements of this Appendix provide the criteria for calculating the following forces and moments:

- bending moment M_{Bi} in the rudder stock (defined as the maximum of absolute values of bending moment M_{Bi} over the rudder stock length)
- support forces F_{Ai}
- bending moment M_R and shear force Q_R in the rudder body.

1.1.2 Calculation of forces and moments

The forces and moments in [1.1.1] are to be calculated according to [1.4], for each type of rudder.

They are to be used for the stress analysis required in:

- Ch 9, Sec 1, [4], for the rudder stock
- Ch 9, Sec 1, [6], for the rudder stock and the pintle bearings
- Ch 9, Sec 1, [7] for the rudder blade
- Ch 9, Sec 1, [8] for the rudder horn and the solepiece.

1.2 Required data

1.2.1 Forces per unit length

The forces per unit length are to be calculated, in N/m, for each type of rudder, according to requirements given under [1.4].

1.2.2 Support stiffness properties

Three general cases are considered:

a) All supports are completely rigid. This is assumed for the rudder types 1 and 3.

b) Combination of one elastic support with several rigid supports.

The elastic support is represented by a spring, with its constant calculated in N/m, according to [1.3.1] and [1.3.2]:

- Z_C for rudders with solepiece (rudder type 2 as in Fig 1, and rudder type 5 as in Fig 3)
- Z_P for semi-spade rudders with one elastic support provided by a rudder horn (rudder type 4 as in Fig 2, rudder type 7 as in Fig 7, and rudder type 8 as in Fig 8)
- Z_{TRU} for spade rudders with rudder trunk (rudder type 6c, as shown in Fig 6).

c) Combination of 2-conjugate elastic supports and one rigid support (rudder type 9 as in Fig 9, and rudder type 10 as in Fig 10).

The 2-conjugate elastic supports are defined by using two additional equations, according to [1.3.3].

1.3 Calculation of support stiffness properties

1.3.1 Sole piece

The spring constant Z_C for the support in the solepiece (see Fig 11) is to be obtained, in N/m, from the following formula:

$$Z_C = \frac{3\,EJ_{50}}{\ell_{50}^3} \cdot 10^{-8}$$

1.3.2 Rudder horn with 1-elastic support

The spring constant Z_P for the support in the rudder horn (see Fig 12 and Fig 13) is to be obtained, in N/m, from the following formula:

$$Z_P = \frac{1}{f_B + f_T}$$

where:

f_B : Unit displacement of rudder horn due to a unit force of 1 N acting in the centroid of the rudder horn, to be obtained, in m/N, from the following formula:

$$f_B = 1{,}3\frac{d^3}{3EJ_N} \cdot 10^8$$

f_T : Unit displacement due to torsion, in m/N, to be obtained, in case of a rudder horn with a hollow cross section, from the following formula:

$$f_T = \frac{de^2}{4GF_T^2}\sum_i \frac{u_i}{t_i}$$

with:

d : Height, in m, of the rudder horn as defined in Fig 12 and Fig 13. 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

J_N : Moment of inertia of rudder horn about the x axis, in cm^4

e : Rudder-horn torsion lever, in m, as defined in Fig 12 and Fig 13(value taken at z = d/2)

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 of the individual plates mentioned above, in mm.

1.3.3 Rudder horn with 2-conjugate elastic supports

The 2-conjugate elastic supports are defined 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 N, at the lower and upper rudder horn bearings, respectively

K_{11}, K_{22}, K_{12}: Rudder horn compliance constants obtained, in m/N, 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 14 and Fig 15. 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 14 and Fig 15. 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 $\lambda = 0$, the above formulae converge to those given in [1.3.2], in case of a rudder horn with a hollow cross-section

e : Rudder-horn torsion lever, in m, as defined in Fig 14 and Fig 15 (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 15)

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 $d - \lambda$ (see Fig 15)

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.

1.3.4 Rudder trunk

The spring constant Z_{TRU} for the support in the trunk (lower rudder stock bearing as shown in Fig 16) is to be obtained, in N/m, from the following formula:

$$Z_{TRU} = \frac{3EJ_{TRU}}{\ell_{TRU}^3} \cdot 10^{-8}$$

1.4 Calculation of the main structure of the rudder system

1.4.1 Rudder type 1

The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_R = \frac{C_R}{\ell}$$

with:

ℓ : Height of the rudder blade, in m.

The rudder structure is to be calculated according to approximate formulae given here below:

- maximum bending moment in the rudder stock, in N·m:

  $M_B = 0$

- support forces, in N:

  $F_{A1} = F_{A2} = F_{A3} = C_R / 3$

  $F_{A4} = 0$

- bending moment in the rudder blade of streamlined rudders, in N·m:

  $M_R = C_R \, \ell / 24$

1.4.2 Rudder type 2

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 1.

The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_R = \frac{C_R}{\ell}$$

with:

ℓ : Height of the rudder blade, in m, as follows:

$\ell = \ell_{10} + \ell_{30}$

The spring constant Z_c is to be calculated according to [1.3.1].

1.4.3 Rudder type 3

The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_R = \frac{C_R}{\ell}$$

with:

ℓ : Height of the rudder blade, in m.

The rudder structure is to be calculated according to approximate formulae given here below:

- maximum bending moment in the rudder stock, in N·m:

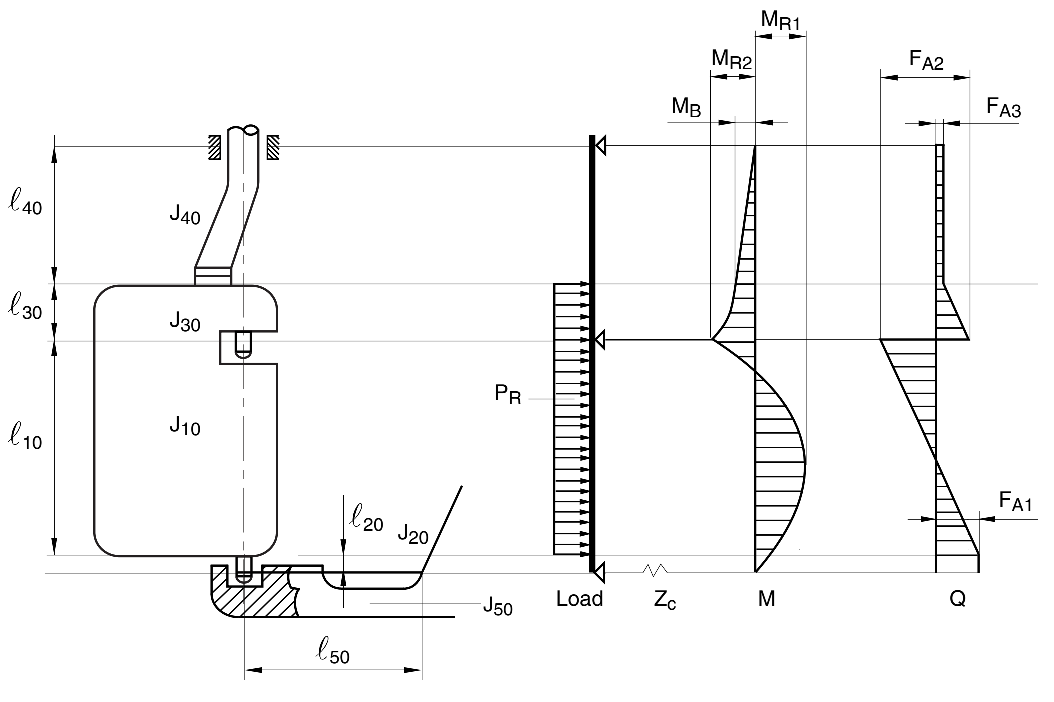
  $M_B = 0$

- support forces, in N:

  $F_{A1} = F_{A2} = C_R/2$

  $F_{A3} = 0$

Figure 1 : Rudder type 2



1.4.4 Rudder type 4

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 2.

The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{\ell_{10}}$$

$$p_{R20} = \frac{C_{R1}}{\ell}$$

with:

$\ell = \ell_{20} + \ell_{30}$

The spring constant Z_P is to be calculated according to [1.3.2].

1.4.5 Rudder type 5

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 3.

The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_R = \frac{C_R}{\ell}$$

with:

ℓ : Height of the rudder blade, in m.

The spring constant Z_c is to be calculated according to [1.3.1].

Figure 2 : Rudder type 4

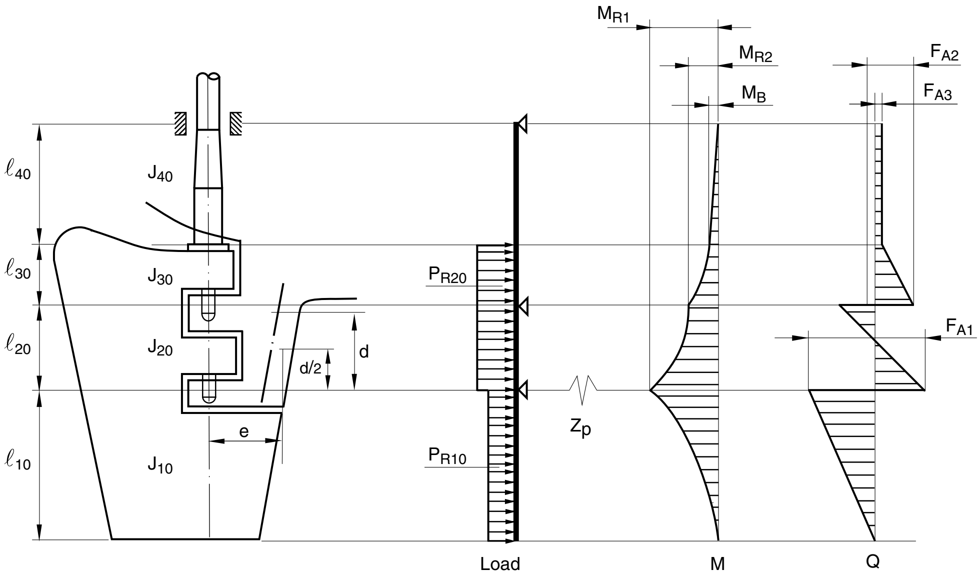


Figure 3 : Rudder type 5

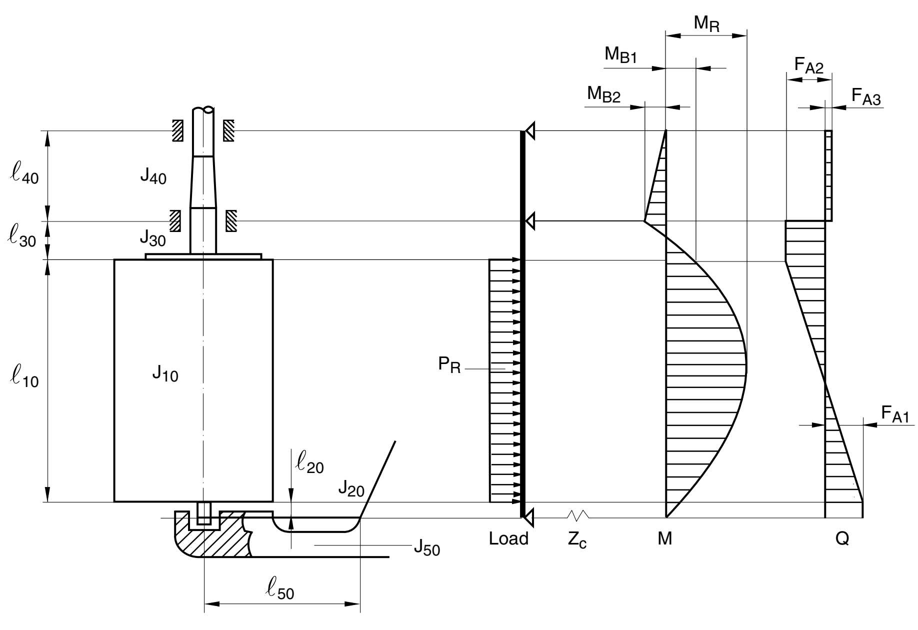
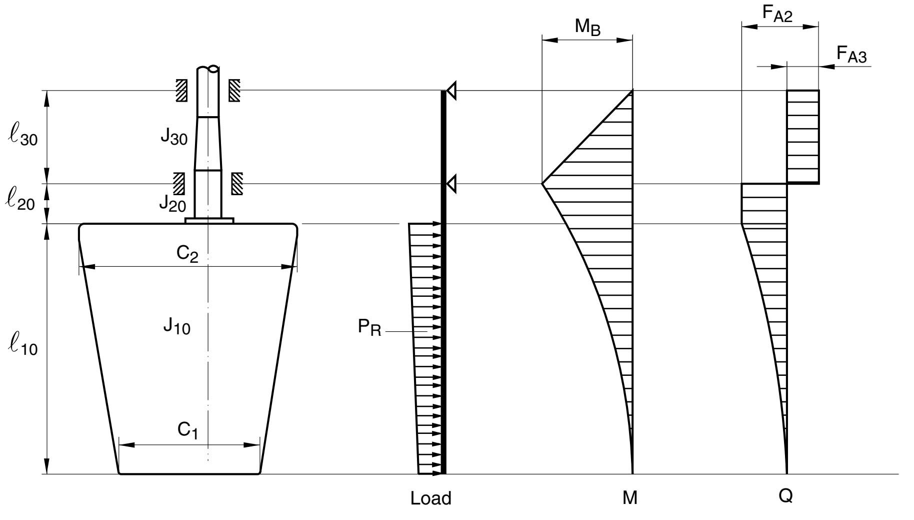


Figure 4 : Rudder type 6a



1.4.6 Rudder type 6a

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 4.

The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_{Rz} = p_{R10} + \left(\frac{p_{R20} - p_{R10}}{\ell_{10}}\right) \cdot z$$

where:

- z : Position of rudder blade section, in m, taken over ℓ_{10} length
- p_{Rz} : Force per unit length, in N/m, obtained at the z position
- p_{R10} : Force per unit length, in N/m, obtained for z equal to zero
- p_{R20} : Force per unit length, in N/m, obtained for z equal to ℓ_{10}.

For this type of rudder, the results of calculations performed according to diagrams shown in Fig 4 may also be obtained from the following formulae:

- maximum bending moment in the rudder stock, in N·m:

  $$M_B = C_R\left(\ell_{20} + \frac{\ell_{10}(2C_1 + C_2)}{3(C_1 + C_2)}\right)$$

  where C_1 and C_2 are the lengths, in m, defined in Fig 4
- support forces, in N:

  $$F_{A3} = \frac{M_B}{\ell_{30}}$$

  $F_{A2} = C_R + F_{A3}$
- maximum shear force in the rudder body, in N:

  $Q_R = C_R$.

1.4.7 Rudder type 6b

This type of rudder is regarding spade rudders with rudder trunks continued into the rudder blade, through a quite short length, in such way the centre of gravity of the rudder blade is located below the lower rudder stock bearing. The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 5.

The force per unit length p_R acting on the lower part of the rudder body is to be obtained, in N/m, from the following formula:

$$p_{Rz} = p_{R10} + \left(\frac{p_{R20} - p_{R10}}{\ell_{10}}\right) \cdot z$$

where:

- z : Position of rudder blade section, in m, taken over ℓ_{10} length
- p_{Rz} : Force per unit length, in N/m, obtained at the z position
- p_{R10} : Force per unit length, in N/m, obtained for z equal to zero
- p_{R20} : Force per unit length, in N/m, obtained for z equal to ℓ_{10}.

The values of p_{R10} and p_{R20} are obtained from the following two equations:

$$p_{R10} = \frac{2C_R(2\ell_{10} - 3\ell_{CG})}{\ell_{10}^2}$$

$$p_{R20} = \frac{2C_R(3\ell_{CG} - \ell_{10})}{\ell_{10}^2}$$

where:

- C_R : Force, in N, acting on the total rudder blade area A, to be calculated in accordance with Ch 9, Sec 1, [2.1.2]
- A : Total rudder blade area, in m^2
- ℓ_{CG} : Vertical position, in m, of the centre of gravity of the total rudder blade area A, to be taken from the bottom of the rudder blade.

The bending moments M_R and M_B, in N·m, for the scantling of both the rudder blade and the lower rudder stock diameter, respectively, are identical and shall be taken as follows:

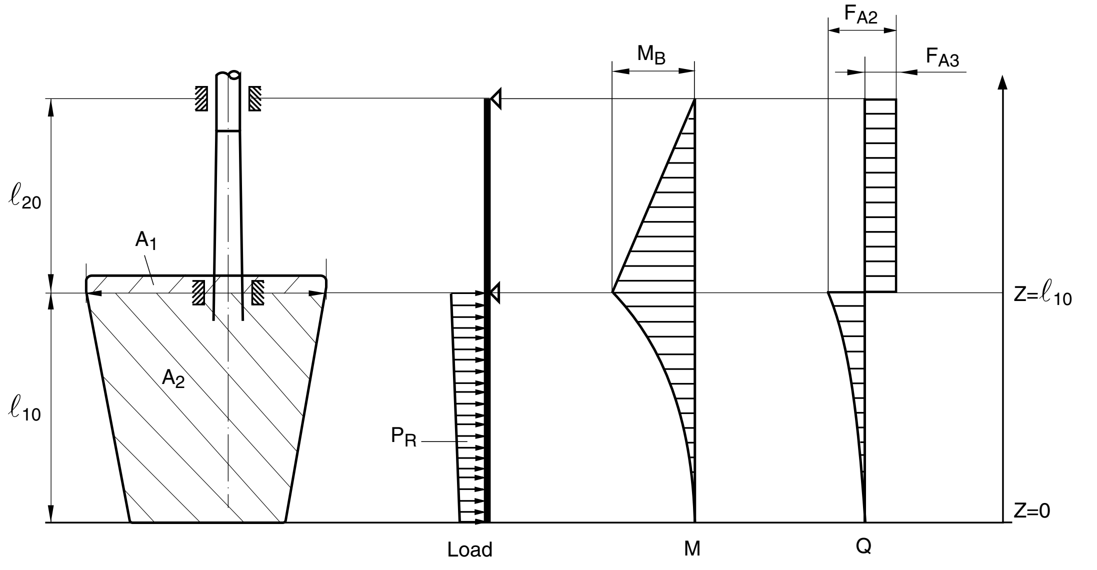
$M_R = M_B = C_R \cdot (\ell_{10} - \ell_{CG})$

The reaction forces F_{A2} and F_{A3}, in N, may be determined as follows:

$F_{A3} = M_B / \ell_{20}$

$F_{A2} = -(C_R + F_{A3})$

Figure 5 : Rudder type 6b



1.4.8 Rudder type 6c

This type of rudder provides a more general solution for the scantling of spade rudders with rudder trunks continued into the rudder blade. There is no limitation on the location of the centre of gravity of the total rudder blade area, which may be located either below the lower rudder stock bearing or slightly above it. The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 6.

The force per unit length p_R acting on the lower part of the rudder body is to be obtained, in N/m, from the following formula:

$$p_{Rz} = p_{R10} + \left(\frac{p_{R20} - p_{R10}}{\ell_{10}}\right) \cdot z$$

where:

- z : Position of rudder blade section, in m, taken over ℓ_{10} length
- p_{Rz} : Force per unit length, in N/m, obtained at the z position
- p_{R10} : Force per unit length, in N/m, obtained for z equal to zero
- p_{R20} : Force per unit length, in N/m, obtained for z equal to ℓ_{10}.

The values of p_{R10} and p_{R20} are obtained from the following two equations:

$$p_{R10} = \frac{2C_{R2}(2\ell_{10} - 3\ell_{CG2})}{\ell_{10}^2}$$

$$p_{R20} = \frac{2C_{R2}(3\ell_{CG2} - \ell_{10})}{\ell_{10}^2}$$

where:

- C_{R2} : Force, in N, acting on the rudder blade area A_2, to be calculated in accordance with Ch 9, Sec 1, [2.2.3]
- A_2 : Rudder blade area, in m^2, located below the lower rudder stock bearing
- ℓ_{CG2} : Vertical position, in m, of the centre of gravity of the rudder blade area A_2, to be taken from the bottom of the rudder blade.

The bending moment M_R, in N·m, for the scantling of the rudder blade, shall be taken as the greatest of the following values:

- $M\_C_{R2} = C_{R2} \cdot (\ell_{10} - \ell_{CG2})$
- $M\_C_{R1} = C_{R1} \cdot (\ell_{CG1} - \ell_{10})$

where:

- M_C_{R2} : Bending moment, in N·m, induced by the rudder force C_{R2} (M_C_{R2} is assumed to be of a negative sign)
- M_C_{R1} : Bending moment, in N·m, induced by the rudder force C_{R1} (M_C_{R1} is assumed to be of a positive sign)
- C_{R1} : Force, in N, acting on the rudder blade area A_1, to be calculated in accordance with Ch 9, Sec 1, [2.2.3]
- A_1 : Rudder blade area, in m^2, located above the lower rudder stock bearing
- ℓ_{CG1} : Vertical position, in m, of the centre of gravity of the rudder blade area A_1, to be taken from the bottom of the rudder blade.

The bending moment M_B, in N·m, for the scantling of the lower rudder stock diameter, is given by the algebraic sum of M_C_{R2} and M_C_{R1}, as follows:

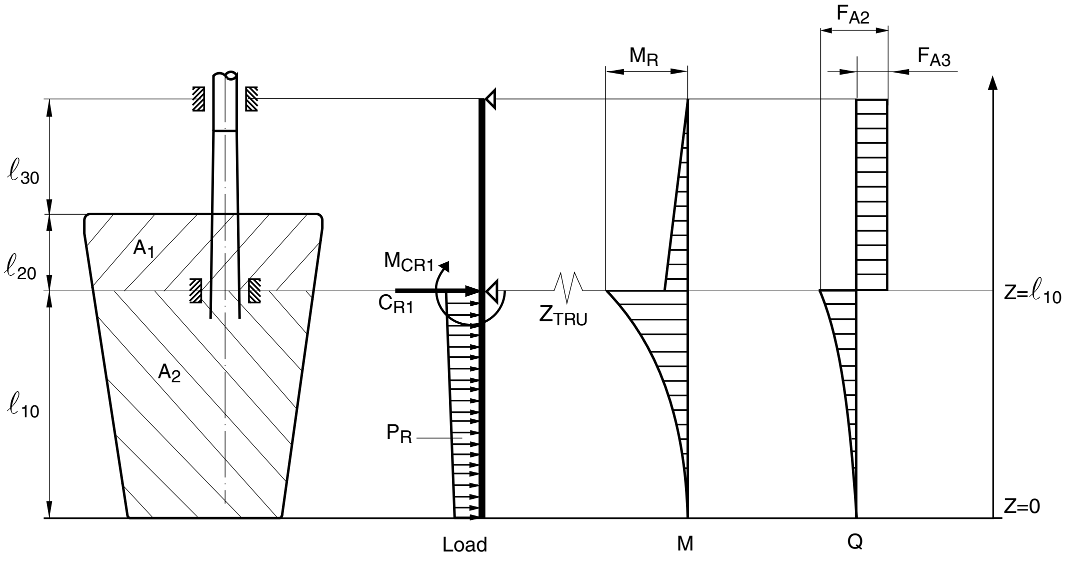
$M_B = M\_C_{R2} + M\_C_{R1}$

The reaction forces F_{A2} and F_{A3}, in N, may be determined as follows:

$F_{A3} = M_B / (\ell_{20} + \ell_{30})$

$F_{A2} = -(C_{R1} + C_{R2} + F_{A3})$

Figure 6 : Rudder type 6c



1.4.9 Rudder type 7

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 7.

The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{\ell_{10}}$$

$$p_{R20} = \frac{C_{R1}}{\ell}$$

where:

ℓ : Value equal to: $\ell = \ell_{20}$

The spring constant Z_p is to be calculated according to [1.3.2].

1.4.10 Rudder type 8

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 8.

The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{\ell_{10}}$$

$$p_{R20} = \frac{C_{R1}}{\ell}$$

with:

$\ell = \ell_{20} + \ell_{30}$

The spring constant Z_p is to be calculated according to [1.3.2].

Figure 7 : Rudder type 7

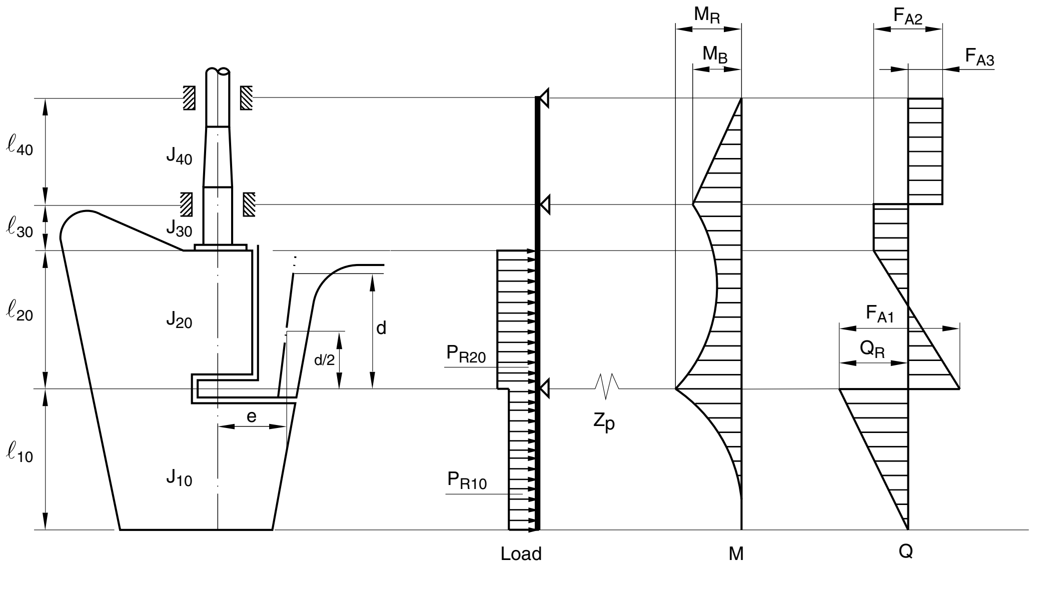
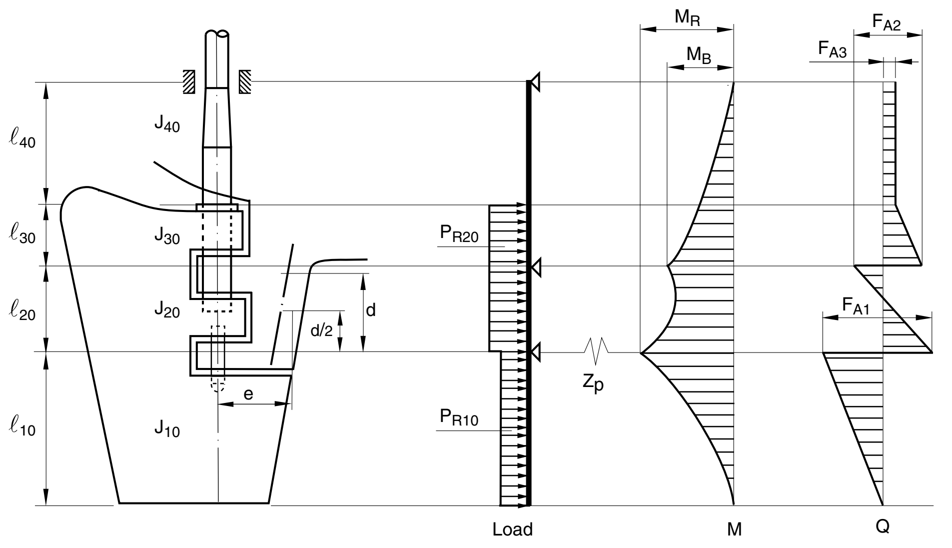


Figure 8 : Rudder type 8



1.4.11 Rudder type 9

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 9.

The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{\ell_{10}}$$

$$p_{R20} = \frac{C_{R1}}{\ell}$$

with:

$\ell = \ell_{20}$

The stiffness properties of the 2-conjugate elastic supports are to be calculated according to [1.3.3].

1.4.12 Rudder type 10

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 10.

The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{\ell_{10}}$$

$$p_{R20} = \frac{C_{R1}}{\ell}$$

with:

$\ell = \ell_{20} + \ell_{30}$

The stiffness properties of the 2-conjugate elastic supports are to be calculated according to [1.3.3].

Figure 9 : Rudder type 9

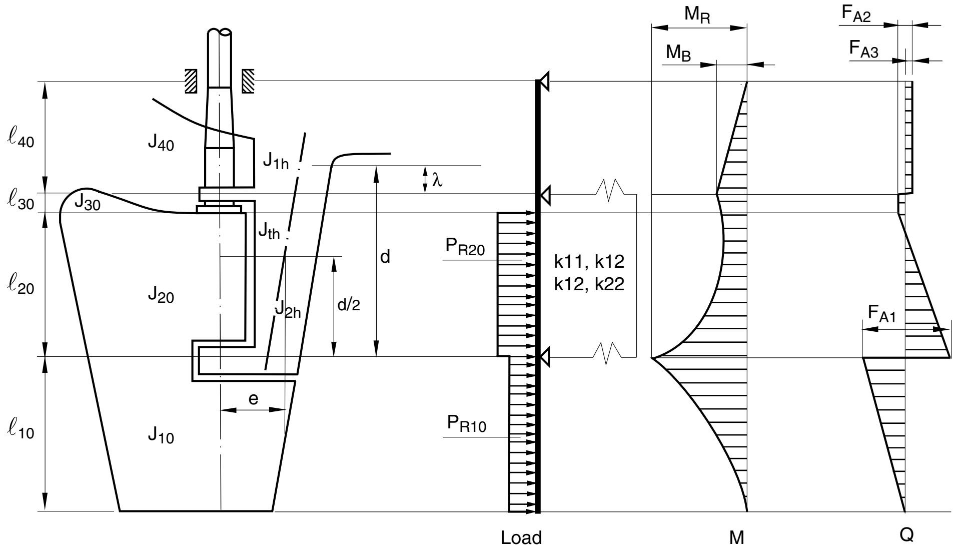
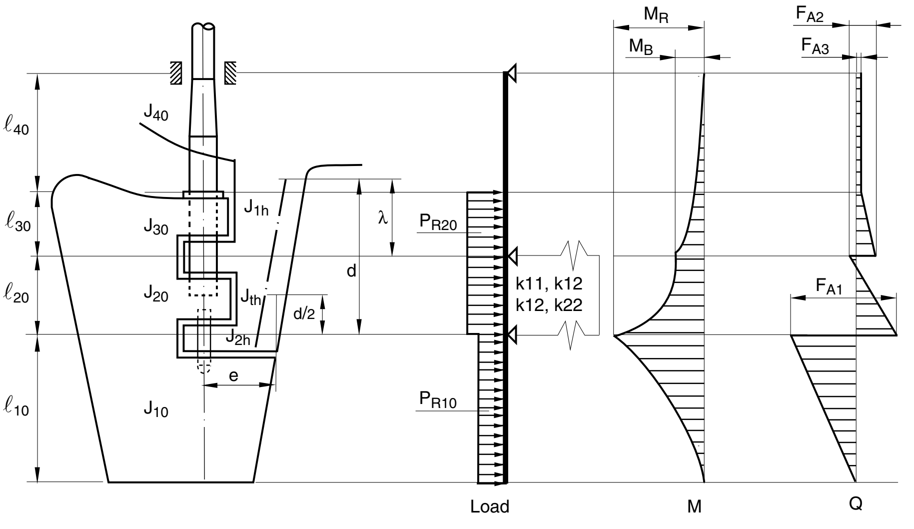


Figure 10 : Rudder type 10



1.5 Calculation of the solepiece

1.5.1 Bending moment

The bending moment acting on the generic section of the solepiece is to be obtained, in N·m, from the following formula:

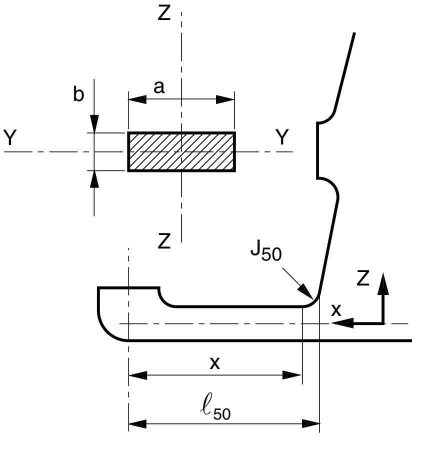
$M_S = F_{A1}\ x$

where:

F_{A1} : Supporting force, in N, in the pintle bearing, to be determined according to [1.4], for the relevant type of rudder

x : Distance, in m, defined in Fig 11.

Figure 11 : Solepiece geometry



1.5.2 Stress calculations

For the generic section of the solepiece within the length ℓ_{50}, defined in Fig 11, the following stresses are to be calculated:

σ_B : Bending stress to be obtained, in N/mm², from the following formula:

$$\sigma_B = \frac{M_S}{W_Z}$$

τ : Shear stress to be obtained, in N/mm², from the following formula:

$$\tau = \frac{F_{A1}}{A_S}$$

M_S : Bending moment, in N·m, at the section considered, as defined in [1.5.1]

F_{A1} : Force, in N, defined in [1.5.1]

W_Z : Section modulus, in cm³, around the vertical axis Z (see Fig 11)

A_S : Shear sectional area, in mm², in a plane perpendicular to the X axis of the solepiece.

1.6 Rudder horn calculation (case of 1-elastic support)

1.6.1 Bending moment

The bending moment acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formula:

$M_H = F_{A1}\ z$

where:

F_{A1} : Support force at the rudder horn lower-pintle, in N, to be obtained according to [1.4], for the relevant type of rudder

z : Distance, in m, defined in Fig 13, to be taken less than the distance d, in m, defined in the same figure.

1.6.2 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 formula:

$Q_H = F_{A1}$

where:

F_{A1} : Force, in N, defined in [1.6.1].

1.6.3 Torque

The torque acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formula:

$M_T = F_{A1}\ e_{(z)}$

where:

F_{A1} : Force, in N, defined in [1.6.1]

$e_{(z)}$: Torsion lever, in m, defined in Fig 13.

1.6.4 Stress calculations

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 to be obtained, in N/mm², from the following formula:

$$\sigma_B = \frac{M_H}{W_X}$$

M_H : Bending moment at the section considered, in N·m, defined in [1.6.1]

W_X : Section modulus, in cm³, around the horizontal axis X (see Fig 13)

τ_S : Shear stress to be obtained, in N/mm², from the following formula:

$$\tau_S = \frac{F_{A1}}{A_H}$$

F_{A1} : Force, in N, defined in [1.6.1]

A_H : Effective shear sectional area of the rudder horn, in mm², in y-direction

τ_T : Torsional stress to be obtained for hollow rudder horn, in N/mm², from the following formula:

$$\tau_T = \frac{M_T 10^{-3}}{2 F_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case-by-case basis

M_T : Torque, in N·m, defined in [1.6.3]

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 τ_T, is obtained at the minimum value of t_H .

Figure 12 : Rudder and rudder horn geometries (1-elastic support)

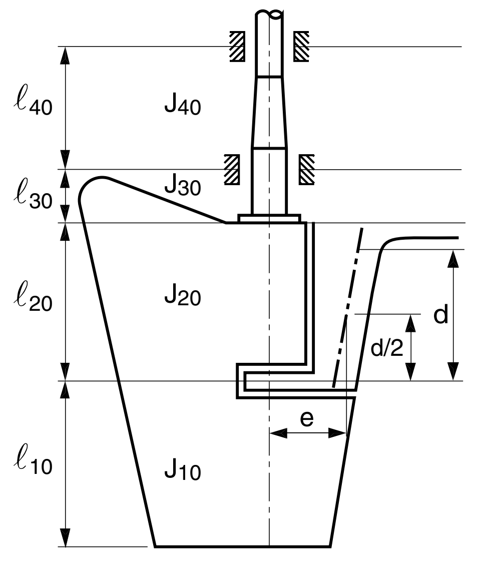
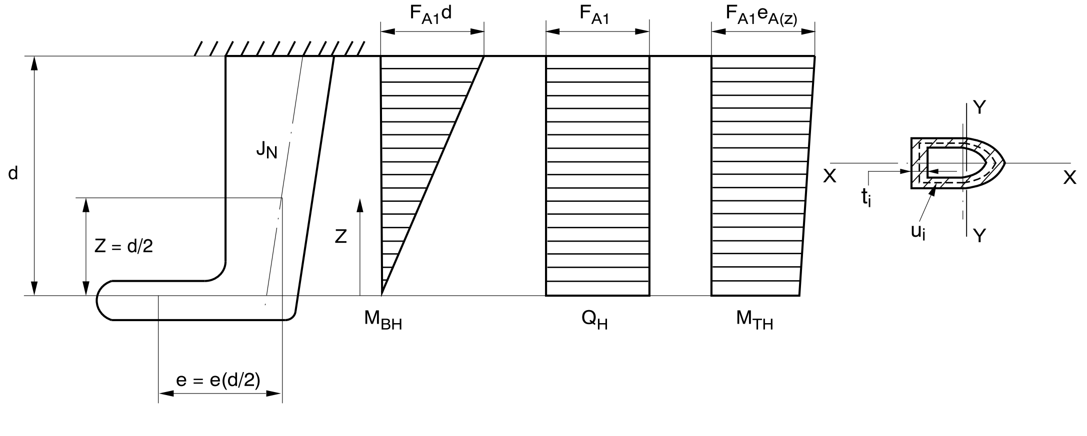


Figure 13 : Rudder horn geometry (1-elastic support)



1.7 Rudder horn calculation (case of 2-conjugate elastic supports)

1.7.1 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:

  $M_H = F_{A1}\ z$

- above the rudder horn upper-support:

  $M_H = F_{A1}\ z + F_{A2}\ (z - d_{lu})$

where:

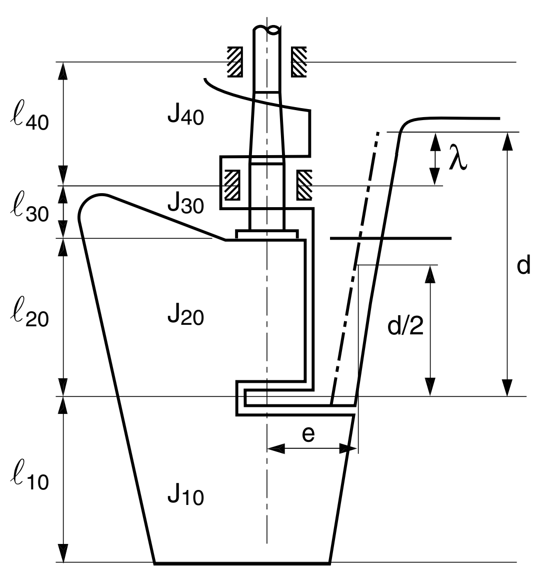
F_{A1} : Support force at the rudder horn lower-support, in N, to be obtained according to [1.4], for the relevant type of rudder

F_{A2} : Support force at the rudder horn upper-support, in N, to be obtained according to [1.4], for the relevant type of rudder

z : Distance, in m, defined in Fig 15, 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 14, $d_{lu} = d - \lambda$).

Figure 14 : Rudder and rudder horn geometries (2-conjugate elastic supports)



1.7.2 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, defined in [1.7.1].

1.7.3 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, defined in [1.7.1]

$e_{(z)}$: Torsion lever, in m, defined in Fig 15.

1.7.4 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/mm², to be obtained from the following formula:

   $$\tau_S = \frac{F_{A1}}{A_H}$$

   τ_T : Torsional stress, in N/mm², to be obtained for hollow rudder horn from the following formula:

   $$\tau_T = \frac{M_T 10^{-3}}{2 F_T t_H}$$

   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/mm², to be obtained from the following formula:

   $$\tau_S = \frac{F_{A1} + F_{A2}}{A_H}$$

   τ_T : Torsional stress, in N/mm², to be obtained for hollow rudder horn from the following formula:

   $$\tau_T = \frac{M_T 10^{-3}}{2 F_T t_H}$$

   For solid rudder horn, τ_T is to be considered by the Society on a case-by-case basis

where:

F_{A1}, F_{A2} : Support forces, in N, defined in [1.7.1]

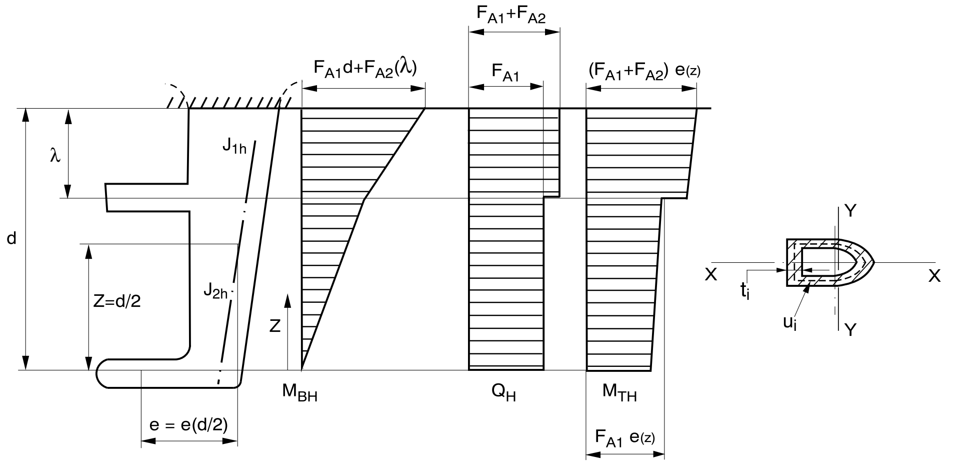
A_H : Effective shear sectional area of the rudder horn, in mm², in y-direction

M_T : Torque, in N·m, defined in [1.7.3]

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 τ_T, is obtained at the minimum value of t_H .

Figure 15 : Rudder horn geometry (2-conjugate elastic supports)



1.7.5 Bending stress calculation

For the generic section of the rudder horn within the length d, defined in Fig 15, the following stresses are to be calculated:

σ_B : Bending stress, in N/mm², 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, defined in [1.7.1]

W_X : Section modulus, in cm³, around the horizontal axis X (see Fig 15).

1.8 Calculation of the rudder trunk

1.8.1 Bending moment

The bending moment acting on the generic section of the trunk is to be obtained, in N·m, from the following formula:

$M_{TRU} = F_{A2}\ z$

where:

F_{A2} : Support force, in N, at the lower rudder stock bearing, as defined in [1.4]

z : Distance, in m, defined in Fig 16.

1.8.2 Stress calculations

For the generic section of the trunk within the length ℓ_{TRU}, defined in Fig 16, the following stresses are to be calculated:

σ_B : Bending stress to be obtained, in N/mm², from the following formula:

$$\sigma_B = \frac{M_{TRU}}{W_{TRU}}$$

τ : Shear stress to be obtained, in N/mm², from the following formula:

$$\tau = \frac{F_{A2}}{A_{TRU}}$$

M_{TRU} : Bending moment, in N·m, at the section considered, as defined in [1.8.1]

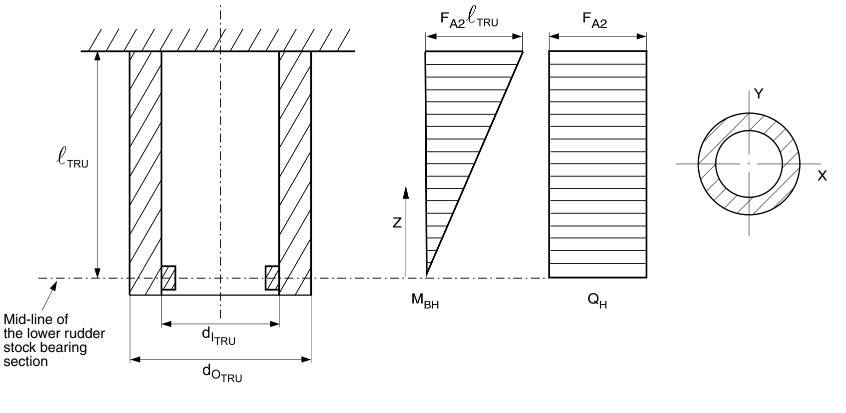
F_{A2} : Support force, in N, at the lower rudder stock bearing, as defined in [1.4]

W_{TRU} : Section modulus, in cm³, around the horizontal axis X (see Fig 16)

A_{TRU} : Shear sectional area, in mm², in a plane perpendicular to the Z axis of the trunk.

The length ℓ_{TRU} is the distance in m, taken between the midline of the lower rudder stock bearing and the "top line" of the trunk. This "top line" is defined either where the trunk is clamped into the shell or at the bottom of the skeg, as shown in the diagram Fig 16.

Figure 16 : Rudder trunk geometry



APPENDIX 2 TOWING AND MOORING ARRANGEMENT

1 General

1.1 Application

1.1.1 The towing and mooring arrangement as defined in the present article and the towing and mooring lines as defined in Article [2] are given as a guidance but are not required as a condition of classification.

1.2 Mooring arrangement

1.2.1 Attention is to be given to the arrangement of the equipment for towing and mooring operations in order to prevent interference of mooring and towing lines as far as practicable. It is beneficial to provide dedicated towing arrangements separate from the mooring equipment.

1.2.2 Mooring lines in the same service (e.g. breast lines as defined in [2.7.1]) are to be of the same characteristic in terms of strength and elasticity.

1.2.3 As far as possible, sufficient number of mooring winches are to be fitted to allow for all mooring lines to be belayed on winches. This allows for an efficient distribution of the load to all mooring lines in the same service and for the mooring lines to shed load before they break. If the mooring arrangement is designed such that mooring lines are partly to be belayed on bitts or bollards, it should be considered that these lines may not be as effective as the mooring lines belayed on winches.

1.2.4 Mooring lines must have as straight a lead as is practicable from the mooring drum to the fairlead.

1.2.5 At points of change in direction sufficiently large radii of the contact surface of a rope on a fitting are to be provided to minimize the wear experienced by mooring lines and as recommended by the rope manufacturer for the rope type intended to be used.

1.3 Towing arrangement

1.3.1 As far as possible, towing lines is to be led through a closed chock. The use of open fairleads with rollers or closed roller fairleads is to be avoided.

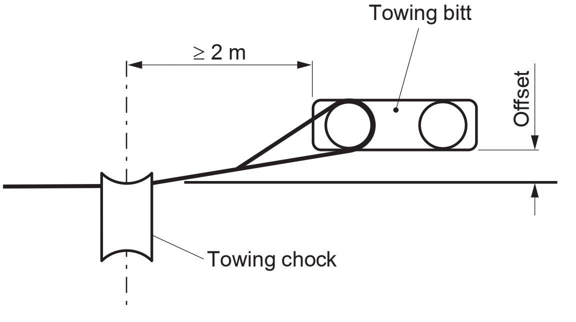
1.3.2 For towing purpose it is recommended to provide at least one chock close to centreline of the ship forward and aft. It is also beneficial to provide additional chocks on port and starboard side at the transom and at the bow.

1.3.3 Towing lines must have a straight lead from the towing bitt or bollard to the chock.

1.3.4 For the purpose of towing, bitts or bollards serving a chock are to be located slightly offset and in a distance of at least 2 m away from the chock, see Fig 1.

1.3.5 Warping drums are to be preferably positioned not more than 20 m away from the chock, measured along the path of the line.

Figure 1 : Bitts or bollards serving a chock for towing purpose



2 Tow lines and mooring lines

2.1 General

2.1.1 The equipment in tow line and mooring lines (length, breaking load and number of lines) is obtained from Tab 1 and Tab 2 based on an Equipment Number EN calculated according to Ch 9, Sec 4, [1.2.2] with a side projected area A including deck cargoes as given by the loading manual.

2.1.2 For mooring lines for ships with EN > 2000, refer to [2.7].

2.1.3 The breaking load given in Tab 1, Tab 2 or in [2.7.4] is used to determine the maximum design load applied to shipboard fittings as defined in Ch 9, Sec 4, [4.2.5].

2.1.4 The tow lines having the characteristics defined in Tab 1 and Tab 2 are intended as those belonging to the ship to be towed by a tug or another ship under normal towing conditions (calm water / harbour).

2.2 Materials

2.2.1 Tow lines and mooring lines may be of wire or synthetic fibre or a mixture of wire and fibre.

2.2.2 The breaking loads defined in Tab 1 and Tab 2 refer to steel wires.

2.2.3 As a guidance, all requirements about manufacturing, sampling and testing for steel wires and fibre ropes are available in NR216 Materials and Welding, Ch 4, Sec 1.

Table 1 : Tow line and mooring lines for EN ≤ 2000

Equipment number EN A < EN ≤ B		Tow line		Mooring lines		
A	B	Minimum length, in m	Breaking load, in kN	N **(1)**	Length of each line, in m	Breaking load, in kN
50	70	180	98	3	80	37
70	90	180	98	3	100	40
90	110	180	98	3	110	42
110	130	180	98	3	110	48
130	150	180	98	3	120	53
150	175	180	98	3	120	59
175	205	180	112	3	120	64
205	240	180	129	4	120	69
240	280	180	150	4	120	75
280	320	180	174	4	140	80
320	360	180	207	4	140	85
360	400	180	224	4	140	96
400	450	180	250	4	140	107
450	500	180	277	4	140	117
500	550	190	306	4	160	134
550	600	190	338	4	160	143
600	660	190	370	4	160	160
660	720	190	406	4	160	171
720	780	190	441	4	170	187
780	840	190	479	4	170	202
840	910	190	518	4	170	218
910	980	190	559	4	170	235
980	1060	200	603	4	180	250
1060	1140	200	647	4	180	272
1140	1220	200	691	4	180	293
1220	1300	200	738	4	180	309
1300	1390	200	786	4	180	336
1390	1480	200	836	4	180	352
1480	1570	220	888	5	190	352
1570	1670	220	941	5	190	362
1670	1790	220	1024	5	190	384
1790	1930	220	1109	5	190	411
1930	2000	220	1168	5	190	437

(1) Refer to [2.6].

Table 2 : Tow line for EN > 2000

Equipment number EN $A < EN \leq B$		Tow line	
A	B	Minimum length, in m	Breaking load, in kN
2000	2080	220	1168
2080	2230	240	1259
2230	2380	240	1356
2380	2530	240	1453
2530	2700	260	1471
2700	2870	260	1471
2870	3040	260	1471
3040	3210	280	1471
3210	3400	280	1471
3400	3600	280	1471
3600	3800	300	1471
3800	4000	300	1471
4000	4200	300	1471
4200	4400	300	1471
4400	4600	300	1471
4600	4800	300	1471
4800	5000	300	1471
5000	5200	300	1471
5200	5500	300	1471
5500	5800	300	1471
5800	6100	300	1471
6100	6500	300	1471
6500	6900	300	1471
6900	7400	300	1471
7400	7900	300	1471
7900	8400	300	1471
8400	8900	300	1471
8900	9400	300	1471
9400	10000	300	1471
10000	10700	300	1471
10700	11500	300	1471
11500	12400	300	1471
12400	13400	300	1471
13400	14600	300	1471
14600	16000	300	1471

Table 3 : Steel wire composition

Breaking load B_L, in kN	Steel wire components		
	Number of threads	Range of ultimate tensile strength of threads, in N/mm²	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

2.3 Steel wires

2.3.1 Steel wires are to be made of flexible galvanised steel and are to be of types defined in Tab 3.

2.3.2 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.

2.4 Length of mooring lines

2.4.1 The length of individual mooring lines may be reduced by up to 7% of the length defined in Tab 1 and [2.7.5] provided that the total length of mooring lines is greater than that obtained by adding the lengths of the individual lines defined in Tab 1 and [2.7.5].

2.4.2 For ships with the service notation **supply**, the length of mooring lines may be reduced. The reduced length ℓ is to be not less than that obtained, in m, from the following formula:

$\ell = L + 20$

2.5 Synthetic fibre ropes

2.5.1 Where synthetic fibre ropes are adopted, their size is to be determined taking into account the type of material used and the manufacturing characteristics of the rope, as well as the different properties of such ropes.

2.5.2 It is recommended to use lines with reduced risk of recoil (snap-back) to mitigate the risk of injuries or fatalities in the case of breaking mooring lines.

2.5.3 The breaking load of synthetic fibre ropes BLS is to be not less than that obtained, in kN, from the following formula:

$B_{LS} = K\ B_{L0}$

where:

B_{L0} : Breaking load, in kN, for the line, defined in Tab 1, Tab 2 and [2.7.4]

K : Coefficient to be taken equal to:

- for polypropylene lines:

  K = 1,3

- for lines made in other synthetic material:

  K = 1,2

2.5.4 Fibre rope diameters are to be not less than 20 mm.

2.6 Additional mooring lines

2.6.1 For ships having the ration A/EN > 0,9, additional mooring lines are defined in Tab 4, in addition to the number of mooring lines defined in Tab 1.

Table 4 : Additional mooring lines

A / EN	Number of additional mooring lines
0,9 < A / EN ≤ 1,1	1
1,1 < A / EN ≤ 1,2	2
1,2 < A / EN	3
Note 1: A and EN are defined in Ch 9, Sec 4, [1.2.2].	

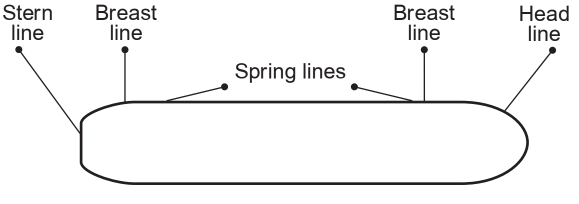
2.7 Mooring lines for ships with EN > 2000

2.7.1 Definitions

The following is defined with respect to the purpose of mooring lines, see also Fig 2:

- Breast line: mooring line that is deployed perpendicular to the ship, restraining the ship in the off-berth direction.
- Spring line: mooring line that is deployed almost parallel to the ship, restraining the ship in fore or aft direction.
- Head/Stern line: mooring line that is oriented between longitudinal and transverse direction, restraining the ship in the off-berth and in fore or aft direction. The amount of restraint in fore or aft and off-berth direction depends on the line angle relative to these directions.

Figure 2 : Breast, spring and head/stern mooring lines



2.7.2 Side projected area A_1

The strength of mooring lines and the number of head, stern, and breast lines for ships with an Equipment Number EN > 2000 are based on the side-projected area A_1.

Side projected area A_1 is to be calculated similar to the side-projected area A according to Ch 9, Sec 4, [1.2.2] but considering the following conditions:

- for ships with one of the service notations **oil tanker**, **chemical tanker**, **bulk carrier** or **ore carrier**:

  the lightest ballast draft.

- for other ships:

  the lightest draft of usual loading conditions if the ratio of the freeboard in the lightest draft and the full load condition is equal to or above two.

- deck cargo as given by the loading manual is to be included.

Note 1: Wind shielding of the pier can be considered for the calculation of the side-projected area A_1 unless the ship is intended to be regularly moored to jetty type piers. A height of the pier surface of 3 m over waterline may be assumed, i.e. the lower part of the side-projected area with a height of 3 m above the waterline for the considered loading condition may be disregarded for the calculation of the side-projected area A_1.

Note 2: Usual loading conditions mean loading conditions as given by the trim and stability booklet that are to be expected to regularly occur during operation and, in particular, excluding light weight conditions, propeller inspection conditions, etc.

Note 3: Deck cargo may not need to be considered if a usual light draft condition without cargo on deck generates a larger side-projected area A_1 than the full load condition with cargo on deck. The larger of both side-projected areas is to be chosen as side-projected area A_1.

2.7.3 Environmental conditions

The mooring lines are based on a maximum current speed of 2 knots (1,0 m/s) and the following maximum wind speed v_w, in m/s:

- for ships with one of the service notations **passenger ship**, **ro-ro passenger ship** or **ro-ro cargo ship**:
  - with 2000 m² < $A_1 \leq$ 4000 m²:

    $v_w = 25{,}0 - 0{,}002\ (A_1 - 2000)$
  - with $A_1 >$ 4000 m²:

    $v_w = 21{,}0$
- for other ships: $v_w = 25{,}0$

The wind speed is considered representative of a 30 second mean speed from any direction and at a height of 10 m above the ground. The current speed is considered representative of the maximum current speed acting on bow or stern (±10°) and at a depth of one-half of the mean draft. Furthermore, it is considered that ships are moored to solid piers that provide shielding against cross current.

Additional loads caused by, e.g., higher wind or current speeds, cross currents, additional wave loads, or reduced shielding from non-solid piers may need to be particularly considered. Furthermore, it should be observed that unbeneficial mooring layouts can considerably increase the loads on single mooring lines.

2.7.4 Minimum breaking strength

The minimum breaking strength MBL, in kN, of the mooring lines is to be taken as:

$MBL = 0{,}1\ A_1 + 350$

The minimum breaking strength MBL may be limited to 1275 kN (130 t).

However, in this case the moorings are to be considered as not sufficient for environmental conditions given in [2.7.3].

For these ships, the acceptable wind speed v_w^*, in m/s, can be estimated as follows:

$$v_w^* = v_w \sqrt{\frac{MBL^*}{MBL}}$$

where v_w as defined in [2.7.3], MBL as defined above and MBL^* the breaking strength of the mooring lines intended to be supplied.

However, the minimum breaking strength is not to be taken less than corresponding to an acceptable wind speed of 21 m/s:

$$MBL^* \geq \left(\frac{21}{v_w}\right)^2 MBL$$

If lines are intended to be supplied for an acceptable wind speed v_w^* higher than v_w as defined in [2.7.3], the minimum breaking strength MBL^* is to be taken as:

$$MBL^* = \left(\frac{v_w^*}{v_w}\right)^2 MBL$$

2.7.5 Length of mooring lines

For ships with EN > 2000, the length of mooring lines may be taken as 200 m.

2.7.6 Head, stern and breast lines

The total number of head, stern and breast lines is to be taken as:

- for ships with one of the service notations oil tanker, chemical tanker, bulk carrier or ore carrier:

  $n = 8{,}3 \cdot 10^{-4} \cdot A_1 + 4$
- for other ships:

  $n = 8{,}3 \cdot 10^{-4} \cdot A_1 + 6$

This number n is to be rounded to the nearest whole number and may be increased or decreased in conjunction with an adjustment to the strength of the lines. The adjusted strength, MBL^*, should be taken as:

- for increased number of lines:

  $MBL^* = 1{,}2 \cdot MBL \cdot n/n^* \leq MBL$
- for reduced number of lines:

  $MBL^* = MBL \cdot n/n^*$

where n^* is the increased or decreased total number of head, stern and breast lines and n the number of lines for the considered ship type as calculated by the above formulas without rounding.

Vice versa, the strength of head, stern and breast lines may be increased or decreased in conjunction with an adjustment to the number of lines.

2.7.7 Spring lines

The total number of spring lines is to be taken not less than:

- for ship with EN < 5000: two lines
- for ships with EN ≥ 5000: four lines

The strength of spring lines should be the same as that of the head, stern and breast lines. If the number of head, stern and breast lines is increased in conjunction with an adjustment to the strength of the lines, the number of spring lines should be likewise increased, but rounded up to the nearest even number.

Part B
Hull and Stability

Chapter 10
CORROSION PROTECTION AND LOADING INFORMATION

SECTION 1 PROTECTION OF HULL METALLIC STRUCTURES

1 Protection by coating

1.1 General

1.1.1 It is the responsibility of the shipbuilder and the Owner to choose the coating and have it applied in accordance with the manufacturer's requirements.

1.2 Structures to be protected

1.2.1 All salt water ballast spaces with boundaries formed by the hull envelope are to have a corrosion protective coating, epoxy or equivalent, applied in accordance with the manufacturer's requirements.

For ships assigned with the additional service feature or the additional class notation **CPS (WBT)** according to Pt A, Ch 1, Sec 2, [4.3.2], Pt A, Ch 1, Sec 2, [4.4.2] and Pt A, Ch 1, Sec 2, [6.15.4], reference is to be made to NR530 Coating Performance Standard.

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

1.2.3 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.

2 Protection against galvanic corrosion in tanks

2.1 General

2.1.1 Non-stainless steel is to be electrically insulated from stainless steel or from aluminium alloys.

2.1.2 Where stainless steel or aluminium alloys are fitted in the same tank as non-stainless steel, a protective coating is to cover both materials.

3 Protection of bottom by ceiling

3.1 General

3.1.1 In double bottom ships, ceiling is to be laid over the inner bottom and lateral bilges, if any.

Ceiling on the inner bottom is not required where the thickness of the inner bottom is increased in accordance with Ch 7, Sec 1, [2.4.1].

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 facilitate 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.

4 Protection of decks by wood sheathing

4.1 General

4.1.1 Where decks are intended to carry specific loads, such as caterpillar trucks and unusual vehicles, the Society may require such decks wood sheathed.

4.2 Arrangement

4.2.1 Wood sheathing is to be fixed to the plating by welded studs or bolts of at least 12 mm in diameter, every second frame.

4.2.2 Before fitting the wood sheathing, deck plates are to be provided with protective coating declared to be suitable by the Shipyard.

Caulking is Shipyard’s responsibility.

4.3 Scantlings

4.3.1 The thickness of wood sheathing of decks is to be not less than:

- 65 mm if made of pine
- 50 mm if made of hardwood, such as teak.

The width of planks is not to exceed twice their thickness.

5 Protection of cargo sides by battens

5.1 General

5.1.1 The requirements in [5.2] apply to sides in cargo spaces of ships with the service notation **general cargo ship** or **livestock carrier**.

5.2 Arrangement

5.2.1 In the case of transversally framed sides, longitudinal battens formed by spaced planks are to be fitted to the frames by means of clips.

5.2.2 Where sides are longitudinally framed, battens are to be fitted vertically.

5.2.3 Battens are to extend from the bottom of the cargo space to at least the underside of the beam knees.

5.2.4 Cargo battens are to be not less than 50 mm in thickness and 150 mm in width. The space between battens is not to exceed 300 mm.

SECTION 2 LOADING MANUAL AND LOADING INSTRUMENTS

1 Definitions

1.1 Perpendiculars

1.1.1 Forward perpendicular

The forward perpendicular is the perpendicular to the waterline at the forward side of the stem on the summer load waterline.

1.1.2 After perpendicular

The after perpendicular is the perpendicular to the waterline at the after side of the rudder post on the summer load waterline. For ships without rudder post, the after perpendicular is the perpendicular to the waterline at the centre of the rudder stock on the summer load waterline.

1.1.3 Midship perpendicular

The midship perpendicular is the perpendicular to the waterline at half the distance between forward and after perpendiculars.

2 Loading manual and loading instrument requirement criteria

2.1 Ship categories

2.1.1 Category I ships

- ships with large deck openings where combined stresses due to vertical and horizontal hull girder bending and torsional and lateral loads need to be considered
- ships liable to carry non-homogeneous loadings, where the cargo and/or ballast may be unevenly distributed; exception is made for ships less than 120 metres in length, when their design takes into account uneven distribution of cargo or ballast: such ships belong to Category II
- ships having the service notation **chemical tanker ESP**, **liquefied gas carrier** or **LNG bunkering ship**.

2.1.2 Category II ships

- ships whose arrangement provides small possibilities for variation in the distribution of cargo and ballast
- ships on a regular and fixed trading pattern where the loading manual gives sufficient guidance
- the exception given under Category I.

2.2 Requirement criteria

2.2.1 All ships

An approved loading manual is to be supplied for all ships equal to or greater than 65 m in length, except those of Category II less than 90 m in length in which the deadweight does not exceed 30% of the displacement at the summer loadline draught.

In addition, an approved loading instrument is to be supplied for all ships of Category I of 65 m in length and above.

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.

2.2.2 In any case, when a loading instrument is present onboard, it is to be approved by the Society.

2.2.3 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

Ships with one of the service notations **bulk carrier**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, 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.

2.2.4 Bulk carriers, ore carriers or combination carriers less than 150 m in length

Ships with one of the service notation **bulk carrier**, **ore carrier ESP** or **combination carrier ESP**, and less than 150 m in length, are to be provided with an approved computer-based loading instrument in accordance with the applicable requirements of this Section. The approved loading instrument is to be capable of providing information on the ship's stability in the intact condition.

2.2.5 Oil tankers and chemical tankers

Ships with one of the service notation **oil tanker ESP**, or **chemical tanker**, are to be provided with an approved computer-based loading instrument in accordance with the applicable requirements of this Section.The approved loading instrument is to be capable of verifying compliance with the intact and applicable damage stability requirements. Exemptions may be granted on a case by case basis.

3 Loading manual

3.1 Definitions

3.1.1 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 forces and, where applicable, limitations due to torsional and lateral loads
- the allowable local loading for the structure (hatch covers, decks, double bottom, etc.).

3.1.2 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

In addition to [3.1.1], for ships with one of the service notations **bulk carrier**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, the loading manual is also to describe:

- for cargo holds of ships with the service notation **bulk carrier**: the envelope results and permissible limits of still water bending moments and shear forces in the hold flooded condition
- the cargo hold(s) or combination of cargo holds which might be empty at full draught
- hold mass curves for each single hold in the relevant loading conditions listed in Pt D, Ch 4, Sec 3, [2.1], showing the maximum allowable and the minimum required masses of cargo and double bottom contents of each hold as a function of the draught at mid-hold position (for determination of permissible mass in cargo holds, refer to Ch 10, App 1)
- hold mass curves for any two adjacent holds in the relevant loading conditions listed in Pt D, Ch 4, Sec 3, [2.1], showing the maximum allowable and the minimum required masses 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 (for determination of permissible mass in cargo holds, refer to Ch 10, App 1)
- 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
- the maximum rate of ballast change together with the advice that a load plan is to be agreed with the terminal on the basis of the achievable rates of change of ballast.

3.2 Conditions of approval

3.2.1 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, defined in Ch 5, Sec 2, [2.1.2].

In the case of modifications resulting in changes to the main data of the ship, a new approved loading manual is to be issued.

3.2.2 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

In addition to [3.2.1], for ships with one of the service notations **bulk carrier**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, the following loading conditions, subdivided into departure and arrival conditions as appropriate, are also to be included in the loading manual:

- alternate light and heavy cargo loading conditions at maximum draught, where applicable
- homogeneous light and heavy cargo loading conditions at maximum draught
- ballast conditions

  For ships with ballast holds adjacent to topside wing, hopper and double bottom tanks, it may be 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 a 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 the loading rate and deballasting capability
- typical sequences for change of ballast at sea, where applicable.

3.2.3 Language

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.

4 Loading instrument

4.1 Additional class notations LI

4.1.1 The additional class notations **LI-HG**, **LI-S1**, **LI-S2**, **LI-S3**, **LI-S4**, **LI-HG-S1**, **LI-HG-S2**, **LI-HG-S3**, **LI-HG-S4** and **LI-LASHING** may be assigned in accordance with Pt A, Ch 1, Sec 2, [6.14.28] to ships equipped with a loading instrument, as defined in [4.1.2].

4.1.2 When the ship is equipped with a loading instrument performing:

- only hull girder calculations, the additional class notation **LI-HG** is assigned
- only intact stability calculations (when the ship is not required to meet damage stability requirements), the additional class notation **LI-S1** is assigned
- intact stability calculations and damage stability on a basis of a limit curve, the additional class notation **LI-S2** is assigned
- intact stability calculations and direct damage stability calculations based on pre-programmed damage cases, the additional class notation **LI-S3** is assigned.
- damage stability calculations associated with an actual loading condition and actual flooding case, using direct application of user defined damage, for the purpose of providing operational information for safe return to port, the additional class notation **LI-S4** is assigned.
- lashing calculations, the additional class notation **LI-LASHING** is assigned.

When the loading instrument performs hull girder and stability calculations, the additional class notation **LI-HG-S1**, **LI-HG-S2**, **LI-HG-S3**, **LI-HG-S4** is assigned, as applicable.

4.2 Definitions

4.2.1 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 and still water torsional moments and lateral loads, where applicable, 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.

The approval of a loading instrument for lashing calculation is to be performed according to the approval of lashing software as applicable in NR625, Ch 14, Sec 1, [7].

4.2.2 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

For ships with one of the service notations **bulk carrier**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, the loading instrument is an approved digital system as defined in [4.2.1]. In addition to [4.2.1], 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, where required,

do not exceed the specified permissible values.

4.3 Conditions of approval

4.3.1 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.

4.3.2 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

In addition, for ships with one of the service notations **bulk carrier**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, 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 (for determination of permissible mass in cargo holds, refer to Ch 10, App 1)
- acceptance of limits for the mass of cargo and double bottom contents in any two adjacent holds as a function of draught (for determination of permissible mass in cargo holds, refer to Ch 10, App 1).

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

4.3.4 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.

4.3.5 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.

4.3.6 When the loading instrument also performs stability calculations, it is to be approved for stability purposes in accordance with the procedures indicated in [4.6], [4.7] and [4.8], as applicable.

4.4 Approval procedure

4.4.1 General

The loading instrument approval process includes the following procedures for each ship:

- data verification which results in endorsed test conditions
- approval of computer hardware, where necessary, as specified in Pt C, Ch 3, Sec 6, [2.4.1]
- installation testing which results in an Installation Test Report.

4.4.2 Data verification approval - Endorsed test conditions

The Society is to verify the results and actual ship data used by the calculation program for the particular ship on which the program will be installed.

Upon application for data verification, the Society is to advise the applicant of a minimum of four loading conditions, taken from the ship's approved loading manual, which are to be used as the test conditions. Within the range of these test conditions, each compartment is to be loaded at least once. The test conditions normally cover the range of load draughts from the deepest envisaged loaded condition to the light ballast condition. In addition, the lightship test condition is to be submitted.

When the additional class notation **LI-S4** is assigned, at least three damage cases are to be examined, each of them associated with at least three loading conditions taken from the ship's approved stability information. Output of the software is to be compared with results of corresponding load / damage case in the approved damage stability booklet or an alternative independent software source.

When the loading instrument also performs stability calculations, it is to cover all the stability requirements applicable to the ship. The test conditions are to be taken from the ship's approved trim and stability booklet.

The data indicated in [4.4.3] and contained in the loading program are to be consistent with the data specified in the approved loading manual. Particular attention is drawn to the final lightship weight and centres of gravity derived from the inclining experiment or lightweight check.

The approval of the computer application software is based on the acceptance of the results of the test conditions according to [4.5], [4.6], [4.7], and [4.8], as applicable.

When the requested information has been submitted and the results of the test conditions are considered satisfactory, the Society endorses the test conditions, a copy of which is to be available on board.

4.4.3 Data to be submitted

The following data, submitted by the applicant, are to be consistent with the as-built ship:

- identification of the calculation program including the version number
- main dimensions, hydrostatic particulars and, if applicable, ship profile
- position of the forward and after perpendiculars and, if appropriate, the calculation method to derive the forward and after draughts at the actual position of the ship's draught marks
- ship lightweight and lightweight distribution along the ship's length
- lines plans and/or offset tables
- compartment definitions, including frame spacing and centre of volumes, together with capacity tables (sounding/ullage tables), if appropriate
- deadweight definitions for each loading condition.

4.4.4 Installation testing

During the installation test, one of the ship's senior officers is to operate the loading instrument and calculate the test conditions. This operation is to be witnessed by a Surveyor of the Society. The results obtained from the loading instrument are to be identical to those stated in the endorsed test conditions. If the numerical output from the loading instrument is different from the endorsed test conditions, no approval will be confirmed.

An installation test is also to be carried out on the second nominated computer, when applicable as indicated in Pt C, Ch 3, Sec 6, [2.4.1], which would be used in the event of failure of the first computer. Where the installation test is carried out on a type approved computer, a second nominated computer and test are not required.

Subject to the satisfactory completion of installation tests, the Society's Surveyor endorses the test conditions, adding details of the place and the date of the installation test survey, as well as the Society stamp and the Surveyor's signature.

4.4.5 Operational manual

A uniquely identified ship specific operational manual is to be submitted to the Society for documentation.

The operational manual is to be written in a concise and unambiguous manner. The use of illustrations and flowcharts is recommended.

The operational manual is to contain:

- a general description of the program denoting identification of the program and its stated version number
- details of the hardware specification needed to run the loading program
- a description of error messages and warnings likely to be encountered, and unambiguous instructions for subsequent actions to be taken by the user in each case
- where applicable, the shear force correction factors
- where applicable, the local permissible limits for single and two adjacent hold loadings as a function of the appropriate draught and the maximum weight for each hold
- where applicable, the Society's restrictions (maximum allowable load on double bottom, maximum specific gravity allowed in liquid cargo tanks, maximum filling level or percentage in liquid cargo tanks)
- example of a calculation procedure supported by illustrations and sample computer output
- example computer output of each screen display, complete with explanatory text.

Table 1 : Data to be provided to, or to be accepted by, the Society

Calculation	Data to be provided to, or accepted by, the Society
Still Water Shear Force (SWSF)	• The read-out points (frame locations) for the SWSF calculations. These points are normally selected at the position of the transverse bulkhead or other obvious boundaries. Additional read-out points may be specified between the bulkheads of long holds or tanks or between container stacks. • Shear force correction factors and method of application. • The permissible seagoing and harbour SWSF limits at the read-out points. Where appropriate, additional sets of permissible SWSF values may be specified.
Still Water Bending Moment (SWBM)	• The read-out points (frame locations) for the SWBM calculations. These points are normally selected at the position of the transverse bulkhead, mid-hold or other obvious boundaries. • The permissible seagoing and harbour SWBM limits at the read-out points. Where appropriate, additional sets of permissible SWBM values may be specified.
Still Water Torsion Moment (SWTM), where applicable	• The read-out points (frame locations) for the SWTM calculations, where applicable. • The permissible limits at the read-out points.

4.4.6 Calculation program specifications

The software is to be written so as to ensure that the user cannot alter the critical ship data files containing the following information:

- lightship weight and lightship weight distribution and associated centres of gravity
- the Society's structural limitations or restrictions, including but not limited to trim, draught, liquid densities, tank filling levels, initial heel, limit KG/GM curves when applicable and restrictions to the stowage height for timber
- geometric hull form data
- hydrostatic data and cross curves, where applicable
- compartment definitions, including frame spacing and centre of volumes, together with capacity tables (sounding/ullage tables), if appropriate
- when intact stability criteria are given, a listing of all calculated stability criteria with the obtained values and the conclusions (criteria fulfilled or not fulfilled), the down-flooding angle and the corresponding down-flooding opening.

Any changes in the software are to be made by the manufacturer or his appointed representative and the Society is to be informed immediately of such changes. Failure to advise of any modifications to the calculation program may invalidate the approval issued. In cases where the approval is considered invalid by the Society, the modified calculation program is to be re-assessed in accordance with the approval procedure.

4.4.7 General functional requirements

The calculation program is to be user-friendly and designed such that it limits possible input errors by the user.

The forward, midship and after draughts, at the respective perpendiculars, are to be calculated and presented to the user on screen and hardcopy output in a clear and unambiguous manner.

It is recommended that the forward, midship and after draughts, at the actual position of the ship's draught marks are calculated and presented to the user on screen and hard copy output in a clear and unambiguous manner.

The displacement is to be calculated for the specified loading condition and corresponding draught readings and presented to the user on screen and hardcopy output.

The loading instrument is to be capable of producing print-outs of the results in both numerical and graphical forms. The numerical values are to be given in both forms, as absolute values and as the percentage of the permissible values. This print-out is to include a description of the corresponding loading condition.

All screen and hardcopy output data is to be presented in a clear and unambiguous manner with an identification of the calculation program (the version number is to be stated).

When the additional class notation **LI-S3** is assigned, the software is to include pre-defined relevant damage cases according to the applicable rules for automatic check of a given loading condition.

When the additional class notation **LI-S3** or **LI-S4** is assigned, the damage stability is to be based on a hull form model, that is, directly calculated from a full three-dimensional geometric model. In addition, the system shall be pre-loaded with a detailed computer model of the complete hull, including appendages, all compartments, tanks and the relevant parts of the superstructure considered in the damage stability calculation, wind profile, down-flooding and up-flooding openings, cross-flooding arrangements, internal compartment connections and escape routes, as applicable and according to the type of stability software.

When the additional class notation **LI-S1** or **LI-S2** is assigned, in case a full three dimensional model is used for stability calculations, the requirements of the computer model for the additional class notation **LI-S3** or **LI-S4** are applicable.

For ships engaged in anchor handling operations, planning tools are to be provided in compliance with operational manual requirements. Information such as ballasting and consumables sequences, permissible tension, working sectors, heeling angles and use of roll-reduction devices are to be stated.

4.4.8 Specific functional requirements for LI-S4

The software used for damage stability for SRTP need not to be totally separated from other software used for normal stability.

When the software for damage stability for SRTP is not separated:

- the function of switching between normal software and SRTP software is to be provided
- the actual intact loading condition is to be the same for both functions (normal operation and SRTP)
- the SRTP module needs only to be activated in case of an incident.

For passenger ships which are subject to SRTP and have an onboard stability computer and shore-based support, such software need not be identical.

Each internal space is to be assigned its permeability as given in Tab 2, unless a more accurate permeability has been reflected in the approved stability information.

Table 2 : Permeability for internal spaces

Spaces	Default	Full	Partially filled	Empty
Container spaces	0,95	0,70	0,80	0,95
Dry cargo spaces	0,95	0,70	0,80	0,95
Ro-Ro spaces	0,95	0,90	0,90	0,95
Cargo liquids	0,95	0,70	0,80	0,95
Intended for consumable liquids	0,95	0,95	0,95	0,95
Stores	0,95	0,60	0,60	0,95
Occupied by machinery	0,85			
Void spaces	0,95			
Occupied by accommodation	0,95			

The system is to be capable of accounting for applied moments such as wind, lifeboat launching, cargo shifts and passenger relocation.

The system is to take into account for the effect of wind by using the method in SOLAS regulation II-1/7-2.4.1.2 as the default, but allow for manual input of the wind speed/pressure if the on-scene pressure is significantly different (P = 120 N/m^2 equates to Beaufort 6; approximately 13,8 m/s or 27 knots).

The system is to be capable of assessing the impact of open main watertight doors on stability (e.g. for each damage case provided for verification, additional damage stability calculation shall be done and presented, taking into account any watertight door located within the damaged compartment(s)).

The system is to utilize the latest approved lightship weight and centre of gravity information.

The output of the software is to be such that it provides the master with sufficient clear unambiguous information to enable quick and accurate assessment of the stability of the vessel for any actual damage, the impact of flooding on the means of escape and the controls of devices necessary for managing and/or controlling the stability of the ship.

When the actual loading condition is input in the software, in addition to the information required in [4.4.6] and in [4.4.7], the following output corresponding to intact stability are to be available:

- free surfaces
- GZ values relevant to an adequate range of heeling (not less than 60°) available indicatively at the following intervals: 0 5 10 15 20 25 30 40 50 60 deg
- GM/KG limiting curve according to SOLAS, Ch II-1, Regulation 5-1

When the actual loading condition is associated to the actual damage case(s) due to the casualty, in addition to the information required in [4.4.6] and in [4.4.7], the following output corresponding to the damage stability are to be available:

- progressive flooding angle and corresponding progressive flooding openings
- GM value
- GZ values relevant to an adequate range of heeling (not less than 60°) available indicatively at the following intervals: 0 5 10 15 20 25 30 40 50 60 deg
- the survivability criteria are left to the discretion of the Society
- relevant flooding points (unprotected or weathertight) with the distance from the damage waterline to each point
- list of all flooded compartments with the permeability considered
- amount of water in each flooded compartment
- escape route immersion angles
- a profile view, deck views and cross-sections of the ship indicating the flooded waterplane and the damaged compartments.

For Ro-Ro Passenger ships subject to the Stockholm Agreement (IMO Circular Letter No. 1891), the software is to include algorithms for estimating the effect of water accumulation on deck (WOD). For example, in addition to the predefined significant wave height taken from the approved stability document, the software allows the crew to input manually the significant wave height of the ship navigation area. For checking the correctness of the algorithms for estimating the effect of WOD, the calculations with two additional significant wave heights are to be submitted.

4.5 Hull girder forces and moments

4.5.1 General

The loading program is to be capable of calculating the following hull girder forces and moments in accordance with Ch 5, Sec 2, [2]:

- Still Water Shear Force (SWSF) including the shear force correction, where applicable
- Still Water Bending Moment (SWBM)
- Still Water Torsion Moment (SWTM), where applicable
- For ships with relatively large deck openings, additional considerations such as torsional loads are to be considered.

The data which are to be provided to, or accepted by, the Society are specified in Tab 1.

Read-out points are usually to be selected at the position of the transverse bulkheads or other obvious boundaries. Additional read-out points may be required between bulkheads of long holds or tanks, or between container stacks.

Where the still water torsion moments are required to be calculated, one test condition is to demonstrate such a calculation.

The calculated forces and moments are to be displayed in both graphical and tabular formats, including the percentage of permissible values. The screen and hardcopy output is to display the calculated forces or moments, and the corresponding permissible limits, at each specified read-out point. Alternative limits may be considered by the Society on a case by case basis.

4.5.2 Acceptable tolerances

The accuracy of the calculation program is to be within the acceptable tolerance band, specified in Tab 3, of the results at each read-out point obtained by the Society, using an independent program or the approved loading manual with identical input.

Table 3 : Tolerance band for the comparison of computational accuracy

Computation	Tolerance (percentage of the permissible values)
Still Water Shear Force	± 5%
Still Water Bending Moment	± 5%
Still Water Torsion Moment, where applicable	± 5%

4.5.3 Permissible limits and restrictions

The user is to be able to view the following Society structural limitations in a clear and unambiguous manner:

- all permissible still water shear forces and still water bending moments
- where applicable, the permissible still water torsion moments
- where applicable, all local loading limits both for one hold and for adjacent hold loadings
- cargo hold weight
- ballast tank/hold capacities
- filling restrictions.

It is to be readily apparent to the user when any of the structural limits has been exceeded.

4.6 Intact stability

4.6.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs stability calculations, as stated in [4.3.6].

4.6.2 Data verification approval - Endorsed test conditions

The requirements in [4.4.2] apply. In addition, at least one of the four loading conditions required is to show the compartments, intended for liquid loads in which the free surface effect is considerable, filled in order to have the maximum free surface moment.

The additional data necessary for the approval of the loading instrument for stability purposes are specified in [4.6.3].

In order to obtain the approval of the loading instrument, all the intact stability requirements (and relevant criteria) applicable to the ship, reported in Ch 3, Sec 2 as well as in Part D or Part E, are to be available in the computer output; the lack of any one of them is sufficient to prevent the endorsement of the test conditions.

4.6.3 Additional data to be submitted

In addition to the data required in [4.4.3], the following are to be submitted:

- cross curves of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves
- capacity tables indicating, for each compartment or space, the values of the co-ordinates X_G, Y_G and Z_G of the centre of gravity, as well as the inertia, corresponding to an adequate number of filling percentages
- list of all the openings (location, tightness, means of closure), pipes or other sources which may lead to progressive flooding
- deadweight definitions for each loading condition in which, for any load taken into account, the following information is to be specified:
  - weight and centre of gravity co-ordinates
  - percentage of filling (if liquid load)
  - free surface moment (if liquid load)
- information on loading restrictions (maximum filling level or percentage in liquid cargo tanks, maximum KG or minimum GM curve or table which can be used to determine compliance with the applicable intact and damage stability criteria), when applicable
- all the intact stability criteria applicable to the ship concerned.

4.7 Grain loading

4.7.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs grain loading stability calculations, as stated in [4.3.6].

In such case, the loading instrument is also to perform intact stability calculations, and therefore the approval is to be based on the requirements specified in [4.6].

Additional requirements relevant to grain stability are provided in [4.7.2] and [4.7.3].

4.7.2 Data verification approval - Endorsed test conditions

The requirements stated in [4.6.2] apply. In addition, when the ship is allowed to carry grain in slack hold, at least one of the four loading conditions required is to include partially filled holds.

The additional data necessary for the approval of the loading instrument for grain stability purposes are specified in [4.7.3].

In order to obtain the approval of the loading instrument, all the grain stability requirements and relevant criteria specified in Pt D, Ch 4, Sec 3, [1.2] are to be available in the computer output.

In addition, the outputs are to include:

- the reference to the type of calculation (trimmed or untrimmed ends)
- the value of the actual grain heeling moment for each hold
- the value of the maximum permissible grain heeling moment for each hold
- the total value of the actual grain heeling moment
- the total value of the maximum permissible grain heeling moment.

The lack of any of the above is sufficient to prevent the endorsement of the test conditions.

4.7.3 Additional data to be submitted

In addition to the data required in [4.6.3], the following are to be submitted:

- calculation of the total grain heeling moment
- calculation of the maximum permissible total grain heeling moment as a function of the draught (or displacement) and maximum KG
- curves or tables of volume, centre of volume and volumetric heeling moment for partially filled compartments (if applicable)
- for filled holds: volumetric heeling moment for trimmed and/or untrimmed ends, as applicable, including temporary bulkheads, if any.

4.8 Damage stability

4.8.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs damage stability calculations, as stated in [4.3.6].

In such case, the loading instrument is also to perform intact stability calculations, and therefore the approval is to be based on the requirements specified in [4.6].

Additional requirements relevant to damage stability are given in [4.8.2] and [4.8.3].

4.8.2 Data verification approval - Endorsed test conditions

The requirements specified in [4.6.2] apply.

The additional data necessary for the approval of the loading instrument for stability purposes are specified in [4.8.3].

The approval of damage stability calculations performed by a loading instrument is limited to those relevant to deterministic damage stability rules specified in Part D applicable to ships with one of the service notations **passenger ship**, **oil tanker ESP**, **chemical tanker ESP**, **liquefied gas carrier** or **LNG bunkering ship**. In order to obtain the approval of the loading instrument, all the damage stability requirements (and relevant criteria) applicable to the ship are to be available in the computer output. The lack of any one of them is sufficient to prevent the endorsement of the test conditions.

4.8.3 Additional data to be submitted

In addition to the data required in [4.6.3], the following are to be submitted:

- list of all the damage cases which are to be considered in accordance with the relevant deterministic damage stability rules. Each damage case is to clearly indicate all the compartments or spaces taken into account, as well as the permeability associated with each compartment or space.

  This information is to be taken from the approved damage stability documentation, and the source details are to be clearly indicated; in the case of unavailability of such documentation, the above-mentioned information may be requested from the Society.

- all the damage stability criteria applicable to the ship concerned.

4.9 Acceptable tolerances

4.9.1 General

The acceptable tolerances for the stability particulars are to be in agreement with the requirements of IACS Unified Requirements UR L5 as amended.

APPENDIX 1 PERMISSIBLE MASS IN CARGO HOLDS OF BULK CARRIERS

Symbols

T : Scantling draught, in m

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

ℓ_H : Length, in m, of the hold, to be taken as the longitudinal distance between the transverse bulkheads which form boundaries of the hold considered

y_{HT} : Half breadth, in m, of the hold, measured at the middle of ℓ_H and at a vertical level corresponding to the top of the hopper tank (see Fig 1)

b_{HT} : Breadth, in m, of the hopper tank, to be taken as the transverse distance from the outermost double bottom girder to the outermost point of the hopper tank (see Fig 1)

h_{HT} : Height, in m, of the hopper tank, to be taken as the vertical distance from the baseline to the top of the hopper tank (see Fig 1)

h_{DB} : Height, in m, of the double bottom, to be taken as the vertical distance from the baseline to the inner bottom (see Fig 1)

V_{LS} : Volume, in m^3, of the transverse bulkhead lower stool (above the inner bottom), to be taken equal to zero in the case of bulkheads fitted without lower stool

h_1 : Relative motion, in m, in the upright ship condition, defined in Ch 5, Sec 3, [3.3.1]

ℓ_{H1}, ℓ_{H2} : Individual lengths, in m, of the two adjacent cargo holds

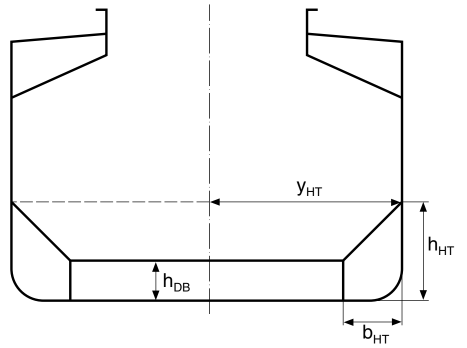
$$h_m = \frac{1}{2y_{HT}}\left[\frac{P}{\rho_B \ell_H} + \frac{V_{LS}}{\ell_H} + b_{HT}(h_{HT} - h_{DB})\right]$$

1 General

1.1 Application

1.1.1 The requirements of this Appendix apply to all bulk carriers of 150 m in length and above.

Figure 1 : Bulk cargo hold Geometrical characteristics



1.1.2 This Appendix describes the procedure to be used for determination of:

- the maximum and minimum mass of cargo in each hold as a function of the draught at mid-length of hold
- the maximum and minimum mass of cargo in any two adjacent holds as a function of the mean draught in way of these holds.

Results of these calculations are to be included in the reviewed Loading Manual which has also to indicate the maximum permissible mass of cargo at scantling draught in each hold or in any two adjacent holds, as obtained from the design review.

2 Maximum and minimum masses of cargo in each hold

2.1 General

2.1.1 Definitions

T_1 : External mean draught, in m, at mid-length of hold

T_{max} : Maximum permissible draught, in m, in way of holds which may be empty at sea, measured at mid-length of hold

P : Maximum mass of cargo in the hold under consideration, in t, for seagoing conditions at full draught

M_{DB} : Mass of ballast, in t, in the double bottom, where applicable, taken equal to:

$M_{DB} = 2{,}05\ \ell_H\ (y_{HT} - b_{HT})\ h_{DB}$

2.2 Maximum and minimum masses of cargo in each hold in seagoing condition

2.2.1 Maximum mass

For any particular seagoing condition, the maximum mass of cargo in each hold in terms of the draught at mid-length of hold is given by:

- if $h_m - \frac{1,025}{\rho_B}(T - T_1) \geq h_{HT} - h_{DB}$:

  $P_{max} = P - 2,05\ \ell_H\ y_{HT}\ (T - T_1)$

- if $h_m - \frac{1,025}{\rho_B}(T - T_1) < h_{HT} - h_{DB}$:

  $$P_{max} = \rho_B\left[\ell_H \frac{(b_{m1} + 2y_{HT} - 2b_{HT})b_{m1}}{b_{HT}}(h_{HT} - h_{DB}) - V_{LS}\right]$$

  where:

  $$b_{m1} = \frac{b_{HT}}{h_{HT} - h_{DB}}\left[h_m - \frac{1,025}{\rho_B}(T - T_1)\right]$$

2.2.2 Minimum mass

For any particular seagoing condition, the minimum mass of cargo in each hold which could be empty at sea at a draught greater than the maximum permissible one is given in terms of the draught at mid-length of hold by:

- if $\frac{1,025}{\rho_B}(T_1 - T_{max}) \geq h_{HT} - h_{DB}$:

  $P_{min} = 2,05\ \ell_H\ y_{HT}\ (T_1 - T_{max}) - \rho_B\ [\ell_H\ b_{HT}\ (h_{HT} - h_{DB}) + V_{LS}]$

- if $\frac{1,025}{\rho_B}(T_1 - T_{max}) < h_{HT} - h_{DB}$:

  $$P_{min} = \rho_B\left[\ell_H \frac{(b_{m2} + 2y_{HT} - 2b_{HT})b_{m2}}{b_{HT}}(h_{HT} - h_{DB}) - V_{LS}\right]$$

  where:

  $$b_{m2} = \frac{1,025}{\rho_B}\frac{b_{HT}}{h_{HT} - h_{DB}}(T_1 - T_{max})$$

with:

$P_{min} \geq 0$

In the former expressions, T_1 is to be taken greater than T_{max}.

2.3 Maximum and minimum masses of cargo in each hold in harbour condition

2.3.1 Maximum mass

For any particular harbour condition, the maximum mass of cargo in each hold in terms of the draught at mid-length of hold is given by:

- if $h_m - \frac{1,025}{\rho_B}(T - 0,5h_1 - T_1) - \frac{M_{DB}}{2\ell_H y_{HT}\rho_B} \geq h_{HT} - h_{DB}$:

  $P_{max} = P - 2,05\ \ell_H\ y_{HT}\ (T - 0,5\ h_1 - T_1) - M_{DB}$

- if $h_m - \frac{1,025}{\rho_B}(T - 0,5h_1 - T_1) - \frac{M_{DB}}{2\ell_H y_{HT}\rho_B} < h_{HT} - h_{DB}$:

  $$P_{max} = \rho_B\left[\ell_H \frac{(b_{m3} + 2y_{HT} - 2b_{HT})b_{m3}}{b_{HT}}(h_{HT} - h_{DB}) - V_{LS}\right] - M_{DB}$$

  where:

  $$b_{m3} = \frac{b_{HT}}{h_{HT} - h_{DB}}\left[h_m - \frac{1,025}{\rho_B}(T - 0,5h_1 - T_1)\right]$$

2.3.2 Minimum mass

For any particular harbour condition, the minimum mass of cargo in each hold which could be empty at sea at a draught greater than the maximum permissible one is given in terms of the draught at mid-length of hold by:

- if $\frac{1,025}{\rho_B}(T_1 - 0,5h_1 - T_{max}) + \frac{M_{DB}}{2\ell_H y_{HT}\rho_B} \geq h_{HT} - h_{DB}$:

  $P_{min} = P_{min0} - M_{DB}$

  where:

  $P_{min0} = 2,05\ \ell_H\ y_{HT}\ (T_1 - 0,5\ h_1 - T_{max})$
  $- \rho_B\ [\ell_H\ b_{HT}\ (h_{HT} - h_{DB}) + V_{LS}]$

- if $\frac{1,025}{\rho_B}(T_1 - 0,5h_1 - T_{max}) + \frac{M_{DB}}{2\ell_H y_{HT}\rho_B} < h_{HT} + -h_{DB}$:

  $$P_{min} = \rho_B\left[\ell_H \frac{(b_{m4} + 2y_{HT} - 2b_{HT})b_{m4}}{b_{HT}}(h_{HT} - h_{DB}) - V_{LS}\right] - M_{DB}$$

  where:

  $$b_{m4} = \frac{1,025}{\rho_B}\frac{b_{HT}}{h_{HT} - h_{DB}}(T_1 - 0,5h_1 - T_{max})$$

with:

$P_{min} \geq 0$

In the former expressions, T_1 is to be taken greater than T_{max}.

3 Maximum and minimum masses of cargo in two adjacent holds

3.1 General

3.1.1 Definitions

T_1 : Mean draught, in m, in way of the two adjacent holds

T_{max} : Maximum permissible mean draught, in m, in way of two adjacent holds which may be empty at sea, measured at mid-length of hold

$P_1 + P_2$: Maximum mass of cargo, in t, in two adjacent holds at full draught for seagoing conditions

M_{DB1}, M_{DB2}: Mass of ballast, in t, in the double bottom of each adjacent hold, where applicable, taken equal to:

$M_{DBi} = 2,05\ \ell_{Hi}\ (y_{HT} - b_{HT})\ h_{DB}$

3.2 Maximum and minimum masses of cargo in two adjacent holds in seagoing condition

3.2.1 Maximum mass

For any particular seagoing loading condition, the maximum mass of cargo $(P_1 + P_2)_{max}$ in two adjacent holds, in terms of the mean draught in way of these two holds, is given by:

$$(P_1 + P_2)_{max} = P_1 + P_2 - 2{,}05\ (\ell_{H1} + \ell_{H2})\ y_{HT}\ (T - T_1)$$

3.2.2 Minimum mass

For any particular seagoing conditions, the minimum mass of cargo $(P_1 + P_2)_{min}$ in two adjacent holds which could be empty at a draught greater than the permissible one is given in terms of the mean draught in way of these two adjacent holds by the greater of:

$$(P_1 + P_2)_{min} = 2{,}05\ (\ell_{H1} + \ell_{H2})\ y_{HT}\ (T_1 - T_{max})$$

$$(P_1 + P_2)_{min} = 0$$

3.3 Maximum and minimum masses of cargo in two adjacent holds in harbour condition

3.3.1 Maximum mass

For any particular harbour loading condition, the maximum mass of cargo $(P_1 + P_2)_{max}$ in two adjacent holds, in terms of the mean draught in way of these two holds, is given by:

$$(P_1 + P_2)_{max} = P_1 + P_2 - 2{,}05(\ell_{H1} + \ell_{H2})y_{HT}(T - 0{,}5h_1 - T_1) - M_{DB1} - M_{DB2}$$

3.3.2 Minimum mass

For any particular seagoing or harbour conditions, the minimum mass of cargo $(P_1 + P_2)_{min}$ in two adjacent holds which could be empty at a draught greater than the permissible one is given in terms of the mean draught in way of these two adjacent holds by the greater of:

$$(P_1 + P_2)_{min} = 2{,}05(\ell_{H1} + \ell_{H2})y_{HT}(T_1 - 0{,}5h_1 - T_{max}) - M_{DB1} - M_{DB2}$$

$$(P_1 + P_2)_{min} = 0$$

Chapter 11

CONSTRUCTION AND TESTING

SECTION 1 WELDING AND WELD CONNECTIONS

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the preparation, execution and inspection of welded connections in hull structures.

They are to be complemented by the criteria given in Ch 11, App 1, to which reference is made. These criteria being given as recommendations, minor departures may be accepted by the Society, on a case by case basis.

The general requirements relevant to fabrication by welding and qualification of welding procedures are given in NR216 Materials and Welding, Chapter 5.

1.1.2 Weld connections are to be executed according to the approved plans. A detail not specifically represented in the plans is, if any, to comply with the applicable requirements.

1.1.3 It is understood that welding of the various types of steel is to be carried out by means of welding procedures approved for the purpose, even though an explicit indication to this effect may not appear on the approved plans.

1.1.4 The quality standard adopted by the shipyard is to be submitted to the Society and applies to all constructions unless otherwise specified on a case by case basis.

1.2 Base material

1.2.1 The requirements of this Section apply for the welding of hull structural steels or aluminium alloys of the types considered in NR216 Materials and Welding or other types accepted as equivalent by the Society.

1.2.2 The service temperature is intended to be the ambient temperature, unless otherwise stated.

1.3 Welding consumables and procedures

1.3.1 Approval of welding consumables and procedures

Welding consumables and welding procedures adopted are to be approved by the Society.

The requirements for the approval of welding consumables are given in NR216 Materials and Welding, Ch 5, Sec 2.

The requirements for the approval of welding procedures are given in NR216 Materials and Welding, Ch 5, Sec 1, NR216 Materials and Welding, Ch 5, Sec 4 and NR216 Materials and Welding, Ch 5, Sec 5.

1.3.2 Consumables

For welding of hull structural steels, the minimum consumable grades to be adopted are specified in Tab 1 depending on the steel grade.

Consumables used for manual or semi-automatic welding (covered electrodes, flux-cored and flux-coated wires) of higher strength hull structural steels are to be at least of hydrogen-controlled grade H15 (H). Where the carbon equivalent Ceq is not more than 0,41% and the thickness is below 30 mm, any type of approved higher strength consumables may be used at the discretion of the Society.

Especially, welding consumables with hydrogen-controlled grade H15 (H) and H10 (HH) shall be used for welding hull steel forgings and castings of respectively ordinary strength level and higher strength level.

Table 1 : Consumable grades

Steel grade	Consumable minimum grade	
	Butt welding, partial and full T penetration welding	Fillet welding
A	1	1
B - D	2	
E	3	
AH32 - AH36 - DH32 - DH36	2Y	2Y
EH32 - EH36 - EH36CAS	3Y	
FH32 - FH36 - FH36CAS	4Y	
AH40	2Y40	2Y40
DH40 - EH40 - EH40CAS	3Y40	
FH40 - FH40-CAS	4Y40	
EH47 - EH47-CAS	3Y47	3Y47

Note 1: Welding consumables approved for welding higher strength steels (Y) may be used in lieu of those approved for welding normal strength steels having the same or a lower grade; welding consumables approved in grade Y40 may be used in lieu of those approved in grade Y having the same or a lower grade.
Note 2: In the case of welded connections between two hull structural steels of different grades, as regards strength or notch toughness, welding consumables appropriate to one or the other steel are to be adopted.

1.4 Personnel and equipment

1.4.1 Welders

Welders for manual welding and for semi-automatic welding processes are to be certified by the Society unless otherwise agreed for welders already certified in accordance with a recognised standard accepted by the Society.

1.4.2 Automatic welding operators

Personnel manning automatic welding machines and equipment are to be competent and sufficiently trained.

1.4.3 Organisation

The internal organisation of the shipyard is to be such as to ensure compliance with the requirements in [1.4.1] and [1.4.2] and to provide for assistance and inspection of welding personnel, as necessary, by means of a suitable number of competent supervisors.

1.4.4 NDE operators

Non-destructive tests are to be carried out by qualified personnel, certified by recognised bodies in compliance with appropriate standards.

The qualifications are to be appropriate to the specific applications.

1.4.5 Technical equipment and facilities

The welding equipment is to be appropriate to the adopted welding procedures, of adequate output power and such as to provide for stability of the arc in the different welding positions.

In particular, the welding equipment for special welding procedures is to be provided with adequate and duly calibrated measuring instruments, enabling easy and accurate reading, and adequate devices for easy regulation and regular feed.

Manual electrodes, wires and fluxes are to be stored in suitable locations so as to ensure their preservation in proper condition. Especially, where consumables with hydrogen-controlled grade are to be used, proper precautions are to be taken to ensure that manufacturer's instructions are followed to obtain (drying) and maintain (storage, maximum time exposed, re-backing, ...) hydrogen-controlled grade.

1.5 Documentation to be submitted

1.5.1 The structural plans to be submitted for approval, according to Ch 1, Sec 3, are to contain the necessary data relevant to the fabrication by welding of the structures and items represented as far as class is concerned.

For important structures, the main sequences of prefabrication, assembly and welding and non-destructive examination planned are also to be represented in the plans.

1.5.2 A plan showing the location of the various steel types is to be submitted at least for outer shell, deck and bulkhead structures.

1.6 Design

1.6.1 General

For the various structural details typical of welded construction in shipbuilding and not dealt with in this Section, the rules of good practice, recognised standards and past experience are to apply as agreed by the Society.

1.6.2 Plate orientation

The plates of the shell and strength deck are generally to be arranged with their length in the fore-aft direction. Possible exceptions to the above will be considered by the Society on a case-by-case basis; tests as deemed necessary (for example, transverse impact tests) may be required by the Society.

1.6.3 Overall arrangement

Particular consideration is to be given to the overall arrangement and structural details of highly stressed parts of the hull.

Plans relevant to the special details specified in Ch 11, Sec 2 are to be submitted.

1.6.4 Prefabrication sequences

Prefabrication sequences are to be arranged so as to facilitate positioning and assembling as far as possible.

The amount of welding to be performed on board is to be limited to a minimum and restricted to easily accessible connections.

1.6.5 Distance between welds

Welds located too close to one another are to be avoided. The minimum distance between two adjacent welds is considered on a case by case basis, taking into account the level of stresses acting on the connected elements.

In general, the distance between two adjacent butts in the same strake of shell or deck plating is to be greater than two frame spaces.

2 Type of connections and preparation

2.1 General

2.1.1 The type of connection and the edge preparation are to be appropriate to the welding procedure adopted, the structural elements to be connected and the stresses to which they are subjected.

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 procedures or specific techniques, considered equivalent by the Society, are adopted.

Connections different from the above may be accepted by the Society on a case by case basis; in such cases, the relevant detail and workmanship specifications are to be approved.

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:

- 3 mm, if the thinner plate has a gross thickness equal to or less than 10 mm
- 4 mm, if the thinner plate has a gross thickness greater than 10 mm,

a taper having a length of not less than 4 times the difference in gross thickness is to be adopted for connections of plating perpendicular to the direction of main stresses. For connections of plating parallel to the direction of main stresses, the taper length may be reduced to 3 times the difference in gross thickness.

When the difference in thickness is less than the above values, it may be accommodated in the weld transition between plates.

2.2.3 Edge preparation, root gap

Typical edge preparations and gaps are indicated in Ch 11, App 1, [1.2].

The acceptable root gap is to be in accordance with the adopted welding procedure and relevant bevel preparation.

2.2.4 Butt welding on permanent backing

Butt welding on permanent backing, i.e. butt welding assembly of two plates backed by the flange or the face plate of a stiffener, may be accepted where back welding is not feasible or in specific cases deemed acceptable by the Society.

The type of bevel and the gap between the members to be assembled are to be such as to ensure a proper penetration of the weld on its backing and an adequate connection to the stiffener as required.

2.2.5 Section, bulbs and flat bars

When lengths of longitudinals of the shell plating and strength deck within 0,6 L amidships, or elements in general subject to high stresses, are to be connected together by butt joints, these are to be full penetration. Other solutions may be adopted if deemed acceptable by the Society on a case by case basis.

The work is to be done in accordance with an approved procedure; in particular, this requirement applies to work done on board or in conditions of difficult access to the welded connection. Special measures may be required by the Society.

Welding of bulbs without a doubler is to be performed by welders specifically certified by the Society for such type of welding.

2.3 Fillet welding

2.3.1 General

Ordinary fillet welding may be adopted for T connections of the various simple and composite structural elements, where they are subjected to low tensile stress or where they are not critical for fatigue.

Where this is not the case, partial or full T penetration welding according to [2.4] is to be adopted.

2.3.2 Fillet welding types

Fillet welding may be of the following types:

- continuous fillet welding, where the weld is constituted by a continuous fillet on each side of the abutting plate (see [2.3.3])
- intermittent fillet welding, which may be subdivided (see [2.3.4]) into:
  - chain welding
  - scallop welding
  - staggered welding.

2.3.3 Continuous fillet welding

Continuous fillet welding is to be adopted:

- for watertight connections
- for connections of brackets, lugs and scallops
- at the ends of connections for a length of at least 75mm
- where intermittent welding is not allowed, according to [2.3.4]
- for connections of stiffeners subject to wheeled loads.

Continuous fillet welding may also be adopted in lieu of intermittent welding wherever deemed suitable, and it is recommended where the spacing p, calculated according to [2.3.4], is low.

2.3.4 Intermittent welding

The spacing p and the length d, in mm, of an intermittent weld, shown in:

- Fig 1, for chain welding
- Fig 2, for scallop welding
- Fig 3, for staggered welding

are to be such that:

$$\frac{p}{d} \le \varphi$$

where the coefficient φ is defined in Tab 2 and Tab 3 for the different types of intermittent welding, depending on the type and location of the connection.

In general, staggered welding is not allowed for connections subjected to high alternate stresses.

One side continuous welding may be accepted instead of chain and staggered intermittent welding for connections of stiffeners in the dry spaces of deckhouses and superstructures, where not affected by sea pressure, tank pressure or concentrated loads.

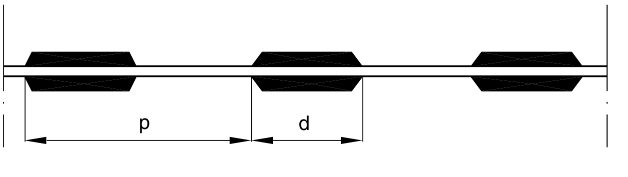
In addition, the following limitations are to be complied with:

- chain welding (see Fig 1):

  $d \ge 75$ mm

  $p - d \le 200$ mm

Figure 1 : Intermittent chain welding



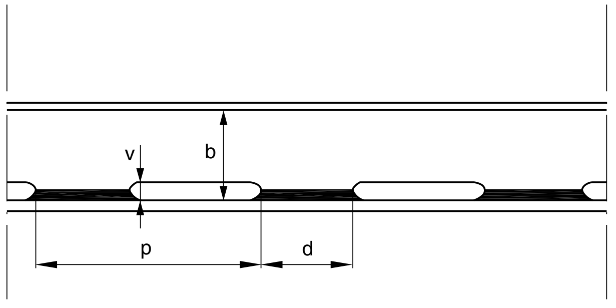
- scallop welding (see Fig 2):

  $d \geq 75$ mm

  $p - d \leq 150$ mm

  $v \leq 0{,}25\ b$ without being greater than 75 mm

Figure 2 : Intermittent scallop welding



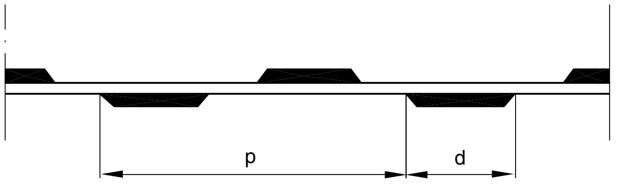
- staggered welding (see Fig 3):

  $d \geq 75$ mm

  $p - 2d \leq 300$ mm

  $p \leq 2d$ for connections subjected to high alternate stresses.

Figure 3 : Intermittent staggered welding



2.3.5 Throat thickness of fillet weld T connections

The minimum throat thickness of fillet weld T connections is to be obtained, in mm, from the following formula:

$$t_T = w_F t \frac{p}{d}$$

where:

w_F : Welding factor, defined in Tab 2 for the various hull structural connections; for connections of primary supporting members belonging to single skin structures and not mentioned in Tab 2, w_F is defined in Tab 3; for some connections of specific ship types, the values of w_F specified in Part D or Part E for these ship types are to be used in lieu of the corresponding values in Tab 2 or Tab 3

t : Thickness, in mm, of the thinner plate in the considered assembly

p, d : Spacing and length, in mm, of an intermittent weld, defined in [2.3.4].

For continuous fillet welds, p/d is to be taken equal to 1.

A lower value of the minimum throat thickness may be accepted on a case by case basis depending on the results of structural analyses.

The maximum throat thickness of fillet weld T connections is equal to, in mm:

$t_T = 0{,}7\ t$

Whether the welds are continuous or intermittent, the throat thickness of the fillet welds is not to be less than, as a rule:

- 3,0 mm, for plating thickness of less than 6 mm
- 3,5 mm, otherwise.

In the case of automatic or semi-automatic deep penetration weld, the throat thickness (the minimum values included) may be reduced according to [2.3.9].

The throat thickness may be required by the Society to be increased, depending on the results of structural analyses.

The leg length of fillet weld T connections is to be not less than 1,4 times the required throat thickness.

2.3.6 Weld dimensions in a specific case

Where intermittent fillet welding is adopted with:

- length d = 75 mm
- throat thickness t_T specified in Tab 4 depending on the thickness t defined in [2.3.5],

the weld spacing may be taken equal to the value p_1 defined in Tab 2. The values of p_1 in Tab 2 may be used when $8 \leq t \leq 16$ mm.

For thicknesses t less than 8 mm, the values of p_1 may be increased, with respect to those in Tab 2, by:

- 10 mm for chain or scallop welding
- 20 mm for staggered welding,

without exceeding the limits in [2.3.4].

For thicknesses t greater than 16 mm, the values of p_1 are to be reduced, with respect to those in Tab 2, by:

- 10 mm for chain or scallop welding
- 20 mm for staggered welding.

2.3.7 Throat thickness of welds between cut-outs

The throat thickness of the welds between the cut-outs in primary supporting member webs for the passage of ordinary stiffeners is to be not less than the value obtained, in mm, from the following formula:

$$t_{TC} = t_T \frac{\varepsilon}{\lambda}$$

where:

t_T : Throat thickness defined in [2.3.5]

ε, λ : Dimensions, in mm, to be taken as shown in:

- Fig 4 for continuous welding
- Fig 5 for intermittent scallop welding.

Figure 4 : Continuous fillet welding between cut-outs

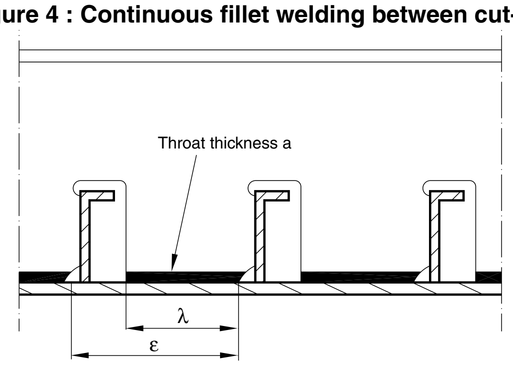


Figure 5 : Intermittent scallop fillet welding between cut-outs

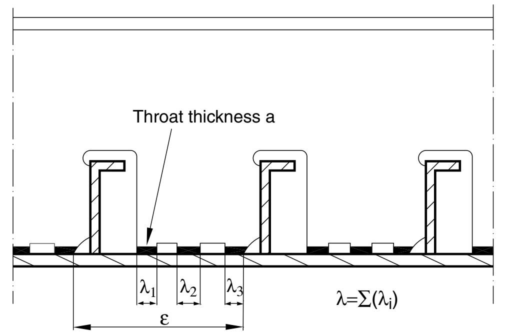


Table 2 : Welding factors w_F and coefficient φ for the various hull structural connections

Hull area	Connection			w_F **(1)**	φ **(2) (3)**			p_1, in mm (see [2.3.6]) **(3)**
	of	to			CH	SC	ST	
General, unless otherwise specified in the table	watertight plates	boundaries		0,35				
	webs of ordinary stiffeners	plating	at ends **(4)**	0,13				
			elsewhere	0,13	3,5	3,0	4,6	ST 260
		face plate of fabricated stiffeners	at ends **(4)**	0,13				
			elsewhere	0,13	3,5	3,0	4,6	ST 260
Bottom and double bottom	longitudinal ordinary stiffeners	bottom and inner bottom plating **(5)**		0,13	3,5	3,0	4,6	ST 260
	centre girder	keel		0,25	1,8	1,8		CH/SC 130
		inner bottom plating		0,20	2,2	2,2		CH/SC 160
	side girders	bottom and inner bottom plating		0,13	3,5	3,0	4,6	ST 260
		floors (interrupted girders)		0,20	2,2			CH 160
	floors	bottom and inner bottom plating	in general	0,13	3,5	3,0	4,6	ST 260
			at ends (20% of span) for longitudinally framed double bottom	0,25	1,8			CH 130
		inner bottom plating in way of brackets of primary supporting members		0,25	1,8			CH 130
		girders (interrupted floors)		0,20	2,2			CH 160
		side girders in way of hopper tanks		0,35				
	partial side girders	floors		0,25	1,8			CH 130
	web stiffeners	floor and girder webs		0,13	3,5	3,0	4,6	ST 260
Side and inner side	ordinary stiffeners	side and inner side plating		0,13	3,5	3,0	4,6	ST 260
	girders and web frames in double side skin ships	side and inner side plating		0,35				
Deck	strength deck	side plating		w_F = 0,45 if t ≤ 15 mm Partial penetration welding if t >15mm				
	non-watertight decks	side plating		0,20	2,2			CH 160
	ordinary stiffeners and intercostal girders	deck plating		0,13	3,5	3,0	4,6	ST 260
	hatch coamings	deck plating	in general	0,35				
			at corners of hatchways for 15% of the hatch length	0,45				
	web stiffeners	coaming webs		0,13	3,5	3,0	4,6	ST 260

Hull area	Connection of	Connection to		w_F **(1)**	φ **(2) (3)** CH	φ **(2) (3)** SC	φ **(2) (3)** ST	p_1, in mm (see [2.3.6]) **(3)**
Bulkheads	tank bulkhead structures	tank bottom	plating and ordinary stiffeners (plane bulkheads)	0,45				
			vertical corrugations (corrugated bulkheads)	Full penetration welding, in general				
		boundaries other than tank bottom		0,35				
	watertight bulkhead structures	boundaries		0,35				
	non-watertight bulkhead structures	boundaries	wash bulkheads	0,20	2,2	2,2		CH/SC 160
			others	0,13	3,5	3,0	4,6	ST 260
	ordinary stiffeners	bulkhead plating	in general **(5)**	0,13	3,5	3,0	4,6	ST 260
			at ends (25% of span), where no end brackets are fitted	0,35				
Structures located forward of 0,75 L from the AE **(6)**	bottom longitudinal ordinary stiffeners	bottom plating		0,20	2,2			CH 160
	floors and girders	bottom and inner bottom plating		0,25	1,8			CH 130
	side frames in panting area	side plating		0,20	2,2			CH 160
	webs of side girders in single side skin structures	side plating and face plate	$A < 65$ cm^2 **(7)**	0,25	1,8	1,8		CH/SC 130
			$A \geq 65$ cm^2 **(7)**	See Tab 3				
After peak **(6)**	internal structures	each other		0,20				
	side ordinary stiffeners	side plating		0,20				
	floors	bottom and inner bottom plating		0,20				
Machinery space **(6)**	centre girder	keel and inner bottom plating	in way of main engine foundations	0,45				
			in way of seating of auxiliary machinery and boilers	0,35				
			elsewhere	0,25	1,8	1,8		CH/SC 130
	side girders	bottom and inner bottom plating	in way of main engine foundations	0,45				
			in way of seating of auxiliary machinery and boilers	0,35				
			elsewhere	0,20	2,2	2,2		CH/SC 160
	floors (except in way of main engine foundations)	bottom and inner bottom plating	in way of seating of auxiliary machinery and boilers	0,35				
			elsewhere	0,20	2,2	2,2		CH/SC 160
	floors in way of main engine foundations	bottom plating		0,35				
		foundation plates		0,45				
	floors	centre girder	single bottom	0,45				
			double bottom	0,25	1,8	1,8		CH/SC 130

Hull area	Connection of	Connection to		w_F **(1)**	φ **(2) (3)** CH	φ SC	φ ST	p_1, in mm (see [2.3.6]) **(3)**
Super-structures and deckhouses	external bulkheads	deck	in general	0,35				
			engine and boiler casings at corners of openings (15% of opening length)	0,45				
	internal bulkheads	deck		0,13	3,5	3,0	4,6	ST 260
	ordinary stiffeners	external and internal bulkhead plating		0,13	3,5	3,0	4,6	ST 260
Hatch covers	ordinary stiffener	plating		0,13	3,5	3,0	4,6	ST 260
Pillars	elements composing the pillar section	each other (fabricated pillars)		0,13				
	pillars	deck	pillars in compression	0,35				
			pillars in tension	See [3.7]				
Ventilators	coamings	deck		0,35				
Rudders	horizontal and vertical webs directly connected to solid parts	solid parts or rudder stock		According to Ch 9, Sec 1, [7.4] or Ch 9, Sec 1, [7.5]				
		elsewhere	for shear force greater than or equal to 45% of the maximum rudder body value	0,45				
			for shear force lower than 45% of the maximum rudder body value	0,20				
	other webs	each other		0,20		2,2		SC 160
		plating	in general	0,20		2,2		SC 160
			top and bottom plates of rudder plating	0,35				

(1) In connections for which $w_F \geq 0,35$, continuous fillet welding is to be adopted.
(2) For coefficient φ, see [2.3.4]. In connections for which no φ value is specified for a certain type of intermittent welding, such type is not permitted and continuous welding is to be adopted.
(3) CH = chain welding, SC = scallop welding, ST = staggered welding.
(4) The web at the end of intermittently welded girders or stiffeners is to be continuously welded to the plating or the flange plate, as applicable, over a distance d at least equal to the depth h of the girder or stiffeners, with 300 mm ≥ d ≥ 75 mm. Where end brackets are fitted, ends means the area extended in way of brackets and at least 50 mm beyond the bracket toes.
(5) In tanks intended for the carriage of ballast or fresh water, continuous welding with $w_F = 0,35$ is to be adopted.
(6) For connections not mentioned, the requirements for the central part apply.
(7) A is the face plate sectional area of the side girders, in cm².

2.3.8 Throat thickness of welds connecting ordinary stiffeners with primary supporting members

The throat thickness t_T of fillet welds connecting ordinary stiffeners and collar plates, if any, to the web of primary supporting members is to be not less than the value obtained, in mm, from the following formula:

$$t_T = \frac{4k(\gamma_{S2}p_S + \gamma_{W2}p_W)s\ell\left(1 - \frac{s}{2\ell}\right)(1 - k_1)}{u + v\left(\frac{c + 0,2d}{b + 0,2d}\right)}$$

without being taken less than the value obtained from the following formula:

$t_T = 0,27\ f_{yd}\ t + 0,7\ g$

where:

- k : Greatest material factor of the steels used in the considered assembly, defined in Ch 4, Sec 1, [2.3]
- p_S, p_W : Still water and wave pressure, respectively, in kN/m², acting on the ordinary stiffener, defined in Ch 7, Sec 2, [3.3.2]
- γ_{S2}, γ_{W2} : Partial safety factors defined in Ch 7, Sec 2, [1.2.1]
- k_1 : Coefficient depending on the connection of the primary supporting member web with the ordinary stiffener, taken equal to:
  - $k_1 = 0$, when there is no primary supporting member web stiffener in way of the ordinary stiffener

- the value defined in Ch 4, Sec 3, [4.7.2], when there is a primary supporting member web stiffener in way of the ordinary stiffener

b,c,d,u,v: Main dimensions, in mm, of the cut-out shown in Fig 6. In case of different radius between the upper and the lower part, c is to be taken equal to the greatest one.

t : Gross thickness, in mm, of the thinner plate in the considered assembly

g : Allowance for fillet weld gap, to be taken equal to 2 mm, unless otherwise specified.

f_{yd} : Correction factor taking into account the yield strength of the weld deposit:

$$f_{yd} = \left(\frac{1}{k}\right)^{0,5}\left(\frac{235}{\sigma_{weld}}\right)^{0,75}$$

without being taken less than 0,707

where:

σ_{weld} : Minimum yield stress of the weld deposit. σ_{weld} is not to be less than:

- 305 N/mm² for welding of normal strength steels
- 375 N/mm² for welding of higher strength steels having a yield strength from 265 to 355 N/mm²
- 400 N/mm² for welding of higher strength steels having a yield strength of 390 N/mm²

k : Material factor of the steel used for the thinner plate in the considered assembly, defined in Ch 4, Sec 1, [2.3].

Further requirements are specified in Ch 11, Sec 2.

Table 3 : Welding factors w_F and coefficient φ for connections of primary supporting members

Primary supporting member	Connection			w_F **(1)**	φ **(2)** **(3)**			p_1, in mm (see [2.3.6]) **(3)**
	of	to			CH	SC	ST	
General **(4)**	web, where A < 65 cm²	plating and face plate	at ends	0,20				
			elsewhere	0,15	3,0	3,0		CH/SC 210
	web, where A ≥ 65 cm²	plating		0,35				
		face plate	at ends	0,35				
			elsewhere	0,25	1,8	1,8		CH/SC 130
	end brackets	face plate		0,35				
In tanks, where A < 65 cm² **(5)**	web	plating	at ends	0,25				
			elsewhere	0,20	2,2	2,2		CH/SC 160
		face plate	at ends	0,20				
			elsewhere	0,15	3,0	3,0		CH/SC 210
	end brackets	face plate		0,35				
In tanks, where A ≥ 65 cm²	web	plating	at ends	0,45				
			elsewhere	0,35				
		face plate		0,35				
	end brackets	face plate		0,45				

(1) In connections for which $w_F \geq 0,35$, continuous fillet welding is to be adopted.
(2) For coefficient φ, see [2.3.4]. In connections for which no φ value is specified for a certain type of intermittent welding, such type is not permitted.
(3) CH = chain welding, SC = scallop welding, ST = staggered welding.
(4) For cantilever deck beams, continuous welding is to be adopted.
(5) For primary supporting members in tanks intended for the carriage of ballast or fresh water, continuous welding is to be adopted.

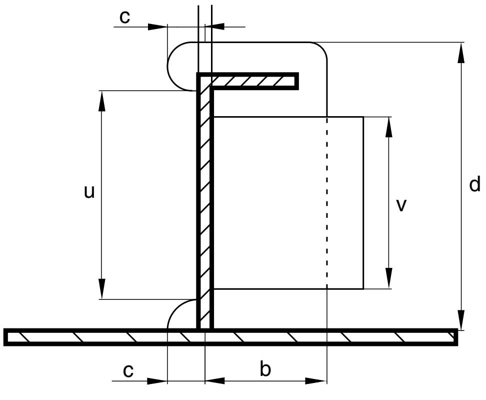
Note 1:
A is the face plate sectional area of the primary supporting member, in cm².

Note 2:
Ends of primary supporting members means the area extended 20% of the span from the span ends. Where end brackets are fitted, ends means the area extended in way of brackets and at least 100 mm beyond the bracket toes.

Table 4 : Required throat thickness

t, in mm	t_T , in mm	t, in mm	t_T , in mm
6	3,0	17	7,0
8	3,5	18	7,0
9	4,0	19	7,5
10	4,5	20	7,5
11	5,0	21	8,5
12	5,5	22	8,5
13	6,0	23	9,0
14	6,0	24	9,0
15	6,5	25	10,0
16	6,5	26	10,0

Figure 6 : End connection of ordinary stiffener Dimensions of the cut-out



2.3.9 Throat thickness of deep penetration fillet welding

When fillet welding is carried out with automatic welding procedures, the throat thickness required in [2.3.5] may be reduced up to 15%, depending on the properties of the electrodes and consumables. However, this reduction may not be greater than 1,5 mm.

The same reduction applies also for semi-automatic procedures where the welding is carried out in the downhand position.

2.4 Partial and full T penetration welding

2.4.1 General

Partial or full T penetration welding is to be adopted for connections subjected to high stresses for which fillet welding is considered unacceptable by the Society.

Partial or full T penetration welding is required, in any event, where indicated for the connections specified in Part D or Part E depending on the ship type. Further requirements are specified in Ch 11, Sec 2.

Typical edge preparations are indicated in:

- for partial penetration welds: Fig 7 and Fig 8, in which f, in mm, is to be taken between 3 mm and t/3, and α between 45° and 60°
- for full penetration welds: Fig 9 and Fig 10, in which f, in mm, is to be taken between 0 and 3 mm, and α between 45° and 60°

  Back gouging is generally required for full penetration welds.

Figure 7 : Partial penetration weld

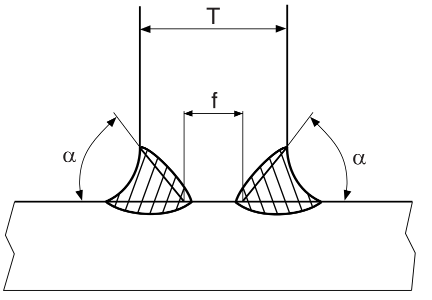


Figure 8 : Partial penetration weld

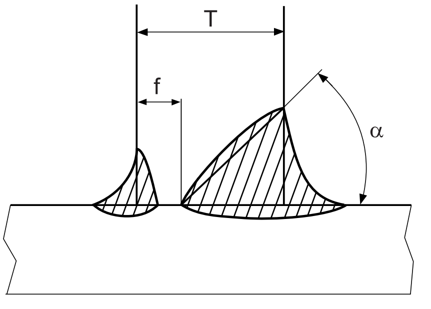


Figure 9 : Full penetration weld

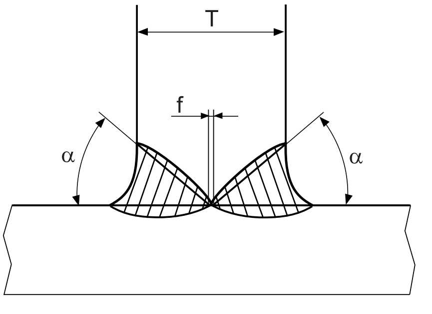
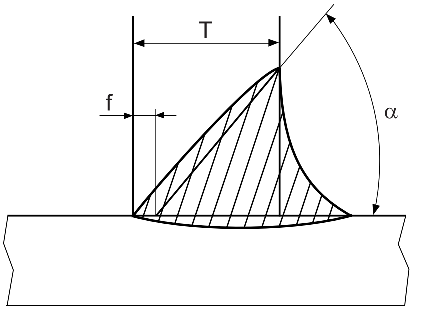


Figure 10 : Full penetration weld



2.4.2 Lamellar tearing

Precautions are to be taken in order to avoid lamellar tears, which may be associated with:

- cold cracking when performing T connections between plates of considerable thickness or high restraint
- large fillet welding and full penetration welding on higher strength steels.

2.5 Lap-joint welding

2.5.1 General

Lap-joint welding may be adopted for:

- peripheral connection of doublers
- internal structural elements subjected to very low stresses.

Elsewhere, lap-joint welding may be allowed by the Society on a case by case basis, if deemed necessary under specific conditions.

Continuous welding is generally to be adopted.

2.5.2 Gap

The surfaces of lap-joints are to be in sufficiently close contact.

2.5.3 Dimensions

The dimensions of the lap-joint are to be specified and are considered on a case by case basis. Typical details are given in Ch 11, App 1, [1.3].

2.6 Slot welding

2.6.1 General

Slot welding may be adopted in very specific cases subject to the special agreement of the Society, e.g. for doublers according to Ch 4, Sec 3, [2.1].

In general, slot welding of doublers on the outer shell and strength deck is not permitted within 0,6L amidships. Beyond this zone, slot welding may be accepted by the Society on a case by case basis.

Slot welding is, in general, permitted only where stresses act in a predominant direction. Slot welds are, as far as possible, to be aligned in this direction.

2.6.2 Dimensions

Slot welds are to be of appropriate shape (in general oval) and dimensions, depending on the plate thickness, and may not be completely filled by the weld.

Typical dimensions of the slot weld and the throat thickness of the fillet weld are given in Ch 11, App 1, [1.3].

The distance between two consecutive slot welds is to be not greater than a value which is defined on a case by case basis taking into account:

- the transverse spacing between adjacent slot weld lines
- the stresses acting in the connected plates
- the structural arrangement below the connected plates.

2.7 Plug welding

2.7.1 Plug welding may be adopted only when accepted by the Society on a case by case basis, according to specifically defined criteria. Typical details are given in Ch 11, App 1, [1.3].

3 Specific weld connections

3.1 Corner joint welding

3.1.1 Corner joint welding, as adopted in some cases at the corners of tanks, performed with ordinary fillet welds, is permitted provided the welds are continuous and of the required size for the whole length on both sides of the joint.

3.1.2 Alternative solutions to corner joint welding may be considered by the Society on a case by case basis.

3.2 Bilge keel connection

3.2.1 The intermediate flat, through which the bilge keel is connected to the shell according to Ch 4, Sec 4, [6], is to be welded as a shell doubler by continuous fillet welds.

The butt welds of the doubler and bilge keel are to be full penetration and shifted from the shell butts.

The butt welds of the bilge plating and those of the doublers are to be flush in way of crossing, respectively, with the doubler and with the bilge keel.

Butt welds of the intermediate flat are to be made to avoid direct connection with the shell plating, in order that they do not alter the shell plating, by using, for example, a copper or a ceramic backing.

3.3 Struts connecting ordinary stiffeners

3.3.1 In case of a strut connected by lap joint to the ordinary stiffener, the throat thickness of the weld is to be obtained, in mm, from the following formula:

$$t_T = \frac{\eta F}{n \ell_W \tau} 10^3$$

where:

F	:	Maximum force transmitted by the strut, in kN
η	:	Safety factor, to be taken equal to 2
n	:	Number of welds in way of the strut axis
ℓ_W	:	Length of the weld in way of the strut axis, in mm
τ	:	Permissible shear stress, to be taken equal to 100 N/mm^2.

3.4 Connection between propeller post and propeller shaft bossing

3.4.1 Fabricated propeller posts are to be welded with full penetration welding to the propeller shaft bossing.

3.5 Bar stem connections

3.5.1 The bar stem is to be welded to the bar keel generally with butt welding.

The shell plating is also to be welded directly to the bar stem with butt welding.

3.6 Deck subjected to wheeled loads

3.6.1 Double continuous fillet welding is to be adopted for the connections of ordinary stiffeners with deck plating.

3.7 Pillars connection

3.7.1 For pillars in tension, continuous fillet welding may be accepted provided that the tensile stress in welds does not exceed 50/k N/mm^2, where k is the greatest material factor of the welded elements and the filler metal.

For pillars subjected to higher tensile stress, full penetration welding is to be adopted.

4 Workmanship

4.1 Welding procedures and consumables

4.1.1 The various welding procedures and consumables are to be used within the limits of their approval and in accordance with the conditions of use specified in the respective approval documents.

4.2 Welding operations

4.2.1 Weather protection

Adequate protection from the weather is to be provided to parts being welded; in any event, such parts are to be dry.

In welding procedures using bare, cored or coated wires with gas shielding, the welding is to be carried out in weather protected conditions, so as to ensure that the gas outflow from the nozzle is not disturbed by winds and draughts.

4.2.2 Butt connection edge preparation

The edge preparation is to be of the required geometry and correctly performed. In particular, if edge preparation is carried out by flame, it is to be free from cracks or other detrimental notches.

4.2.3 Surface condition

The surfaces to be welded are to be free from rust, moisture and other substances, such as mill scale, slag caused by oxygen cutting, grease or paint, which may produce defects in the welds.

Effective means of cleaning are to be adopted particularly in connections with special welding procedures; flame or mechanical cleaning may be required.

The presence of a shop primer may be accepted, provided it has been approved by the Society.

Shop primers are to be approved by the Society for a specific type and thickness according to NR216 Materials and Welding, Ch 5, Sec 3.

4.2.4 Assembling and gap

The setting appliances and system to be used for positioning are to ensure adequate tightening adjustment and an appropriate gap of the parts to be welded, while allowing maximum freedom for shrinkage to prevent cracks or other defects due to excessive restraint.

The gap between the edges is to comply with the required tolerances or, when not specified, it is to be in accordance with normal good practice.

4.2.5 Gap in fillet weld T connections

In fillet weld T connections, a gap g, as shown in Fig 11, not greater than 2 mm may be accepted without increasing the throat thickness calculated according to [2.3.5] or [2.3.8], as applicable.

In the case of a gap greater than 2 mm, the above throat thickness is to be increased accordingly as specified in Ch 11, Sec 2 for some special connections of various ship types.

In any event, the gap g may not exceed 4 mm.

4.2.6 Plate misalignment in butt connections

The misalignment m, measured as shown in Fig 12, between plates with the same gross thickness t is to be less than 0,15 t, without being greater than 3 mm.

Figure 11 : Gap in fillet weld T connections

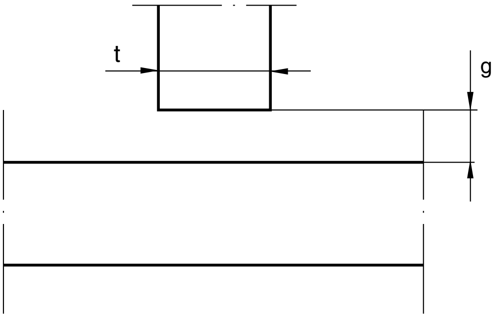
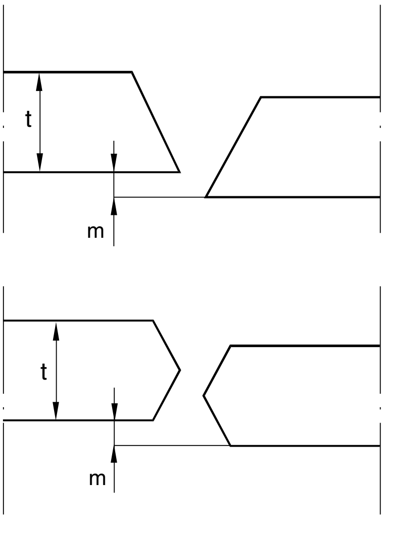


Figure 12 : Plate misalignment in butt connections



4.2.7 Misalignment in cruciform connections

The misalignment m in cruciform connections, measured on the median lines as shown in Fig 13, is to be less than:

- t/2, in general, where t is the gross thickness of the thinner abutting plate
- the values specified in Ch 11, Sec 2 for some special connections of various ship types.

The Society may require lower misalignment to be adopted for cruciform connections subjected to high stresses.

4.2.8 Assembling of aluminium alloy parts

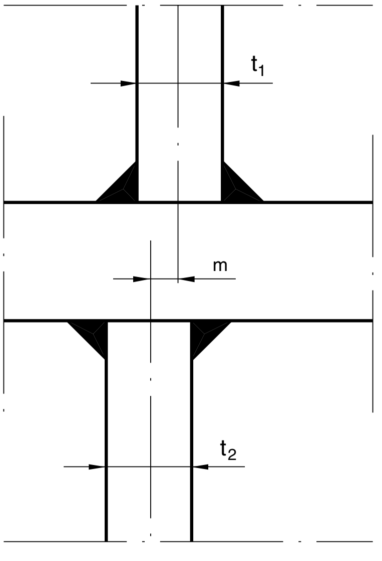
When welding aluminium alloy parts, particular care is to be taken so as to:

- reduce as far as possible restraint from welding shrinkage, by adopting assembling and tack welding procedures suitable for this purpose
- keep possible deformations within the allowable limits.

4.2.9 Preheating and interpass temperatures

Suitable preheating, to be maintained during welding, and slow cooling may be required by the Society on a case by case basis.

Figure 13 : Misalignment in cruciform connections



4.2.10 Welding sequences

Welding sequences and direction of welding are to be determined so as to minimise deformations and prevent defects in the welded connection.

All main connections are generally to be completed before the ship is afloat.

Departures from the above provision may be accepted by the Society on a case by case basis, taking into account any detailed information on the size and position of welds and the stresses of the zones concerned, both during ship launching and with the ship afloat.

Moreover, during the welding operation afloat, loading conditions are to be adjusted in order to have an acceptable level of longitudinal stress.

Note 1: As a general guidance, the level of longitudinal stress during the welding operation is to be below 50 MPa in the concerned area; however, lower limits may be requested by the surveyor depending on the specificities of the ship and/or welding.

4.2.11 Interpass cleaning

After each run, the slag is to be removed by means of a chipping hammer and a metal brush; the same precaution is to be taken when an interrupted weld is resumed or two welds are to be connected.

4.2.12 Stress relieving

It is recommended and in some cases it may be required that special structures subject to high stresses, having complex shapes and involving welding of elements of considerable thickness (such as rudder spades and stern frames), are prefabricated in parts of adequate size and stress-relieved in the furnace, before final assembly, at a temperature within the range 550°C ÷ 620°C, as appropriate for the type of steel.

4.3 Crossing of structural elements

4.3.1 In the case of T crossing of structural elements (one element continuous, the other physically interrupted at the crossing) when it is essential to achieve structural continuity through the continuous element (continuity obtained by means of the welded connections at the crossing), particular care is to be devoted to obtaining the correspondence of the interrupted elements on both sides of the continuous element. Suitable systems for checking such correspondence are to be adopted.

5 Modifications and repairs during construction

5.1 General

5.1.1 Deviations in the joint preparation and other specified requirements, in excess of the permitted tolerances and found during construction, are to be repaired as agreed with the Society on a case by case basis.

5.2 Gap and weld deformations

5.2.1 Welding by building up of gaps exceeding the required values and repairs of weld deformations may be accepted by the Society upon special examination.

5.3 Defects

5.3.1 Defects and imperfections on the materials and welded connections found during construction are to be evaluated for possible acceptance on the basis of the applicable requirements of the Society.

Where the limits of acceptance are exceeded, the defective material and welds are to be discarded or repaired, as deemed appropriate by the Surveyor on a case by case basis.

When any serious or systematic defect is detected either in the welded connections or in the base material, the manufacturer is required to promptly inform the Surveyor and submit the repair proposal.

The Surveyor may require destructive or non-destructive examinations to be carried out for initial identification of the defects found and, in the event that repairs are undertaken, for verification of their satisfactory completion.

5.4 Repairs on structures already welded

5.4.1 In the case of repairs involving the replacement of material already welded on the hull, the procedures to be adopted are to be agreed with the Society on a case by case basis.

6 Inspections and checks

6.1 General

6.1.1 Materials, workmanship, structures and welded connections are to be subjected, at the beginning of the work, during construction and after completion, to inspections by the Shipbuilder suitable to check compliance with the applicable requirements, approved plans and standards.

6.1.2 The Shipbuilder is to make available to the Surveyor a list of the manual welders and welding operators and their respective qualifications.

The Shipbuilder's internal organisation is responsible for ensuring that welders and operators are not employed under improper conditions or beyond the limits of their respective valid qualifications and that welding procedures are adopted within the approved limits and under the appropriate operating conditions.

6.1.3 The Shipbuilder is responsible for ensuring that the operating conditions, welding procedures and work schedule are in accordance with the applicable requirements, approved plans and recognised good welding practice.

6.1.4 The Shipbuilder is responsible for ensuring that non-destructive examination (NDE) procedures and plans are adhered to during the construction and that NDE reports are made available to the Society.

6.2 Non-destructive examination

6.2.1 Non-destructive examination techniques refer to the testing methods applicable to the detection of surface imperfections (Visual Testing, Magnetic particle Testing, Liquid penetrant Testing) or sub-surface imperfections (Ultrasonic Testing, Radiographic Testing, Time Of Flight Diffraction Testing, Phased Array Ultrasonic Testing).

6.2.2 NDE of hull welds are to be performed in accordance with written procedures accepted by the Society. Such procedures are to contain appropriate details about the applied codes or standards, testing method, equipment, calibration, testing conditions and personnel qualification. For each NDE technique, appropriate details means typically the details described in IACS Recommendation 20.

6.2.3 The NDE acceptance criteria defined by the Shipbuilder are to be submitted to the Society and should comply with the IACS Recommendation 20 or with a recognized standard which has been accepted by the Society.

Where applicable, specific criteria defined in Ch 11, Sec 2, for special structural details are to be referred to.

6.2.4 All finished welds are to be subjected to visual testing by the Shipbuilder's qualified personnel.

6.2.5 After completion of the welding operation and workshop inspection, the structure is to be presented to the Surveyor for general visual examination at a suitable stage of fabrication.

As far as possible, the results on non-destructive examinations are to be submitted.

6.2.6 Radiographic testing is to be carried out on the welded connections of the hull in accordance with [6.3]. The results are to be made available to the Society. The surveyor may require to witness some testing preparations.

6.2.7 The Society may accept radiographic testing to be replaced by ultrasonic testing.

6.2.8 The Shipbuilder's NDE plan describing the extent, type and location of NDE is to be submitted to the Society for acceptance.

6.2.9 When the non-destructive examinations reveal the presence of unacceptable indications, the relevant connection is to be repaired to an extent and according to a procedure agreed with the Surveyor.

The repaired zone is then to be submitted to non-destructive examination, using a method deemed suitable by the Surveyor to verify that the repair is satisfactory.

Additional examinations may be required by the Surveyor on a case by case basis.

6.2.10 Ultrasonic and magnetic particle testing may also be required by the Surveyor in specific cases to check the base material.

6.3 Radiographic testing

6.3.1 Radiographic testing is to be carried out on the welded butts of shell plating, strength deck plating as well as of members contributing to the longitudinal strength.

Radiographic Testing may also be required for the joints of members subject to heavy stresses.

The requirements [6.3.2] to [6.3.5] constitute general rules: the number of radiographs may be increased where requested by the Surveyor, mainly where visual inspection or radiographic soundings have revealed major defects, specially for butts of sheerstrake, stringer plate, bilge strake or keel plate.

Provisions alteration to these rules may be accepted by the Society when justified by the organisation of the Shipbuilder or of the inspection department; the inspection is then to be equivalent to that deduced from [6.3.2] to [6.3.5].

6.3.2 As far as automatic welding of the panels butt welds during the premanufacturing stage is concerned, the Shipbuilder is to carry out random non-destructive testing of the welds (radiographic or ultrasonic testing) in order to ascertain the regularity and the constancy of the welding inspection.

6.3.3 In the midship area, radiographies are to be taken at the joinings of panels.

Each radiography is situated in a butt joint at a cross-shaped welding.

In a given ship cross-section bounded by the panels, a radiography is to be made of each butt of sheerstrake, stringer, bilge and keel plate; in addition, the following radiographies are to be taken:

- bottom plating: two
- deck plating: two
- side shell plating: two each side.

For ships where B + D ≤ 15 m, only one radiography for each of the above items is required.

This requirement remains applicable where panel butts are shifted or where some strakes are built independently from the panels. It is recommended to take most of these radiographies at the intersections of butt and panel seams.

Still in the midship area, radiographic testing is to be carried out, at random, of the following main members of the structure:

- butts of continuous longitudinal bulkheads
- butts of longitudinal stiffeners, deck and bottom girders contributing to the overall strength
- assembly joints of insert plates at the corners of the openings.

Moreover, radiographic testing is to be carried out, at random, of the weldings of the bilge keel and of intermediate flat.

6.3.4 Outwards the midship area, a programme of radiographic testing at random is to be set up by the Shipbuilder in agreement with the Surveyor for the major points. It is further recommended:

- to take a number of radiographies of the very thick parts and those comprising restrained joint, such as sternframes, shaft brackets, stabiliser recesses, masts
- to take a complete set of radiographies or to increase the number of radiographies for the first joint of a series of identical joints. This recommendation is applicable not only to the assembly joints of prefabricated members completed on the slip, but also to joints completed in the workshop to prepare such prefabricated members.

6.3.5 Where a radiography is rejected and where it is decided to carry out a repair, the Shipbuilder is to determine the length of the defective part, then a set of radiographies of the repaired joint and of adjacent parts is to be taken. Where the repair has been decided by the inspection office of the Shipbuilder, the film showing the initial defect is to be submitted to the Surveyor together with the film taken after repair of the joint.

SECTION 2 SPECIAL STRUCTURAL DETAILS

Symbols

T_B : Ship's draft in light ballast condition, see Ch 5, Sec 1, [2.4.3].

1 General

1.1 Application

1.1.1 Special structural details are those characterised by complex geometry, possibly associated with high or alternate stresses.

1.1.2 For special structural details, specific requirements are to be fulfilled during:

- design
- construction
- selection of materials
- welding
- survey.

The purpose of these requirements is specified in [1.2] to [1.6].

1.1.3 Special structural details are those listed in [2] together with the specific requirements which are to be fulfilled.

Other structural details may be considered by the Society as special details, when deemed necessary on the basis of the criteria in [1.1.1]. The criteria to be fulfilled in such cases are defined by the Society on a case by case basis.

1.1.4 As regards matters not explicitly specified in [2], the Rule requirements are to be complied with in any event; in particular:

- Part B, Chapter 4 for design principles and structural arrangements
- Part B, Chapter 7, for structural scantling
- Part B, Chapter 11 for construction and welding requirements
- the applicable requirements in Part D, Part E and Part F.

1.2 Design requirements

1.2.1 General requirements

Design requirements specify:

- the local geometry, dimensions and scantlings of the structural elements which constitute the detail
- any local strengthening
- the cases where a fatigue check is to be carried out according to Ch 7, Sec 4.

1.2.2 Fatigue check requirements

Where a fatigue check is to be carried out, the design requirements specify (see Ch 7, Sec 4, [1.1]):

- the locations (hot spots) where the stresses are to be calculated and the fatigue check performed
- the direction in which the normal stresses are to be calculated
- the stress concentration factors K_h and K_ℓ to be used for calculating the hot spot stress range.

1.3 Constructional requirements

1.3.1 Constructional requirements specify the allowable misalignment and tolerances, depending on the detail arrangement and any local strengthening.

1.4 Material requirements

1.4.1 Material requirements specify the material quality to be used for specific elements which constitute the detail, depending on their manufacturing procedure, the type of stresses they are subjected to, and the importance of the detail with respect to the ship operation and overall safety.

In addition, these requirements specify where material inspections are to be carried out.

1.5 Welding requirements

1.5.1 Welding requirements specify where partial or full T penetration welding (see Ch 11, Sec 1, [2.4]) or any particular welding type or sequence is to be adopted. In addition, these requirements specify when welding procedures are to be approved.

Since weld shape and undercuts are influencing factors on fatigue behaviour, fillet welds are to be elongated in the direction of the highest stresses and care is to be taken to avoid undercuts, in particular at the hot spots.

1.6 Survey requirements

1.6.1 Survey requirements specify where non-destructive examinations of welds are to be carried out and, where this is the case, which type is to be adopted.

2 List and characteristics of special structural details

2.1 General

2.1.1 This Article lists and describes, depending on the ship type, the special structural details and specifies the specific requirements which are to be fulfilled according to [1.2] to [1.6]. This is obtained through:

- a description of the hull areas where the details are located
- the detail description
- the requirements for the fatigue check
- a reference to a table in the Appendixes where a picture of the detail is shown together with the specific requirements which are to be fulfilled.

2.2 All types of ships with longitudinally framed sides

2.2.1 The special structural details relevant to all types of longitudinally framed ships are listed and described in Tab 1.

2.3 Oil tankers and chemical tankers

2.3.1 The special structural details relevant to ships with the service notation **oil tanker ESP** and **chemical tanker ESP** are listed and described in Tab 2 for various hull areas.

When the structural arrangement in a certain area is such that the details considered in Tab 2 are not possible, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

2.4 Liquefied gas carriers

2.4.1 The special structural details relevant to ships with the service notation **liquefied gas carrier** or **LNG bunkering ship** are listed and described in Pt D, Ch 9, Sec 4, Tab 3 for various hull areas.

When the structural arrangement in a certain area is such that the details considered in Pt D, Ch 9, Sec 4, Tab 3 are not possible, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

2.5 Bulk carriers

2.5.1 The special structural details relevant to ships with the service notation **bulk carrier** or **bulk carrier ESP**, **self-unloading bulk carrier ESP** are listed and described in Tab 3 for various hull areas.

When the structural arrangement in a certain area is such that the details considered in Tab 3 are not possible, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

2.6 Ore carriers and combination carriers

2.6.1 The special structural details relevant to ships with the service notation **ore carrier ESP** and **combination carrier ESP** are listed and described in Tab 4 for various hull areas.

When the structural arrangement in a certain area is such that the details considered in Tab 4 are not possible, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

3 Grinding of welds for fatigue life improvement

3.1 General

3.1.1 The purpose of grinding is to smoothly blend the transition between the plate and the weld face.

3.1.2 Grinding is generally to be burr grinding. However other techniques of grinding may be considered by the Society on a case by case basis.

3.2 Grinding practice

3.2.1 The burr radius r is generally to be taken greater than 0,6 t, where t is the plate thickness at the weld toe being ground.

3.2.2 In general, grinding must extend to a depth below any visible undercut. However, the grinding depth d, in mm, is to be not greater than:

- $d = 1$ mm for $t \geq 14$
- $d = 0,07\ t$ for $10 \leq t < 14$

where t is the plate thickness, in mm, at the weld toe being ground.

For plate thickness less than 10 mm, grinding is generally not allowed.

3.2.3 After grinding, the weld is to be inspected by the yard quality control in order to check that the finished ground surface is as smooth as possible, with no visible evidence of the original weld toe or undercut or any grinding marks at right angles to the weld toe line. In addition, the Society may require measurements of the remaining thickness in way of the ground weld.

3.3 Grinding procedure

3.3.1 The grinding procedure required in Ch 7, Sec 4, [3.1.3] is to specify the:

- weld preparation
- grinding tool used
- position of the tool over the weld toe
- location of weld toe on which grinding is applied
- extent of grinding at the ends of attachments
- final weld profile (see [3.2.2])
- final examination technique, including NDE.

Table 1 : Ships with longitudinally framed sides - Special structural details

Area reference number	Area description	Detail description	Fatigue check	Reference tables in Ch 11, App 2
1	Part of side extended: • longitudinally, between the after peak bulkhead and the collision bulkhead • vertically, between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members	No	Ch 11, App 2, Tab 1 to Ch 11, App 2, Tab 6
		Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members	For L ≥ 170 m	Ch 11, App 2, Tab 7 to Ch 11, App 2, Tab 13

Table 2 : Oil tankers and chemical tankers - Special structural details

Area reference number	Area description	Detail description	Fatigue check	Reference tables in Ch 11, App 2
1	Part of side extended: • longitudinally, between the after peak bulkhead and the collision bulkhead • vertically, between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members	No	Ch 11, App 2, Tab 1 to Ch 11, App 2, Tab 6
		Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members	For L ≥ 170m	Ch 11, App 2, Tab 7 to Ch 11, App 2, Tab 13
2	Part of inner side and longitudinal bulkheads in the cargo area extended vertically above half tank height, where the tank breadth exceeds 0,55B	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members	No	Ch 11, App 2, Tab 14 to Ch 11, App 2, Tab 19
		Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members	For L ≥ 170m	Ch 11, App 2, Tab 20 to Ch 11, App 2, Tab 26
3	Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors	For L ≥ 170m	Ch 11, App 2, Tab 27 to Ch 11, App 2, Tab 29
		Connection of inner bottom with transverse bulkheads or lower stools	For L ≥ 170m	Ch 11, App 2, Tab 30
4	Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates	For L ≥ 170m	Ch 11, App 2, Tab 32 to Ch 11, App 2, Tab 35
5	Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads	For L ≥ 170m	Ch 11, App 2, Tab 39 to Ch 11, App 2, Tab 45
		Connection of lower stools with corrugated bulkheads	For L ≥ 170m (not for Ch 11, App 2, Tab 49 and Ch 11, App 2, Tab 53)	Ch 11, App 2, Tab 46 to Ch 11, App 2, Tab 53
6	Lower part of inner side	Connection of hopper tank sloping plates with inner side	For L ≥ 170m	Ch 11, App 2, Tab 54 to Ch 11, App 2, Tab 60

Table 3 : Bulk carriers - Special structural details

Area reference number	Area description	Detail description	Fatigue check	Reference tables in Ch 11, App 2
3	Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors	For L ≥ 170m	Ch 11, App 2, Tab 27 to Ch 11, App 2, Tab 29
		Connection of inner bottom with transverse bulkheads or lower stools	For L ≥ 170m	Ch 11, App 2, Tab 30
4	Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates	For L ≥ 170m	Ch 11, App 2, Tab 32 to Ch 11, App 2, Tab 35
5	Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads	For L ≥ 170m	Ch 11, App 2, Tab 39 to Ch 11, App 2, Tab 45
		Connection of lower stools with corrugated bulkheads	For L ≥ 170m (not for Ch 11, App 2, Tab 49 and Ch 11, App 2, Tab 53)	Ch 11, App 2, Tab 46 to Ch 11, App 2, Tab 53
6	Lower part of inner side	Connection of hopper tank sloping plates with inner side	For L ≥ 170m	Ch 11, App 2, Tab 54 to Ch 11, App 2, Tab 60
7	Side frames	Connection of side frames with hopper and topside tanks	No	Ch 11, App 2, Tab 63, Ch 11, App 2, Tab 64
8	Topside tanks	Connection of transverse corrugated bulkheads with topside tanks	No	Ch 11, App 2, Tab 65
10	Hatch corners	Deck plating in way of hatch corners	No	Ch 11, App 2, Tab 66
		Ends of longitudinal hatch coamings	No	Ch 11, App 2, Tab 67, Ch 11, App 2, Tab 68

Table 4 : Ore carriers and combination carriers - Special structural details

Area reference number	Area description	Detail description	Fatigue check	Reference tables in Ch 11, App 2
1	Part of side extended: • longitudinally, between the after peak bulkhead and the collision bulkhead • vertically, between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members	No	Ch 11, App 2, Tab 1 to Ch 11, App 2, Tab 6
		Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members	For L ≥ 170m	Ch 11, App 2, Tab 7 to Ch 11, App 2, Tab 13
3	Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors	For L ≥ 170m	Ch 11, App 2, Tab 27 to Ch 11, App 2, Tab 29
		Connection of inner bottom with transverse bulkheads or lower stools	For L ≥ 170m	Ch 11, App 2, Tab 30
4	Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates	For L ≥ 170m	Ch 11, App 2, Tab 32 to Ch 11, App 2, Tab 35
5	Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads	For L ≥ 170m	Ch 11, App 2, Tab 39 to Ch 11, App 2, Tab 45
		Connection of lower stools with corrugated bulkheads	For L ≥ 170m (not for Ch 11, App 2, Tab 49 and Ch 11, App 2, Tab 53)	Ch 11, App 2, Tab 46 to Ch 11, App 2, Tab 53
6	Lower part of inner side	Connection of hopper tank sloping plates with inner side	For L ≥ 170m	Ch 11, App 2, Tab 54 to Ch 11, App 2, Tab 60
8	Topside tanks	Connection of transverse corrugated bulkheads with topside tanks	No	Ch 11, App 2, Tab 65
10	Hatch corners	Deck plating in way of hatch corners	No	Ch 11, App 2, Tab 66
		Ends of longitudinal hatch coamings	No	Ch 11, App 2, Tab 67, Ch 11, App 2, Tab 68

SECTION 3 TESTING

1 Testing procedures of watertight compartments

1.1 Application

1.1.1 These test procedures are to confirm the watertightness of tanks and watertight boundaries, and the structural adequacy of tanks forming a part of the watertight subdivisions of ships. These procedures may also be applied to verify the weathertightness of structures and shipboard outfitting.

The tightness of all tanks and watertight boundaries of ships during new construction and ships relevant to major conversions or major repairs is to be confirmed by these test procedures prior to the delivery of the ships.

Note 1: Watertight subdivision means the transverse and longitudinal subdivisions of the ship required to satisfy the subdivision requirements of SOLAS Chapter II-1.

Note 2: Major repair means a repair affecting structural integrity.

1.1.2 Testing procedures of watertight compartments for SOLAS Ships are to be carried out in accordance with requirements [1.4.1] to [1.9.1], unless:

a) the shipyard provides documentary evidence of the shipowner's agreement to a request to the Flag Administration for an exemption from the application of SOLAS Chapter II-1, Regulation 11, or for an equivalency agreeing that the content of [1.10] is equivalent to SOLAS Chapter II-1, Regulation 11; and

b) the above-mentioned exemption/equivalency has been granted by the responsible Flag Administration.

1.1.3 All gravity tanks and other boundaries required to be watertight or weathertight are to be tested in accordance with these procedures and proven tight and structurally adequate as follows:

- gravity tanks for their tightness and structural adequacy
- watertight boundaries other than tank boundaries for their watertightness
- weathertight boundaries for their weathertightness.

Note 1: Gravity tank means a tank that is subject to vapour pressure not greater than 70 kPa.

1.1.4 Testing of structures not listed in Tab 2 or Tab 3 is to be specially considered by the Society.

1.2 General

1.2.1 Tests are to be carried out in the presence of a Surveyor at a stage sufficiently close to the completion of work, with all the hatches, doors, windows, etc., installed and all the penetrations including pipe connections fitted, and before any ceiling and cement work is applied over the joints. Specific test requirements are given in [1.6] and Tab 2. For the timing of the application of coating and the provision of safe access to joints, see [1.7], [1.8] and Tab 4.

1.3 Definitions

1.3.1 Structural test

A structural test is a test to verify the structural adequacy of tank construction. This may be a hydrostatic test or, where the situation warrants, a hydropneumatic test.

1.3.2 Leak test

A leak test is a test to verify the tightness of a boundary. Unless a specific test is indicated, this may be a hydrostatic/hydropneumatic test or an air test. A hose test may be considered to be an acceptable form of leak test for certain boundaries, as indicated by footnote **(9)** of Tab 2.

1.3.3 Each type of structural and leak test is defined in Tab 1.

1.4 Structural test procedures

1.4.1 Type and time of test

Where a structural test is specified in Tab 2 and Tab 3, a hydrostatic test in accordance with [1.6.1] is acceptable. Where practical limitations (strength of building berth, light density of liquid, etc.) prevent the performance of a hydrostatic test, a hydropneumatic test in accordance with [1.6.2] may be accepted instead.

A hydrostatic or hydropneumatic test for the confirmation of structural adequacy may be carried out while the ship is afloat, provided the results of a leak test are confirmed to be satisfactory before the ship is set afloat.

1.4.2 Testing schedule for new construction and major structural conversion or repair

a) tanks which are intended to hold liquids, and which form part of the watertight subdivision of the ship, shall be tested for tightness and structural strength as indicated in Tab 2 and Tab 3

b) tank boundaries are to be tested from at least one side. The tanks for the structural test are to be selected so that all the representative structural members are tested for the expected tension and compression

c) watertight boundaries of spaces other than tanks may be exempted from the structural test, provided that the boundary watertightness of the exempted spaces is verified by leak tests and inspections. The tank structural test is to be carried out and the requirements from item a) to item b) are to be applied for ballast holds, chain lockers, and for a representative cargo hold in case of cargo holds intended for in-port ballasting

d) tanks which do not form part of the watertight subdivision of the ship, may be exempted from structural testing provided that the boundary watertightness of the exempted spaces is verified by leak tests and inspections.

1.5 Leak test procedures

1.5.1 For the leak tests specified in Tab 2, tank air tests, compressed air fillet weld tests and vacuum box tests, in accordance respectively with [1.6.3], [1.6.5] and [1.6.6], or their combinations, are acceptable. Hydrostatic or hydropneumatic tests may be also accepted as leak tests, provided [1.7], [1.8] and [1.9] are complied with. Hose tests, in accordance with [1.6.3], are also acceptable for items 14 to 17 referred to in Tab 2, taking footnote **(9)** into account.

1.5.2 Air tests of joints may be carried out at the block stage, provided that all work on the block that may affect the tightness of a joint is completed before the test. The application of the leak test for each type of welded joint is specified in Tab 4. See also [1.7.1] for the application of final coatings, [1.8] for the safe access to joints, and Tab 4 for the summary.

1.6 Test methods

1.6.1 Hydrostatic test

Unless another liquid is approved, hydrostatic tests are to consist in filling the space with fresh water or sea water, whichever is appropriate for testing, to the level specified in Tab 2 or Tab 3. See also [1.9].

In case where a tank is intended for cargoes having a density higher than the density of the liquid used for the test, the testing pressure height is to be adjusted is to simulate the actual loading as far as practicable.

All the external surfaces of the tested space are to be examined for structural distortion, bulging and buckling, any other related damage, and leaks.

1.6.2 Hydropneumatic test

Hydropneumatic tests, where approved, are to be such that the test condition, in conjunction with the approved liquid level and supplemental air pressure, simulates the actual loading as far as practicable. The requirements and recommendations in [1.6.4] for tank air tests apply also to hydropneumatic tests. See also [1.9].

All the external surfaces of the tested space are to be examined for structural distortion, bulging and buckling, any other related damage, and leaks.

1.6.3 Hose test

Hose tests are to be carried out with the pressure in the hose nozzle maintained at least at $2 \cdot 10^5$ Pa during the test. The nozzle is to have a minimum inside diameter of 12 mm and to be at a perpendicular distance from the joint not exceeding 1,5 m. The water jet is to impinge upon the weld.

Where a hose test is not practical because of possible damage to machinery, electrical equipment insulation, or outfitting items, it may be replaced by a careful visual examination of the welded connections, supported where necessary by means such as a dye penetrant test or an ultrasonic leak test, or equivalent.

1.6.4 Tank air test

All boundary welds, erection joints and penetrations including pipe connections are to be examined in accordance with approved procedures and under a stabilized pressure differential above atmospheric pressure not less than $0,15 \cdot 10^5$ Pa, with a leak-indicating solution (such as soapy water/detergent or a proprietary solution) applied.

A U-tube having a height sufficient to hold a head of water corresponding to the required test pressure is to be arranged. The cross-sectional area of the U-tube is not to be less than that of the pipe supplying air to the tank. Arrangements involving the use of two calibrated pressure gauges to verify the required test pressure may be accepted taking into account the provisions in F5.1 and F7.4 of IACS Recommendation 140, "Recommendation for Safe Precautions during Survey and Testing of Pressurized Systems".

A double inspection of the tested welds is to be carried out. The first inspection is to be made immediately upon application of the leak indication solution; the second one is to be made approximately four or five minutes after, in order to detect those smaller leaks which may take time to appear.

1.6.5 Compressed air fillet weld test

In this air test, compressed air is injected from one end of a fillet welded joint, and the pressure verified at the other end of the joint by a pressure gauge. Pressure gauges are to be arranged so that an air pressure of at least $0,15 \cdot 10^5$ Pa can be verified at each end of any passage within the portion being tested.

Note 1: Where a leak test is required for fabrication involving partial penetration welds, a compressed air test is also to be carried out in the same manner as to fillet weld where the root face is large, i.e. 6-8 mm.

1.6.6 Vacuum box test

A box (vacuum testing box) with air connections, gauges and an inspection window is placed over the joint with a leak-indicating solution applied to the weld cap vicinity. The air within the box is removed by an ejector to create a vacuum of $0,20 \cdot 10^5$ to $0,26 \cdot 10^5$ Pa inside the box.

1.6.7 Ultrasonic test

An ultrasonic echo transmitter is to be arranged on the inside of a compartment, and a receiver on the outside. The watertight/weathertight boundaries of the compartment are scanned with the receiver, in order to detect an ultrasonic leak indication. Any leakage in the sealing of the compartment is indicated at a location where sound is detectable by the receiver.

1.6.8 Penetration test

For the test of butt welds or other weld joints, a low surface tension liquid is applied on one side of a compartment boundary or a structural arrangement. If no liquid is detected on the opposite sides of the boundaries after the expiration of a defined period of time, this indicates tightness of the boundaries. In certain cases, a developer solution may be painted or sprayed on the other side of the weld to aid leak detection.

1.6.9 Other test

Other methods of testing may be considered by the Society upon submission of full particulars prior to the commencement of the tests.

1.7 Application of coating

1.7.1 Final coating

For butt joints welded by means of an automatic process, the final coating may be applied at any time before completion of a leak test of the spaces bounded by the joints, provided that the welds have been visually inspected with care, to the satisfaction of the Surveyor.

The Surveyors reserve the right to require a leak test prior to the application of a final coating over automatic erection butt welds.

For all the other joints, the final coating is to be applied after the completion of the joint leak test. See also Tab 4.

1.7.2 Temporary coating

Any temporary coating which may conceal defects or leaks is to be applied at the same time as for a final coating (see [1.7.1]). This requirement does not apply to shop primers.

1.8 Safe access to joints

1.8.1 For leak tests, a safe access to all joints under examination is to be provided. See also Tab 4.

1.9 Hydrostatic or hydropneumatic tightness test

1.9.1 In cases where the hydrostatic or hydropneumatic tests are applied instead of a specific leak test, the examined boundaries are to be dew-free, otherwise small leaks are not visible.

1.10 Non-SOLAS ships and SOLAS Exemption / Equivalent Ships

1.10.1 Testing procedures are to be carried out in accordance with the requirements [1.4.1] to [1.9.1] in association with the following alternative procedures for [1.4.2] and alternative test requirements for Tab 2.

1.10.2 The tank boundaries are to be tested from at least one side. The tanks for structural test are to be selected so that all representative structural members are tested for the expected tension and compression.

1.10.3 Structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test. The acceptance of leak testing using an air test instead of a structural test does not apply to cargo space boundaries adjacent to other compartments in tankers and combination carriers or to the boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships.

1.10.4 Additional tanks may require structural testing if found necessary after the structural testing of the first tank.

1.10.5 Where the structural adequacy of the tanks of a vessel were verified by the structural testing required in Tab 2, subsequent vessels in the series (i.e. sister ships built from the same plans at the same shipyard) may be exempted from structural testing of tanks, provided that:

a) water-tightness of boundaries of all tanks is verified by leak tests and thorough inspections are carried out.

b) structural testing is carried out for at least one tank of each type among all tanks of each sister vessel.

c) additional tanks may require structural testing if found necessary after the structural testing of the first tank or if deemed necessary by the attending Surveyor.

For cargo space boundaries adjacent to other compartments in tankers and combination carriers or boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships, the provisions of [1.10.3] shall apply in lieu of item b).

1.10.6 Sister ships built (i.e. keel laid) two years or more after the delivery of the last ship of the series, may be tested in accordance with [1.10.5] at the discretion of the Classification Society, provided that:

a) general workmanship has been maintained (i.e. there has been no discontinuity of shipbuilding or significant changes in the construction methodology or technology at the yard, shipyard personnel are appropriately qualified and demonstrate an adequate level of workmanship as determined by the Classification Society); and

b) an NDT plan is implemented and evaluated by the Classification Society for the tanks not subject to structural tests. Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during the kick-off meeting. Structural fabrication is to be carried out in accordance with IACS Recommendation 47, "Shipbuilding and Repair Quality Standard", or a recognised fabrication standard which has been accepted by the Classification Society prior to the commencement of fabrication/construction. The work is to be carried out in accordance with the Rules and under survey of the Classification Society.

2 Miscellaneous

2.1 Watertight decks, trunks, etc.

2.1.1 *After completion, a hose or flooding test is to be applied to watertight decks and a hose test to watertight trunks, tunnels and ventilators.*

2.2 Steering nozzles

2.2.1 Upon completion of manufacture, the nozzle is to be subjected to a leak test.

Table 1 : Types of test

Test types	Procedure
Hydrostatic test (leak and structural)	The space to be tested is filled with a liquid to a specified head
Hydropneumatic test (leak and structural)	Combination of a hydrostatic test and an air test, the space to be tested being partially filled with liquid and pressurized with air
Hose test (leak)	Tightness check of the joint to be tested by means of a jet of water, the joint being visible from the opposite side
Air test (leak)	Tightness check by means of an air pressure differential and a leak-indicating solution. It includes tank air tests and joint air tests, such as compressed air fillet weld tests and vacuum box tests
Compressed air fillet weld test (leak)	Air test of fillet welded tee joints, by means of a leak indicating solution applied on fillet welds
Vacuum box test (leak)	A box over a joint with a leak indicating solution applied on the welds. A vacuum is created inside the box to detect any leaks
Ultrasonic test (leak)	Tightness check of the sealing of closing devices such as hatch covers, by means of ultrasonic detection techniques
Penetration test (leak)	Check, by means of low surface tension liquids (i.e. dye penetrant test), that no visual dye penetrant indications of potential continuous leakages exist in the boundaries of a compartment

Table 2 : Test requirements for tanks and boundaries

Item	Tank or boundaries to be tested	Test type	Test head or pressure	Remarks
1	Double bottom tanks **(1)**	leak and structural **(2)**	The greater of: • top of the overflow **(3)** • 2,4 m above top of tank **(4)** • bulkhead deck	
2	Double bottom voids **(5)**	leak	See [1.6.4] to [1.6.6], as applicable	Including pump room double bottom and bunker tank protection double hull required by MARPOL Annex I
3	Double side tanks	leak and structural **(2)**	The greater of: • top of the overflow **(3)** • 2,4 m above top of tank **(4)** • bulkhead deck	
4	Double side voids	leak	See [1.6.4] to [1.6.6], as applicable	
5	Deep tanks other than those listed elsewhere in this Table	leak and structural **(2)**	The greater of: • top of the overflow **(3)** • 2,4 m above top of tank **(4)**	
6	Cargo oil tanks	leak and structural **(2)**	The greater of: • top of the overflow • 2,4 m above top of tank **(4)** • top of tank plus setting of any pressure relief valve **(4)**	
7	Ballast holds of bulk carriers	leak and structural **(2)**	The greater of: • top of the overflow • top of cargo hatch coaming	
8	Peak tanks	leak and structural **(2)**	The greater of: • top of the overflow **(3)** • 2,4 m above top of tank **(4)**	After peak to be tested after installation of stern tube
9	a) Fore peak spaces with equipment	leak	See [1.6.3] to [1.6.6], as applicable	
	b) Fore peak voids	leak	See [1.6.3] to [1.6.6], as applicable	
	c) Aft peak spaces with equipment	leak	See [1.6.3] to [1.6.6], as applicable	
	d) Aft peak voids	leak	See [1.6.4] to [1.6.6], as applicable	After peak to be tested after installation of stern tube

Item	Tank or boundaries to be tested	Test type	Test head or pressure	Remarks
10	Cofferdams	leak	See [1.6.4] to [1.6.6], as applicable	
11	a) Watertight bulkheads	leak **(6)**	See [1.6.3] to [1.6.6], as applicable **(7)**	
	b) Superstructure end bulkheads	leak	See [1.6.3] to [1.6.6], as applicable	
12	Watertight doors below free-board or bulkhead deck	leak **(7)** **(8)**	See [1.6.3] to [1.6.6], as applicable	
13	Double plate rudder blades	leak	See [1.6.4] to [1.6.6], as applicable	
14	Shaft tunnels clear of deep tanks	leak **(9)**	See [1.6.3] to [1.6.6], as applicable	
15	Shell doors	leak **(9)**	See [1.6.3] to [1.6.6], as applicable	
16	Weathertight hatch covers and closing appliances	leak **(7)** **(9)**	See [1.6.3] to [1.6.6], as applicable	Hatch covers closed by tarpaulins and battens excluded
17	Watertight hatch covers and closing appliances	leak and structural	Damage equilibrium waterline **(10)** **(11)**	
18	Dual purpose tank/dry cargo hatch covers	leak **(7)** **(9)**	See [1.6.3] to [1.6.6], as applicable	In addition to the structural test in item 6 or item 7
19	Chain lockers	leak and structural	Head of water up to top of chain pipe	
20	L.O. sump tanks and other similar tanks/spaces under main engines	leak **(12)**	See [1.6.3] to [1.6.6], as applicable	
21	Ballast ducts	leak and structural **(2)**	The greater of: • ballast pump maximum pressure • setting of any pressure relief valve	
22	Fuel oil tanks	leak and structural **(2)**	The greater of: • top of the overflow • 2,4 m above top of tank **(4)** • top of tank plus setting of any pressure relief valve **(4)** • bulkhead deck	
23	Fuel oil overflow tanks not intended to hold fuel	leak and structural **(2)**	The greater of: • top of the overflow **(3)** • 2,4 m above top of tank **(4)** • bulkhead deck	

(1) Including the tanks arranged in accordance with the provisions of Ch 2, Sec 2, [3.1.4].

(2) See [1.4.2]

(3) Test head to the top of overflow does not apply to:
- Tanks filled by gravity (i.e. sewage, grey water and similar tanks, not filled with pumps). In that case the top of overflow is replaced by the highest point of the filling line
- Fuel oil overflow tanks not intended to hold fuel and arranged with level alarm.

(4) The top of a tank is the deck forming the top of the tank, excluding any hatchways.

(5) Including the duct keels and dry compartments arranged in accordance with the provisions of SOLAS, Regulations II-1/11.2 and II-1/9.4 respectively, and/or the oil fuel tank protection and pump room bottom protection arranged in accordance with the provisions of MARPOL Annex I, Chapter 3, Part A, Regulation 12A and Chapter 4, Part A, Regulation 22, respectively.

(6) A structural test (see [1.4.2]) is also to be carried out for a representative cargo hold in case of cargo holds intended for in-port ballasting. The filling level required for the structural test of such cargo holds is to be the maximum loading that will occur in-port, as indicated in the loading manual.

(7) As an alternative to the hose test, other testing methods listed in [1.6.7] to [1.6.9] may be acceptable, subject to adequacy of such testing methods being verified. See SOLAS Regulation II-1/11.1. For watertight bulkheads (item 11 a)), alternatives to the hose test may be used only where the hose test is not practicable.

(8) Where watertightness of watertight doors has not been confirmed by a prototype test, a hydrostatic test (filling of the watertight spaces with water) is to be carried out. See SOLAS Regulation II-1/16.2 and MSC/Circ.1176.

(9) Hose test may be also considered as a medium of the leak test. See [1.3.2].

(10) For cargo ships not covered by damage stability requirements, watertight hatches are to be tested by water pressure to a head of water measured from the lower edge of the opening to one metre above the freeboard deck. (see SOLAS II-1 Part B-2 Reg 16)

(11) A prototype pressure test of each type and size of hatch may be carried out instead of individual hatches tests.

(12) Where L.O. sump tanks and other similar spaces under main engines intended to hold liquid form part of the watertight subdivision of the ship, they are to be tested as per the requirements of Item 5, Deep tanks other than those listed elsewhere in this table.

Table 3 : Additional test requirements for special service ships/tanks

Item	Type of ship/tank	Structure to be tested	Type of test	Test head or pressure	Remarks
1	Liquefied gas carriers	Integral tanks	leak and structural	See Pt D, Ch 9, Sec 4	
		Hull structure supporting membrane or semi-membrane tanks	See Pt D, Ch 9, Sec 4		
		Independent tanks type A			
		Independent tanks type B			
		Independent tanks type C			
2	Edible liquid tanks	Independent tanks	leak and structural **(1)**	The greater of: • top of the overflow • 0,9 m above top of tank **(2)**	
3	Chemical carriers	Integral or independent cargo tanks	leak and structural **(1)**	The greater of: • 2,4 m above top of tank **(2)** • top of tank plus setting of any pressure relief valve **(2)**	An appropriate additional head is to be considered where a cargo tank is designed for the carriage of cargoes with specific gravities greater than 1,0

(1) See [1.4.2]
(2) Top of tank is deck forming the top of the tank excluding any hatchways.

Table 4 : Application of leak test, coating, and provision of safe access for the different types of welded joints

Type of welded joints		Leak test	Coating **(1)**		Safe access **(2)**	
			Before leak test	After leak test but before structural test	Leak test	Structural test
Butt	Automatic	not required	allowed **(3)**	not applicable	not required	not required
	Manual or semi-automatic **(4)**	required	not allowed	allowed	required	not required
Fillet	Boundary including penetrations	required	not allowed	allowed	required	not required

(1) Coating refers to internal (tank/hold) coating, where applied, and external (shell/deck) painting. It does not refer to shop primer.
(2) Temporary means of access for verification of the leak test.
(3) The condition applies provided that the welds have been visually inspected with care, to the satisfaction of the Surveyor.
(4) Flux Core Arc Welding (FCAW) semi-automatic butt welds need not be tested, provided careful visual inspections show continuous and uniform weld profile shape, free from repairs, and the results of NDT show no significant defects.

APPENDIX 1 WELDING DETAILS

1 Contents

1.1 General

1.1.1 Types and edge plate preparation of the manual welds carried out on the various parts of the hull are dealt with in this Appendix.

Other types and tolerances may be used after special examination of the Society.

1.1.2 The method used to prepare the parts to be welded is left to the discretion of each shipyard, according to its own technology and experience. It is approved at the same time as the approval of the welding procedures referred to in Ch 11, Sec 1, [1.3.1].

1.2 Butt welding edge preparation

1.2.1 Typical butt weld plate edge preparation for manual welding is specified in Tab 1 and Tab 2.

1.3 Lap-joint, slot and plug welding

1.3.1 Welding details of lap-joint, slot and plug welds are specified in Tab 3.

Table 1 : Typical butt weld plate edge preparation (manual welding) - See Note 1

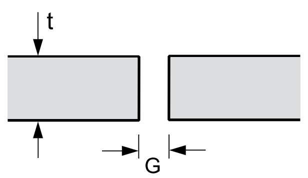
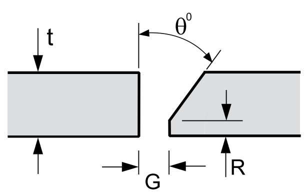
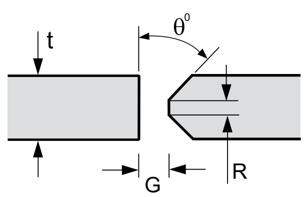
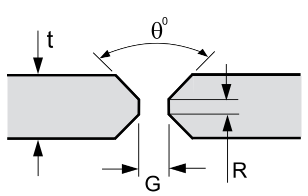
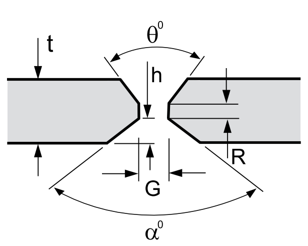
Detail	Dimensions
Square butt 	t ≤ 5 mm G = 3 mm
Single bevel butt 	t > 5 mm G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°
Double bevel butt 	t > 19 mm G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°
Double vee butt, uniform bevels 	G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°
Double vee butt, non-uniform bevels 	G ≤ 3 mm R ≤ 3 mm 6 ≤ h ≤ t/3 mm θ = 50° α = 90°
Note 1: Different plate edge preparation may be accepted by the Society on the basis of an appropriate welding procedure specification.	

Table 2 : Typical butt weld plate edge preparation (manual welding) - See Note 1

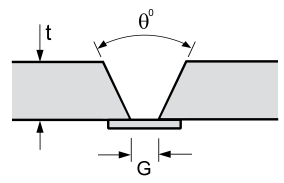
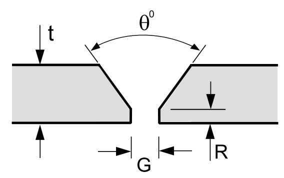
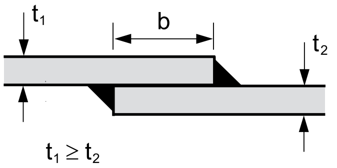
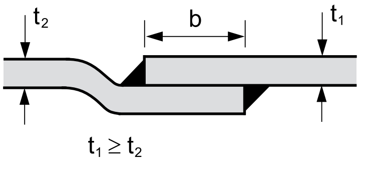
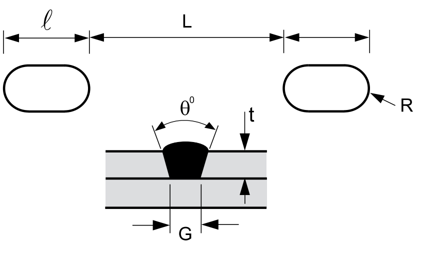
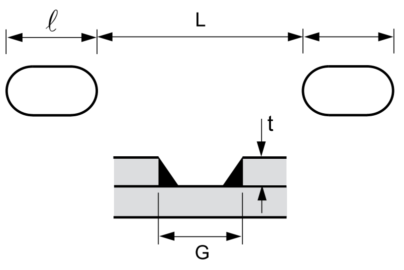
Detail	Dimensions
Single vee butt, one side welding with backing strip (temporary or permanent) 	3 ≤ G ≤ 9 mm 30° ≤ θ ≤ 45°
Single vee butt 	G ≤ 3 mm 50° ≤ θ ≤ 70° R ≤ 3 mm
Note 1: Different plate edge preparation may be accepted by the Society on the basis of an appropriate welding procedure specification.	

Table 3 : Typical lap joint, plug and slot welding (manual welding)

Detail	Standard	Remark
Fillet weld in lap joint 	$b = 2\ t_2 + 25$ mm	location of lap joint to be approved by the Society
Fillet weld in joggled lap joint 	$b \geq 2\ t_2 + 25$ mm	
Plug welding 	• $t \leq 12$ mm $\ell = 60$ mm R = 6 mm $40° \leq \theta \leq 50°$ G = 12 mm $L > 2\ \ell$ • 12 mm $< t \leq 25$ mm $\ell = 80$ mm R = 0,5 t mm $\theta = 30°$ G = t mm $L > 2\ \ell$	
Slot welding 	• $t \leq 12$ mm G = 20 mm $\ell = 80$ mm $2\ \ell \leq L \leq 3\ \ell$, max 250 mm • $t > 12$ mm G = 2 t $\ell = 100$ mm $2\ \ell \leq L \leq 3\ \ell$, max 250 mm	

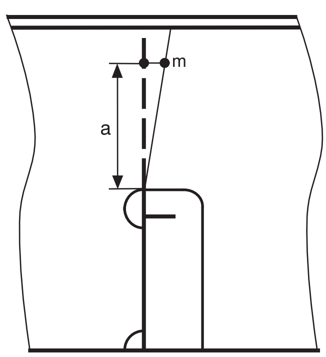
APPENDIX 2 REFERENCE SHEETS FOR SPECIAL STRUCTURAL DETAILS

1 Contents

1.1 General

1.1.1 This Appendix includes the reference sheets for special structural details, as referred to in Ch 11, Sec 2.

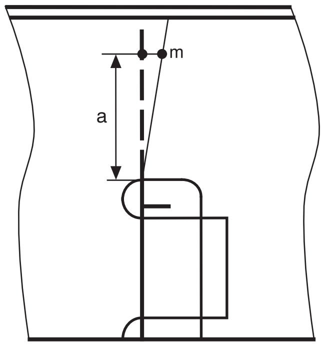
Table 1 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

<table>
<tr><td>AREA 1: Side between 0,7T_B and 1,15T from the baseline</td><td colspan="2">Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - No collar plate</td><td>Sheet 1.1</td></tr>
<tr><td colspan="4">

t_W = web thickness of transverse primary supporting member</td></tr>
<tr><td colspan="2">SCANTLINGS:</td><td colspan="2">FATIGUE:</td></tr>
<tr><td colspan="2">Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].</td><td colspan="2">Fatigue check not required.</td></tr>
<tr><td colspan="2">CONSTRUCTION:</td><td colspan="2">NDE:</td></tr>
<tr><td colspan="2">• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50.
• Cut-outs in the web free of sharps notches.
• Gap between web and side longitudinal to be not greater than 4 mm.</td><td colspan="2">Visual examination 100%.</td></tr>
<tr><td colspan="2">WELDING AND MATERIALS:</td><td colspan="2"></td></tr>
<tr><td colspan="4">Welding requirements:
- continuous fillet welding along the connection of web with side longitudinal,
- throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
- weld around the cuts in the web at the connection with the longitudinal and the side shell,
- avoid burned notches on web.</td></tr>
</table>

Table 2 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	**Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - One collar plate**	**Sheet 1.2**



t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness

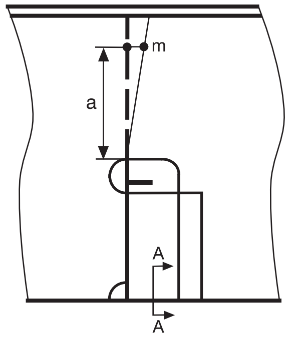
SCANTLINGS:	**FATIGUE:**
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between web and collar plate ≤ t_{CP}. • Cut-outs in the web free of sharps notches. • Gap between web and side longitudinal and between collar plate and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

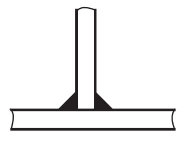
WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of web and collar plate with side longitudinal and at the lap joint between web and collar plate,
  - throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
  - weld around the cuts in the web at the connection with the longitudinal and the side shell,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 3 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - One large collar plate	Sheet 1.3





Section A-A

t_W = web thickness of transverse primary supporting member

t_{CP} = collar plate thickness

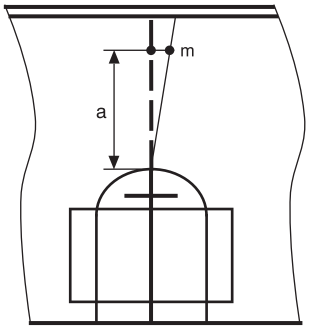
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between web and collar plate ≤ t_{CP}. • Cut-outs in the web free of sharps notches. • Gap between web and side longitudinal and between collar plate and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of web and collar plate with side longitudinal and at the lap joint between web and collar plate,
  - throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
  - T joint connection of collar plate with side shell: see section A-A,
  - weld around the cuts in the web at the connection with the longitudinal and the side shell,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 4 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - Two collar plates	Sheet 1.4



t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness

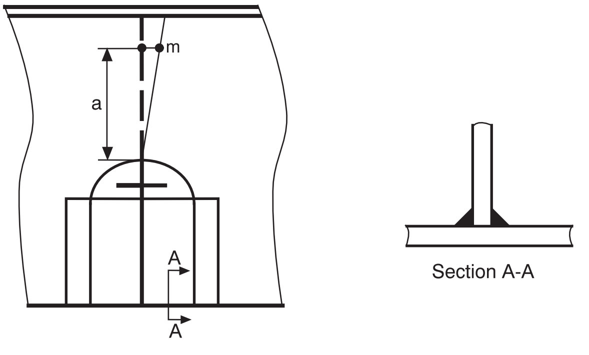
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between collar plates across the side longitudinal ≤ t_{CP} / 2. • Cut-outs in the web free of sharps notches. • Gap between collar plates and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with side longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 5 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between 0,7T_B and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - Two large collar plates	Sheet 1.5



t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness

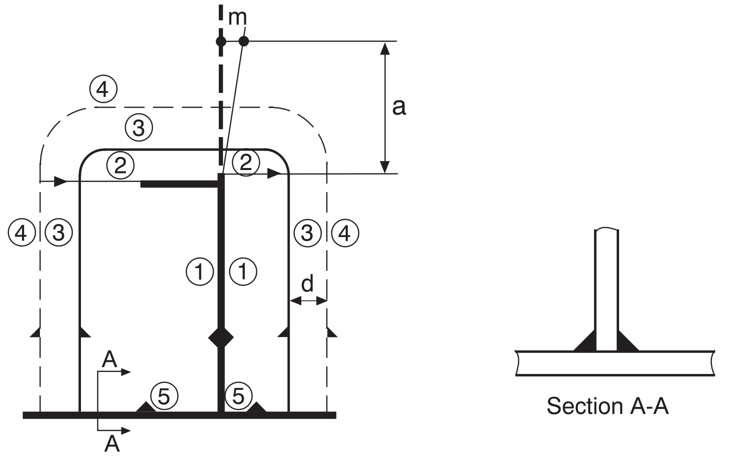
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between collar plates across the side longitudinal ≤ t_{CP} / 2. • Cut-outs in the web free of sharps notches. • Gap between collar plates and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with side longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
  - T joint connection of collar plates with side shell: see section A-A,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 6 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between 0,7T_B and 1,15T from the baseline	Watertight connection of side longitudinal ordinary stiffeners with watertight side diaphragms or transverse bulkheads – Example of connection with lugs	Sheet 1.6



t_W = transverse bulkhead web thickness
t_L = lug thickness

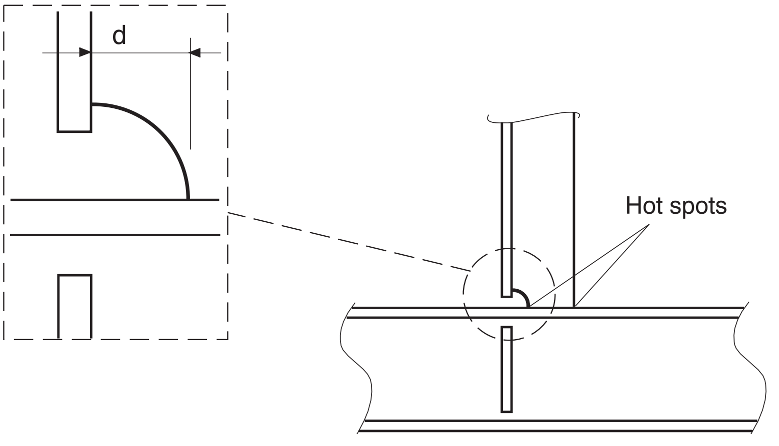
SCANTLINGS:	FATIGUE:
• d = 30 ÷ 60 mm. • $t_L \geq t_W$.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between lugs across the side longitudinal ≤ t_L / 2. • Misalignment at the butts within lug parts ≤ t_L / 5. • Gap between bulkhead plating and lugs to be not greater than 4 mm.	• Visual examination 100%. • Magnetic particle or dye penetrant examination: when deemed necessary depending on the quality of the lap joint weld.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding along the connection of lugs with the side longitudinal and at the lap joints between web and lugs,
- throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
- T joint connection of collar plates with side shell: see section A-A,
- welding sequence: 1 to 5 (see sketch).

Table 7 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between 0,7T_B and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - No bracket	Sheet 1.7



t = minimum thickness between those of:
- web of side longitudinal,
- stiffener of transverse primary supporting member.

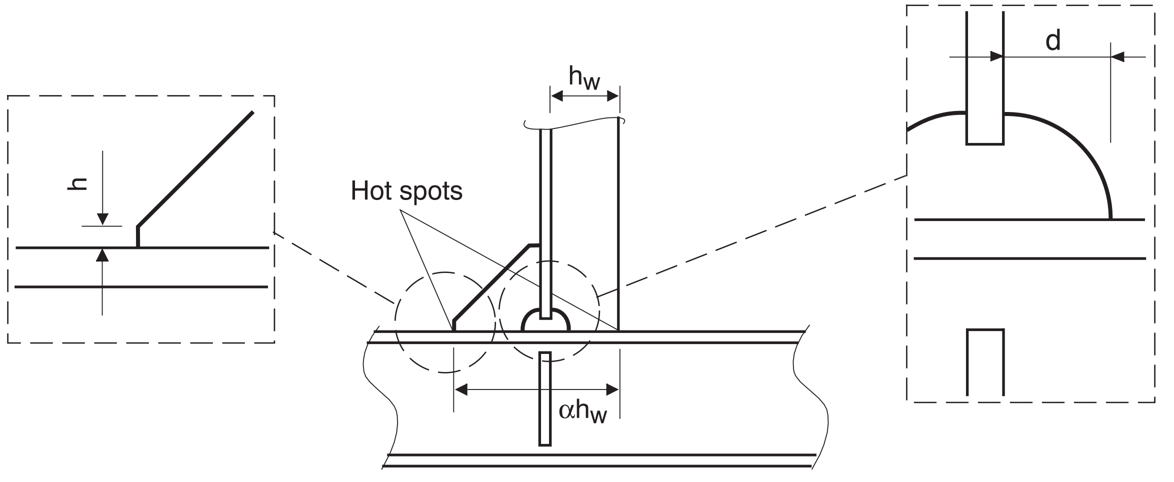
SCANTLINGS:	FATIGUE:
d to be as small as possible, maximum 35 mm recommended.	Fatigue check to be carried out for L ≥ 170 m: • with non-watertight collar plate: K_h = 1,30 K_ℓ = 1,65 • with full collar plate (watertight): K_h = 1,25 K_ℓ = 1,50
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal and web stiffener ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener’s toes,
- fair shape of fillet at toes in longitudinal direction.

Table 8 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0{,}7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 1.8



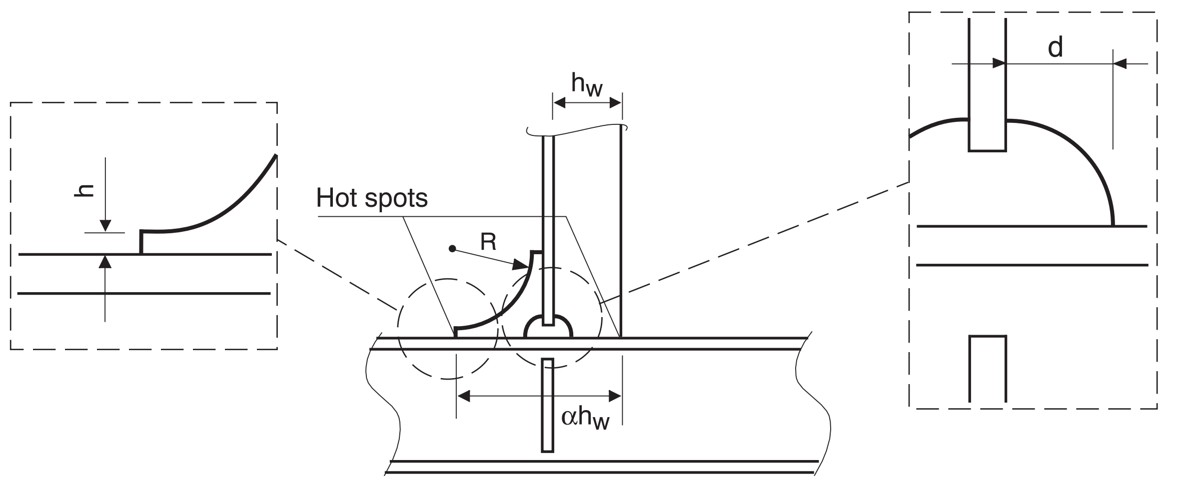
t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 170 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2{,}5$ $K_h = 1{,}20$ $K_\ell = 1{,}40$ - for $\alpha \geq 2{,}5$ $K_h = 1{,}15$ $K_\ell = 1{,}40$ • with full collar plate (watertight): - for $2 \leq \alpha < 2{,}5$ $K_h = 1{,}15$ $K_\ell = 1{,}32$ - for $\alpha \geq 2{,}5$ $K_h = 1{,}10$ $K_\ell = 1{,}32$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction.

Table 9 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between 0,7TB and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 1.9



t = minimum thickness among those of the connected elements

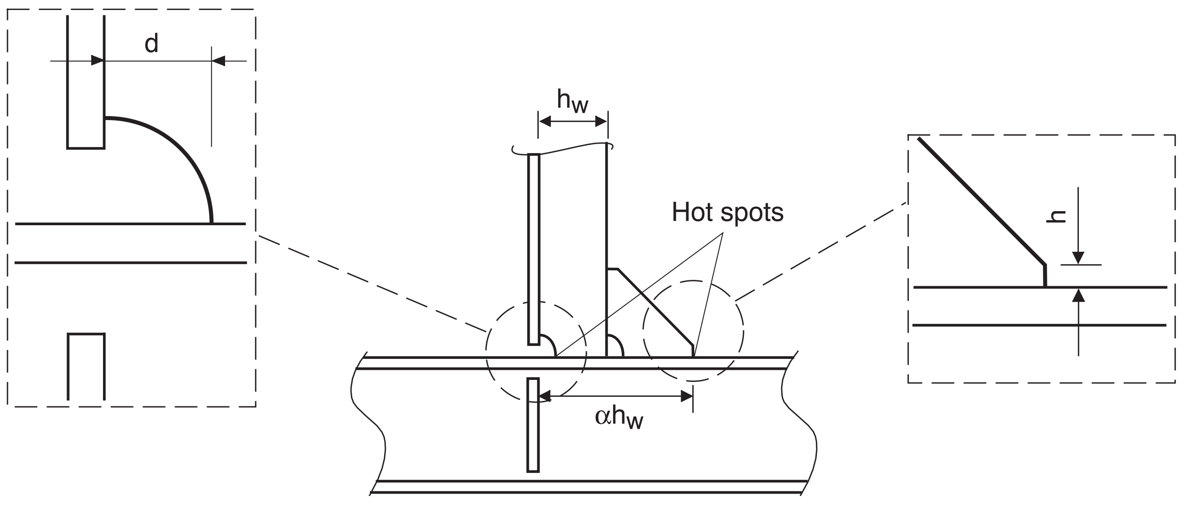
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5 (\alpha - 1) h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 170 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ $K_h = 1,15$ $K_\ell = 1,35$ - for $\alpha \geq 2,5$ $K_h = 1,10$ $K_\ell = 1,35$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ $K_h = 1,13$ $K_\ell = 1,30$ - for $\alpha \geq 2,5$ $K_h = 1,08$ $K_\ell = 1,30$

CONSTRUCTION:	NDE:
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction.

Table 10 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between 0,7T_B and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 1.10



t = minimum thickness among those of the connected elements

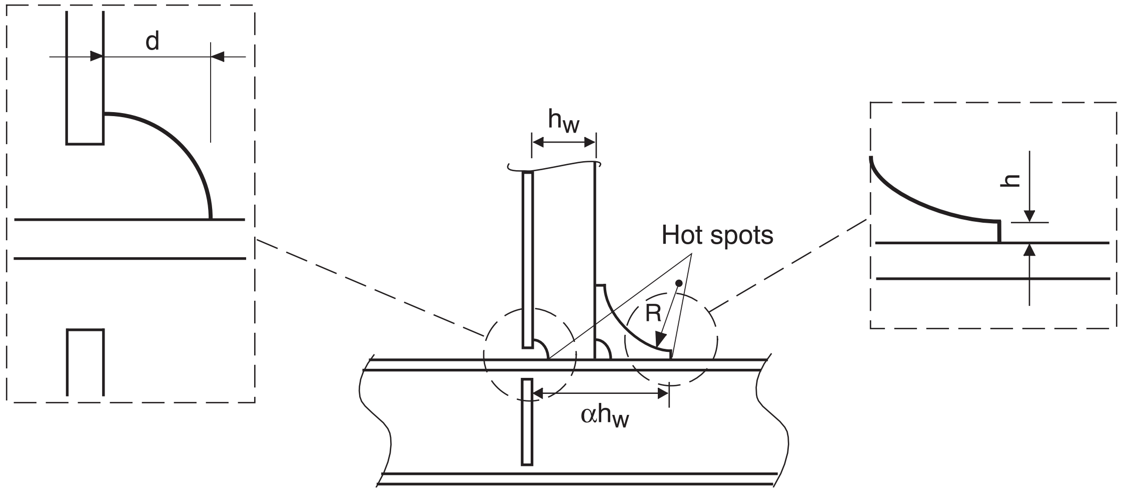
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 170 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ $K_h = 1,30$ $K_\ell = 1,55$ - for $\alpha \geq 2,5$ $K_h = 1,25$ $K_\ell = 1,50$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ $K_h = 1,25$ $K_\ell = 1,46$ - for $\alpha \geq 2,5$ $K_h = 1,20$ $K_\ell = 1,41$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 11 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and $1,15T$ from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 1.11



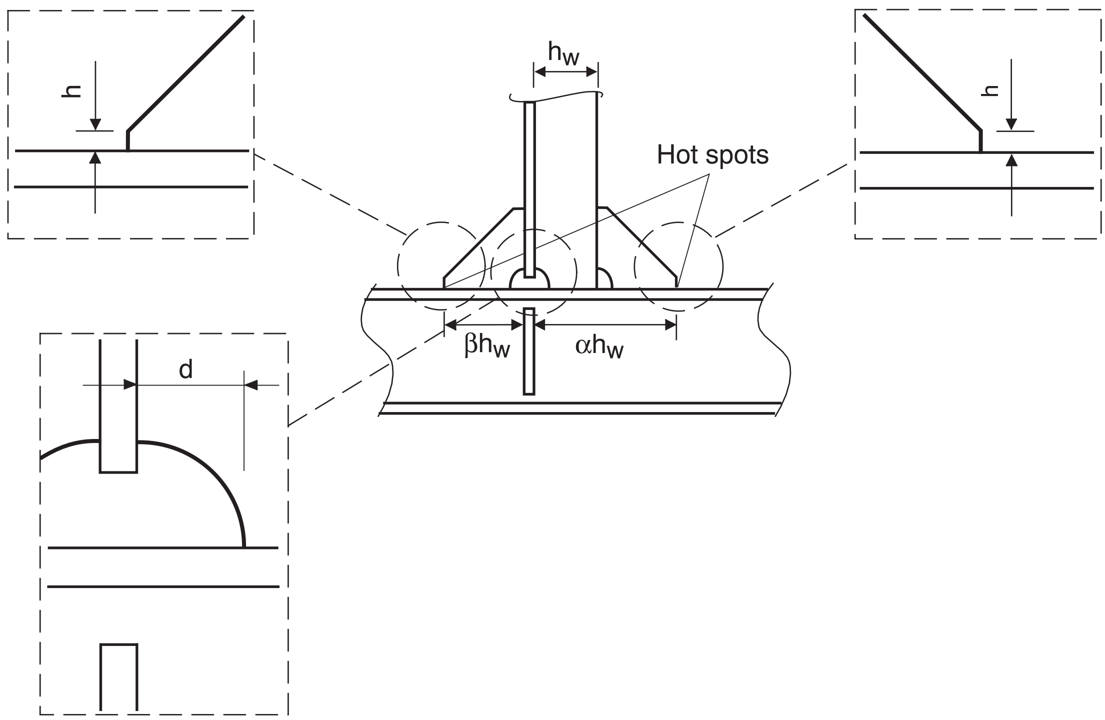
t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5 (\alpha - 1) h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 170 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ $K_h = 1,25$ $K_\ell = 1,50$ - for $\alpha \geq 2,5$ $K_h = 1,20$ $K_\ell = 1,45$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ $K_h = 1,22$ $K_\ell = 1,44$ - for $\alpha \geq 2,5$ $K_h = 1,18$ $K_\ell = 1,39$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction.

Table 12 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two brackets	Sheet 1.12



t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 170 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ and $1 \leq \beta < 1,5$ $K_h = K_\ell = 1,15$ - for $\alpha \geq 2,5$ and $\beta \geq 1,5$ $K_h = K_\ell = 1,10$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ and $1 \leq \beta < 1,5$ $K_h = K_\ell = 1,10$ - for $\alpha \geq 2,5$ and $\beta \geq 1,5$ $K_h = K_\ell = 1,05$

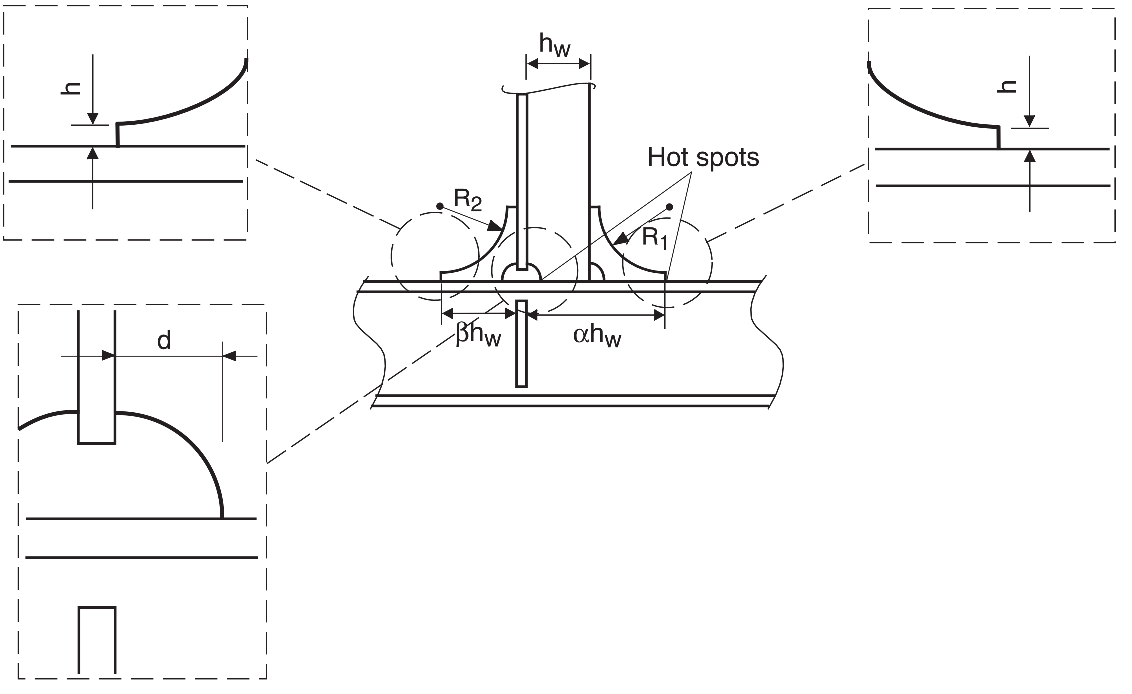
CONSTRUCTION:	NDE:
• Misalignment between side longitudinal, web stiffener and brackets ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding,
  - weld around the stiffener's toes,
  - fair shape of fillet at toes in longitudinal direction.
- Material requirements:
  - material of brackets to be the same of longitudinals.

Table 13 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two radiused brackets	Sheet 1.13



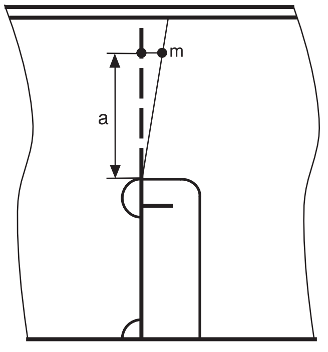
t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • $R_1 \geq 1,5\ (\alpha - 1)\ h_W$ • $R_2 \geq 1,5\ \beta\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 170 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ and $1 \leq \beta < 1,5$ $K_h = K_\ell = 1,10$ - for $\alpha \geq 2,5$ and $\beta \geq 1,5$ $K_h = K_\ell = 1,05$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ and $1 \leq \beta < 1,5$ $K_h = K_\ell = 1,10$ - for $\alpha \geq 2,5$ and $\beta \geq 1,5$ $K_h = K_\ell = 1,05$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and brackets ≤ t /3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
• Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. • Material requirements: - material of brackets to be the same of longitudinals.

Table 14 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	**Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - No collar plate**	**Sheet 2.1**



t_W = web thickness of transverse primary supporting member

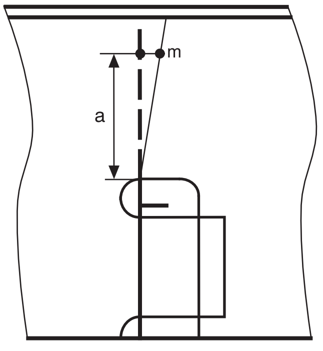
SCANTLINGS:	**FATIGUE:**
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal ≤ a / 50. • Cut-outs in the web free of sharps notches. • Gap between web and longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding along the connection of web with longitudinal,
- throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
- weld around the cuts in the web at the connection with the longitudinal and the plating,
- avoid burned notches on web.

Table 15 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - One collar plate	Sheet 2.2



t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness

SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal ≤ a / 50. • Misalignment between web and collar plate ≤ t_{CP}. • Cut-outs in the web free of sharps notches. • Gap between web and longitudinal and between collar plate and longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of web and collar plate with longitudinal and at the lap joint between web and collar plate,
  - throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
  - weld around the cuts in the web at the connection with the longitudinal and the plating,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 16 : OIL TANKERS, CHEMICAL TANKERS

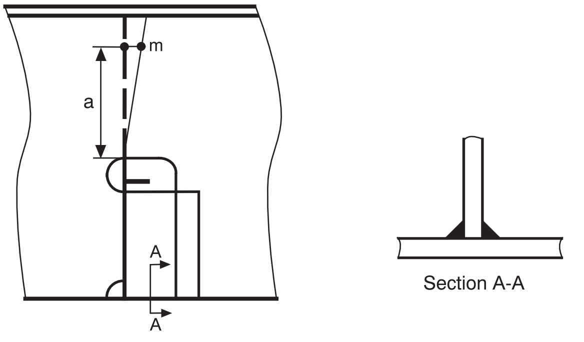
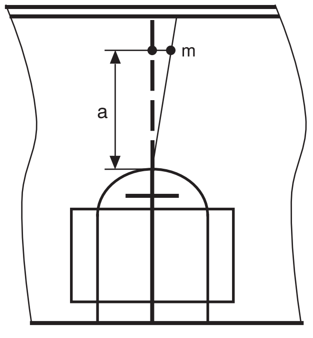
<table>
<tr><td colspan="2">AREA 2: Inner side and longitudinal bulkheads above 0,5H</td><td colspan="2">Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - One large collar plate</td><td>Sheet 2.3</td></tr>
<tr><td colspan="5">
t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness</td></tr>
<tr><td colspan="3">SCANTLINGS:</td><td colspan="2">FATIGUE:</td></tr>
<tr><td colspan="3">Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].</td><td colspan="2">Fatigue check not required.</td></tr>
<tr><td colspan="3">CONSTRUCTION:</td><td colspan="2">NDE:</td></tr>
<tr><td colspan="3">• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal ≤ a / 50.
• Misalignment between web and collar plate ≤ t_{CP}.
• Cut-outs in the web free of sharps notches.
• Gap between web and longitudinal and between collar plate and longitudinal to be not greater than 4 mm.</td><td colspan="2">Visual examination 100%.</td></tr>
<tr><td colspan="5">WELDING AND MATERIALS:</td></tr>
<tr><td colspan="5">• Welding requirements:
- continuous fillet welding along the connection of web and collar plate with longitudinal and at the lap joint between web and collar plate,
- throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
- T joint connection of collar plate with the plating: see section A-A,
- weld around the cuts in the web at the connection with the longitudinal and the plating,
- avoid burned notches on web.
• Fillet welding of overlapped joint to be done all around.</td></tr>
</table>

Table 17 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - Two collar plates	Sheet 2.4



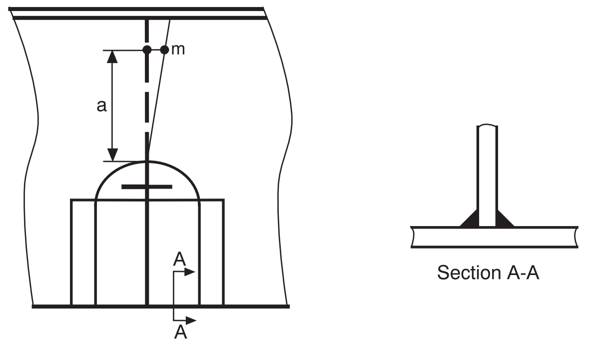
t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness

SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal ≤ a / 50. • Misalignment between collar plates across the longitudinal ≤ t_{CP} / 2. • Cut-outs in the web free of sharps notches. • Gap between collar plates and longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

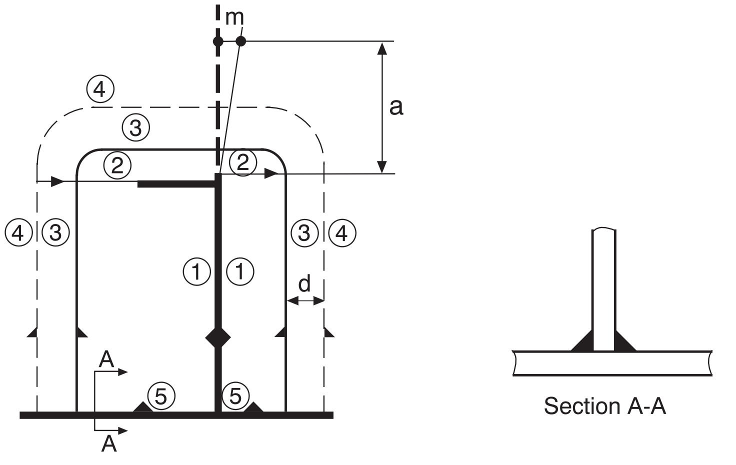
Table 18 : OIL TANKERS, CHEMICAL TANKERS

<table>
<tr><td>AREA 2: Inner side and longitudinal bulkheads above 0,5H</td><td>Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - Two large collar plates</td><td>Sheet 2.5</td></tr>
<tr><td colspan="3">

t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness</td></tr>
<tr><td colspan="2">SCANTLINGS:</td><td>FATIGUE:</td></tr>
<tr><td colspan="2">Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].</td><td>Fatigue check not required.</td></tr>
<tr><td colspan="2">CONSTRUCTION:</td><td>NDE:</td></tr>
<tr><td colspan="2">• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal ≤ a / 50.
• Misalignment between collar plates across the longitudinal ≤ t_{CP} / 2.
• Cut-outs in the web free of sharps notches.
• Gap between collar plates and longitudinal to be not greater than 4 mm.</td><td>Visual examination 100%.</td></tr>
<tr><td colspan="3">WELDING AND MATERIALS:</td></tr>
<tr><td colspan="3">• Welding requirements:
- continuous fillet welding along the connection of collar plates with longitudinal and at the lap joint between web and collar plates,
- throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
- T joint connection of collar plates with the plating: see section A-A,
- avoid burned notches on web.
• Fillet welding of overlapped joint to be done all around.</td></tr>
</table>

Table 19 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Watertight connection of inner side or bulkhead longitudinal ordinary stiffeners with watertight side diaphragms or transverse bulkheads – Example of connection with lugs	Sheet 2.6



t_W = transverse bulkhead web thickness
t_L = lug thickness

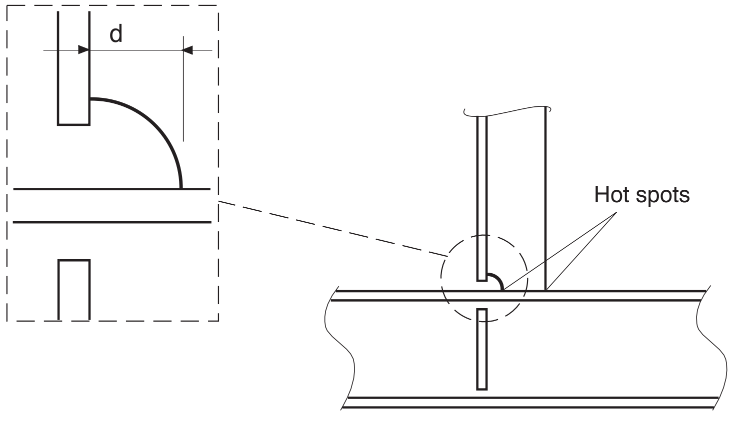
SCANTLINGS:	FATIGUE:
• d = 30 ÷ 60 mm. • $t_L \geq t_W$.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal ≤ a / 50. • Misalignment between lugs across the longitudinal ≤ t_L / 2. • Misalignment at the butts within lug parts ≤ t_L / 5. • Gap between bulkhead plating and lugs to be not greater than 4 mm.	• Visual examination 100%. • Magnetic particle or dye penetrant examination: when deemed necessary depending on the quality of the lap joint weld.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding along the connection of lugs with the longitudinal and at the lap joints between web and lugs,
- throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm,
- T joint connection of collar plates with the plating: see section A-A,
- welding sequence: 1 to 5 (see sketch).

Table 20 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - No bracket	Sheet 2.7



t = minimum thickness between those of:
- web of longitudinal,
- stiffener of transverse primary supporting member.

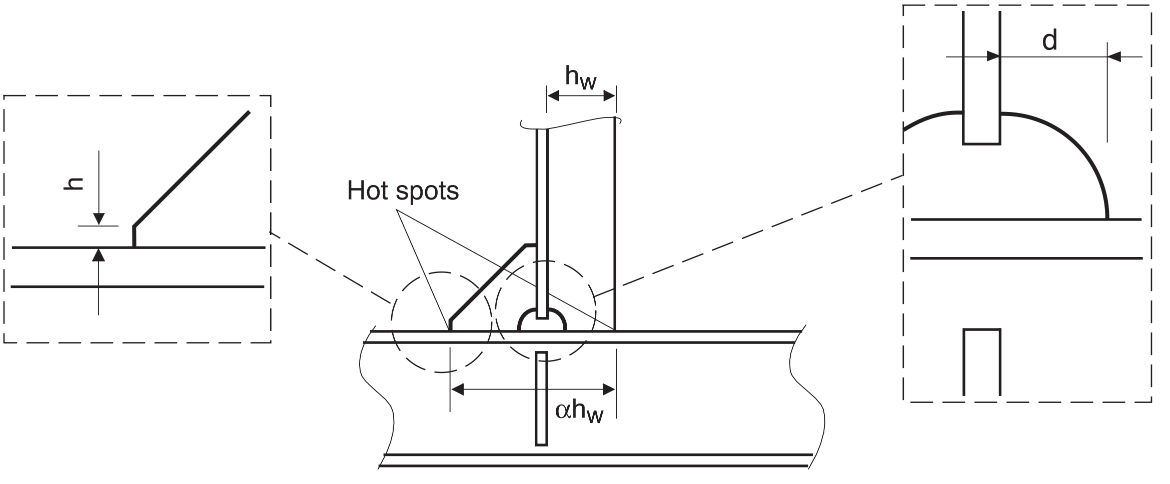
SCANTLINGS:	**FATIGUE:**
d to be as small as possible, maximum 35 mm recommended.	Fatigue check to be carried out for L ≥ 170 m: • with non-watertight collar plate: K_h = 1,30 K_ℓ = 1,65 • with full collar plate (watertight): K_h = 1,25 K_ℓ = 1,50
CONSTRUCTION:	**NDE:**
• Misalignment between longitudinal and web stiffener ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 21 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 2.8



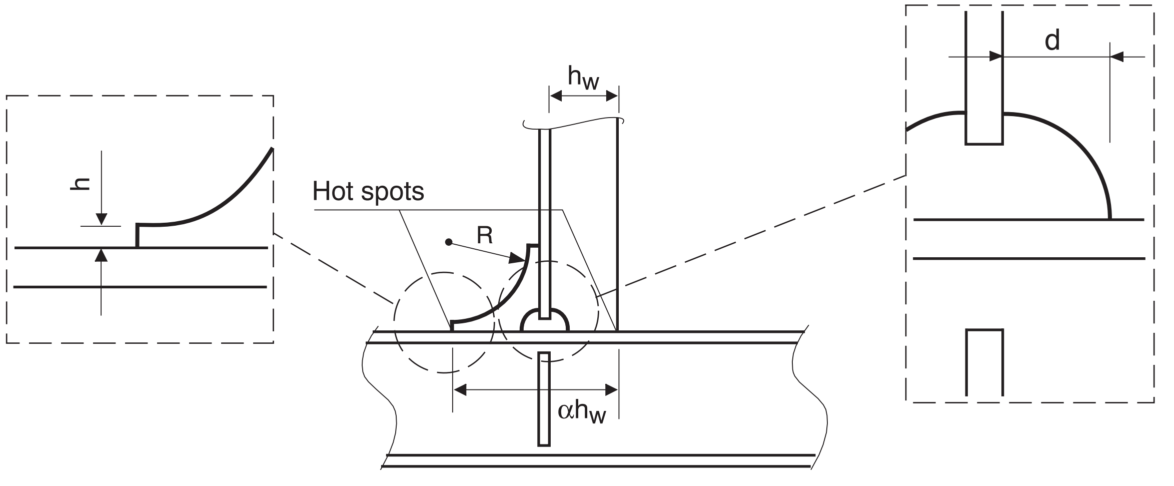
t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 170 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ $K_h = 1,20$ $K_\ell = 1,40$ - for $\alpha \geq 2,5$ $K_h = 1,15$ $K_\ell = 1,40$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ $K_h = 1,15$ $K_\ell = 1,32$ - for $\alpha \geq 2,5$ $K_h = 1,10$ $K_\ell = 1,32$
CONSTRUCTION:	**NDE:**
• Misalignment between longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction.

Table 22 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 2.9



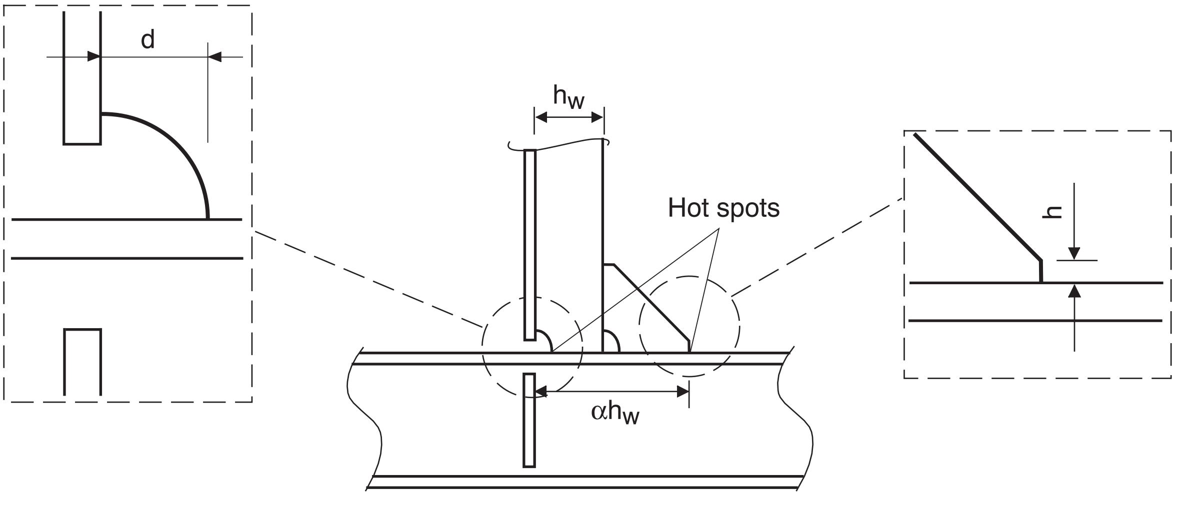
t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5\ (\alpha - 1)\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 170 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ $K_h = 1,15$ $K_\ell = 1,35$ - for $\alpha \geq 2,5$ $K_h = 1,10$ $K_\ell = 1,35$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ $K_h = 1,13$ $K_\ell = 1,30$ - for $\alpha \geq 2,5$ $K_h = 1,08$ $K_\ell = 1,30$
CONSTRUCTION:	**NDE:**
• Misalignment between longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
Welding requirements: - continuous fillet welding, - weld around the stiffener’s toes, - fair shape of fillet at toes in longitudinal direction.

Table 23 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 2.10



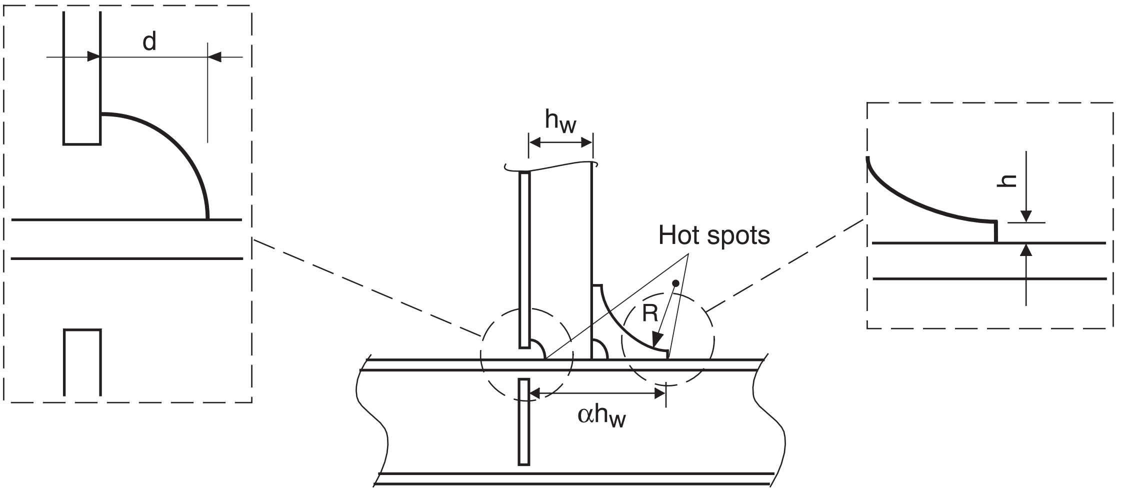
t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 170 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ $K_h = 1,30$ $K_\ell = 1,55$ - for $\alpha \geq 2,5$ $K_h = 1,25$ $K_\ell = 1,50$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ $K_h = 1,25$ $K_\ell = 1,46$ - for $\alpha \geq 2,5$ $K_h = 1,20$ $K_\ell = 1,41$
CONSTRUCTION:	**NDE:**
• Misalignment between longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction.

Table 24 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 2.11



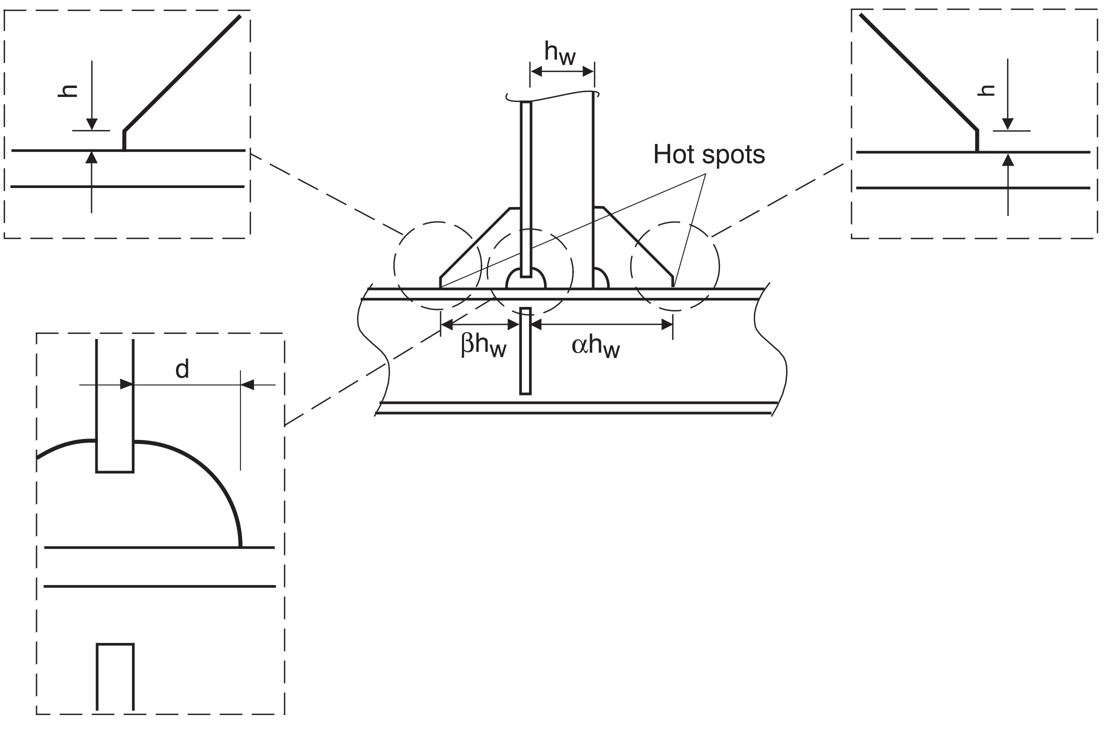
t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5 (\alpha - 1) h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 170 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ $K_h = 1,25$ $K_\ell = 1,50$ - for $\alpha \geq 2,5$ $K_h = 1,20$ $K_\ell = 1,45$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ $K_h = 1,22$ $K_\ell = 1,44$ - for $\alpha \geq 2,5$ $K_h = 1,18$ $K_\ell = 1,39$
CONSTRUCTION:	**NDE:**
• Misalignment between longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction.

Table 25 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two brackets	Sheet 2.12



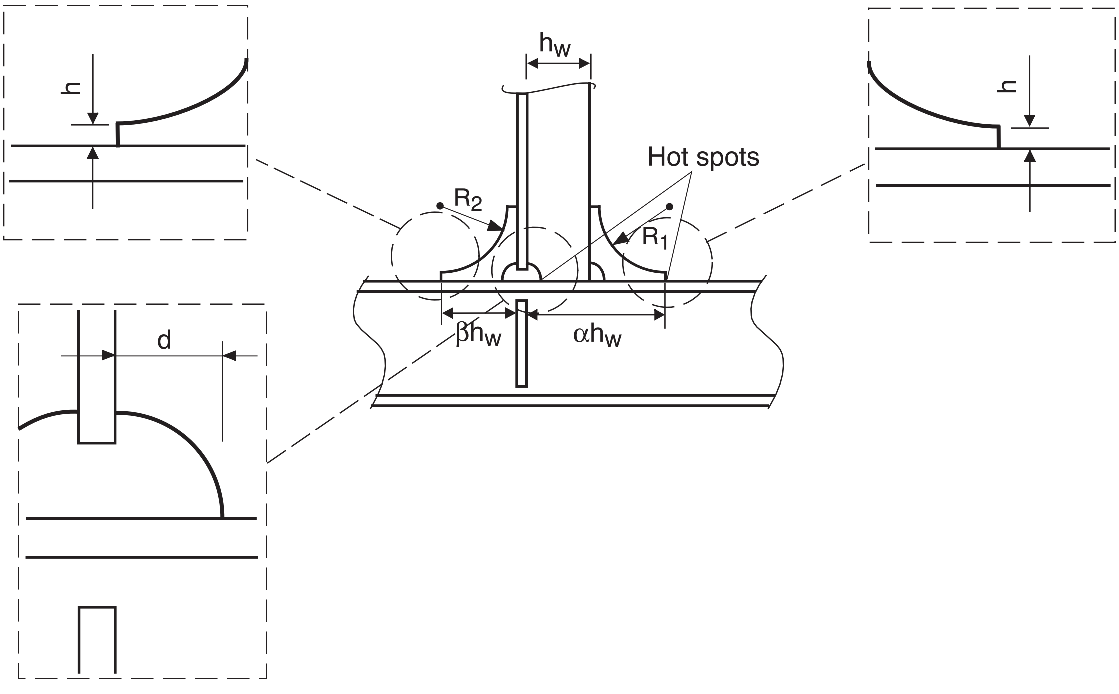
t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 170 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ and $1 \leq \beta < 1,5$ $K_h = K_\ell = 1,15$ - for $\alpha \geq 2,5$ and $\beta \geq 1,5$ $K_h = K_\ell = 1,10$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ and $1 \leq \beta < 1,5$ $K_h = K_\ell = 1,10$ - for $\alpha \geq 2,5$ and $\beta \geq 1,5$ $K_h = K_\ell = 1,05$
CONSTRUCTION:	**NDE:**
• Misalignment between longitudinal, web stiffener and brackets ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
• Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. • Material requirements: - material of brackets to be the same of longitudinals.

Table 26 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two radiused brackets	Sheet 2.13



t = minimum thickness among those of the connected elements

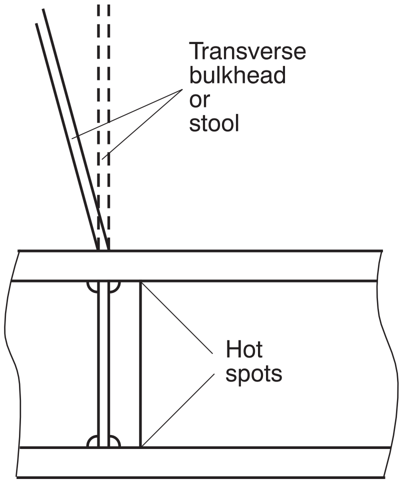
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • $R_1 \geq 1{,}5\ (\alpha - 1)\ h_W$ • $R_2 \geq 1{,}5\ \beta\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out for $L \geq 170$ m: • with non-watertight collar plate: - for $2 \leq \alpha < 2{,}5$ and $1 \leq \beta < 1{,}5$ $K_h = K_\ell = 1{,}10$ - for $\alpha \geq 2{,}5$ and $\beta \geq 1{,}5$ $K_h = K_\ell = 1{,}05$ • with full collar plate (watertight): - for $2 \leq \alpha < 2{,}5$ and $1 \leq \beta < 1{,}5$ $K_h = K_\ell = 1{,}10$ - for $\alpha \geq 2{,}5$ and $\beta \geq 1{,}5$ $K_h = K_\ell = 1{,}05$

CONSTRUCTION:	NDE:
• Misalignment between longitudinal, web stiffener and brackets ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding,
  - weld around the stiffener's toes,
  - fair shape of fillet at toes in longitudinal direction.
- Material requirements:
  - material of brackets to be the same of longitudinals.

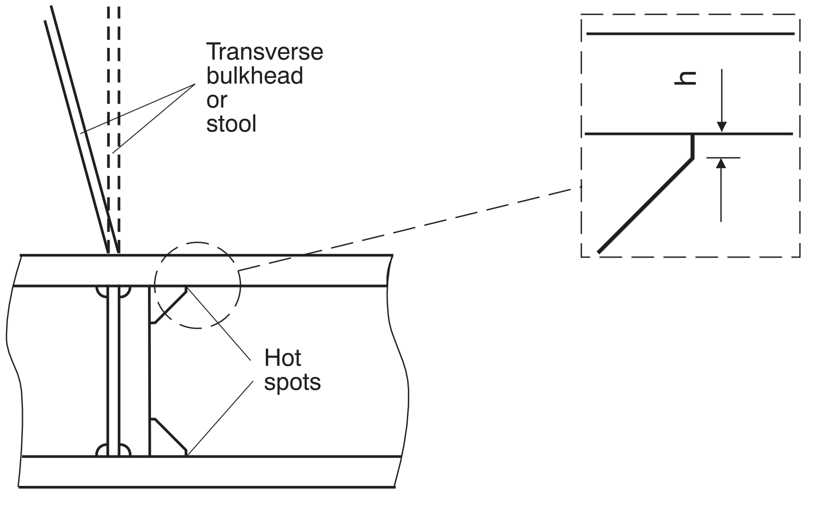
Table 27 : OIL TANKERS, CHEMICAL TANKERS, LIQUEFIED GAS CARRIERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

<table>
<tr><td colspan="2">AREA 3: Double bottom in way of transverse bulkheads</td><td>Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - No bracket</td><td>Sheet 3.1</td></tr>
<tr><td colspan="4">

t = minimum thickness between those of:
- web of bottom or inner bottom longitudinal,
- floor stiffener.</td></tr>
<tr><td colspan="2">SCANTLINGS:</td><td colspan="2">FATIGUE:</td></tr>
<tr><td colspan="2"></td><td colspan="2">Fatigue check to be carried out for L ≥ 170 m:
K_h = 1,30
K_ℓ = 1,65</td></tr>
<tr><td colspan="2">CONSTRUCTION:</td><td colspan="2">NDE:</td></tr>
<tr><td colspan="2">• Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener ≤ t / 3.
• In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.</td><td colspan="2">Visual examination 100%.</td></tr>
<tr><td colspan="4">WELDING AND MATERIALS:</td></tr>
<tr><td colspan="4">Welding requirements:
- floor stiffeners to be connected with continuous fillet welding to bottom and inner bottom longitudinals,
- weld all around the stiffeners,
- fair shape of fillet at toes in longitudinal direction.</td></tr>
</table>

Table 28 : OIL TANKERS, CHEMICAL TANKERS, LIQUEFIED GAS CARRIERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 3: Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - Brackets	Sheet 3.2



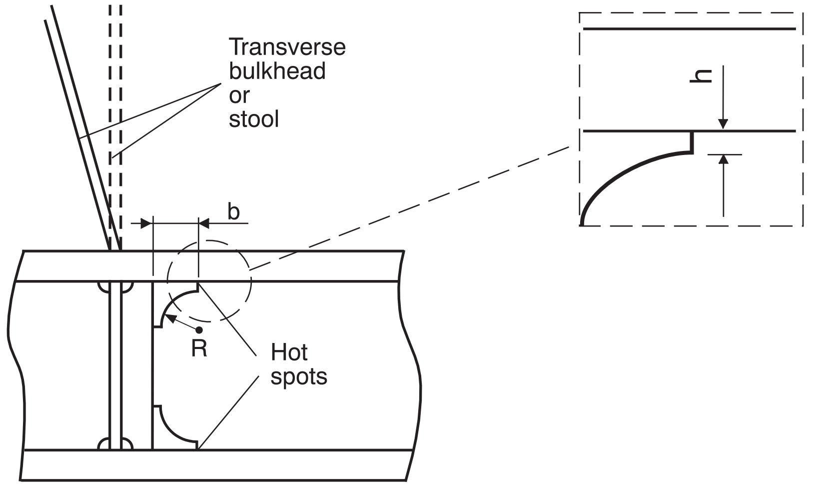
t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
h as necessary to allow the required fillet throat size, but ≤ 15 mm.	Fatigue check to be carried out for L ≥ 170 m: K_h = 1,30 K_ℓ = 1,55
CONSTRUCTION:	**NDE:**
• Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener ≤ t / 3. • In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
Welding requirements: - floor stiffeners and brackets to be connected with continuous fillet welding to bottom and inner bottom longitudinals, - partial penetration welding between stiffeners and brackets, - weld all around the stiffeners and brackets, - fair shape of fillet at toes in longitudinal direction.

Table 29 : OIL TANKERS, CHEMICAL TANKERS, LIQUEFIED GAS CARRIERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 3: Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - Radiused brackets	Sheet 3.3



t = minimum thickness among those of the connected elements

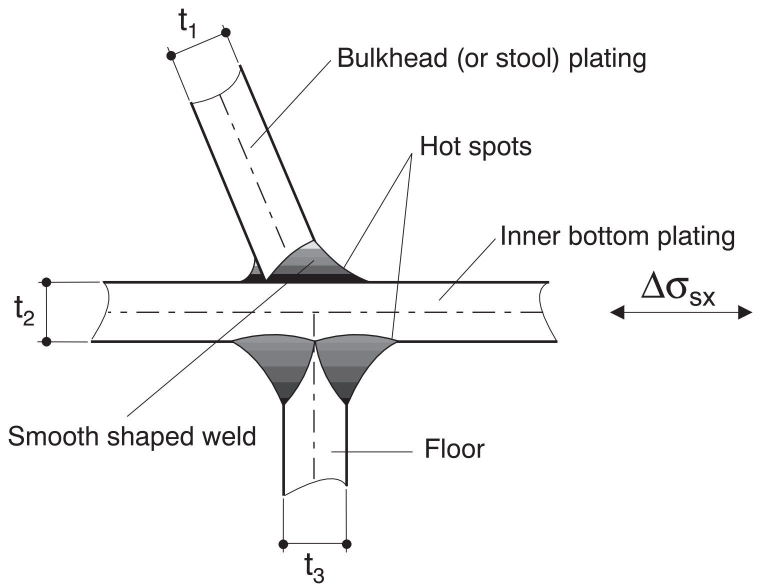
SCANTLINGS:	FATIGUE:
• Brackets to be symmetric. • R ≥ 1,5 b • h as necessary to allow the required fillet throat size, but ≤ 15 mm.	Fatigue check to be carried out for L ≥ 170 m: K_h = 1,25 K_ℓ = 1,50
CONSTRUCTION:	**NDE:**
• Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener ≤ t / 3. • In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- floor stiffeners and brackets to be connected with continuous fillet welding to bottom and inner bottom longitudinals,
- partial penetration welding between stiffeners and brackets,
- weld all around the stiffeners and brackets,
- fair shape of fillet at toes in longitudinal direction.

Table 30 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 3: Double bottom in way of transverse bulkheads	**Connection of inner bottom with transverse bulkheads or lower stools**	**Sheet 3.4**



Hot spot stresses:
$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{sX}$

$t = \min (t_1 , t_2 , t_3)$

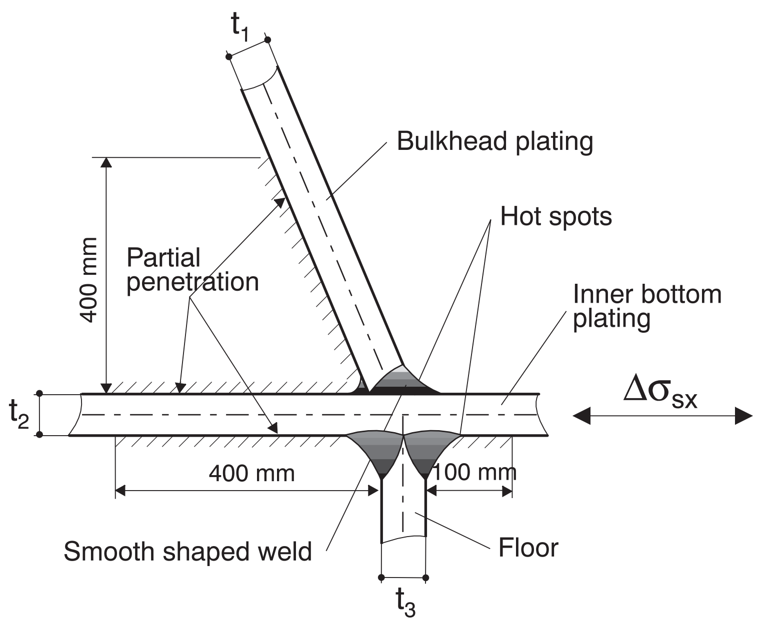
SCANTLINGS:	**FATIGUE:**
	Fatigue check to be carried out for $L \geq 170$ m: $K_{SX} = 3,85$
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between floor and bulkhead (or stool) plating $\leq t / 3$. • Cut-outs for connections of the inner bottom longitudinals to double bottom floors to be closed by collar plates welded to the inner bottom.	The following NDE are required: • VE 100%, • UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirements:
  - bulkhead (or stool) plating and supporting floors generally to be connected with full penetration welding to inner bottom plating (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - special approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating.
- Material requirements:
  - the strake of inner bottom plating in way of the connection is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding.

Table 31 : LIQUEFIED GAS CARRIERS

AREA 3: Double bottom in way of transverse bulkheads	Connection of inner bottom with transverse cofferdam bulkheads	Sheet 3.5



Hot spot stresses:

$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

$t = \min (t_1 , t_2 , t_3)$

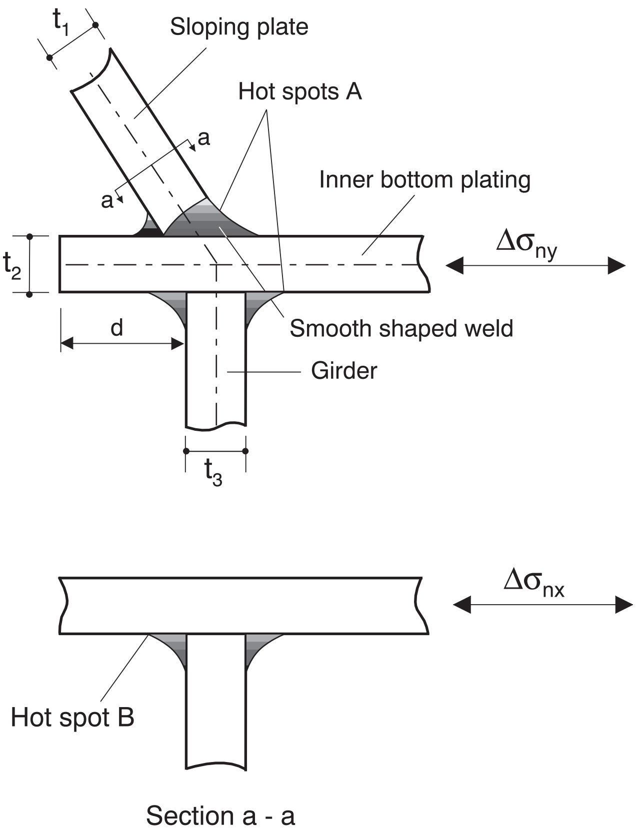
SCANTLINGS:	FATIGUE:
	Fatigue check to be carried out for L ≥ 170 m: $K_{SX} = 3,85$
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between floor and bulkhead plating ≤ t / 3, max 6 mm. • Cut-outs for connections of the inner bottom longitudinals to double bottom floors to be closed by collar plates, welded to the inner bottom.	The following NDE are required: • VE 100%, • UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirements:
  - bulkhead plating and supporting floors to be connected with full penetration welding to inner bottom plating,
  - bulkhead vertical girders and bottom girders are to be connected with partial penetration to inner bottom plating for the extension shown in the sketch,
  - special approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating.
- Material requirements:
  - the strake of inner bottom plating in way of the connection is to be of Z25/ZH25 or of a steel of the same mechanical performances. In particular cases, grade E/EH steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review.

Table 32 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates	Sheet 4.1



Hot spot stresses:
- At hot spot A:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY}$
- At hot spot B:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX} + K_{SYX} \cdot \Delta\sigma_{nY}$

$t_A = \min(t_1, t_2, t_3)$,
t_B = minimum among:
- floor thickness,
- hopper transverse web thickness,
- t_3.

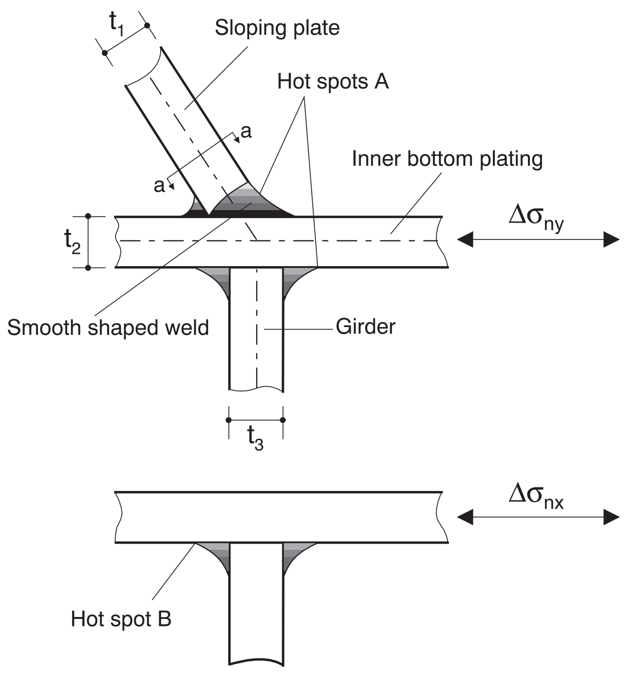
SCANTLINGS:	FATIGUE:
d ≥ 50 mm.	Fatigue check to be carried out for L ≥ 170 m: K_{SY} = 3,85 where closed scallops 5,40 where open scallops K_{SX} = 1,30 K_{SYX} = 2,00
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between girder and sloping plate ≤ t_A / 3. • Misalignment (median lines) between floor and hopper transverse web ≤ t_B / 3.	The following NDE are required: • VE 100%, • UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

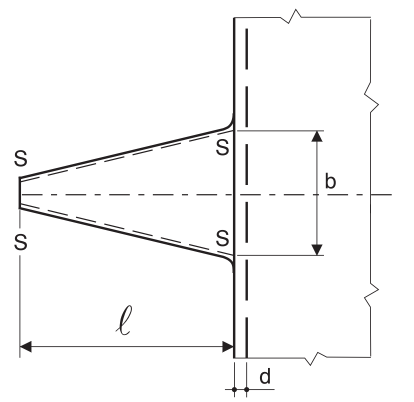
- Welding requirements:
  - sloping plate to be connected with partial penetration welding to inner bottom plating,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating on tank side.
- Material requirements:
  - the strake of inner bottom plating in way of the connection is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding.

Table 33 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Prolonging brackets	Sheet 4.2



Section a - a



Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY}$
- At hot spot B:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX} + K_{SYX} \cdot \Delta\sigma_{nY}$

$t_A = \min (t_1 , t_2 , t_3)$,

t_B = minimum among:

- floor thickness,
- hopper transverse web thickness,
- t_3.

SCANTLINGS:	FATIGUE:
• Inner bottom plating to be prolonged within the hopper tank structure by brackets as shown in the sketch. • $d \geq 50$ mm. • Guidance values, to be confirmed by calculations carried out according to Ch 7, Sec 3: - thickness of the above brackets $\geq t_2$, - $b \geq 0,4$ times the floor spacing, - $\ell \geq 1,5$ b.	Fatigue check to be carried out for $L \geq 170$ m: $K_{SY} = 2,4$ where closed scallops 3,4 where open scallops $K_{SX} = 1,3$ $K_{SYX} = 1,5$

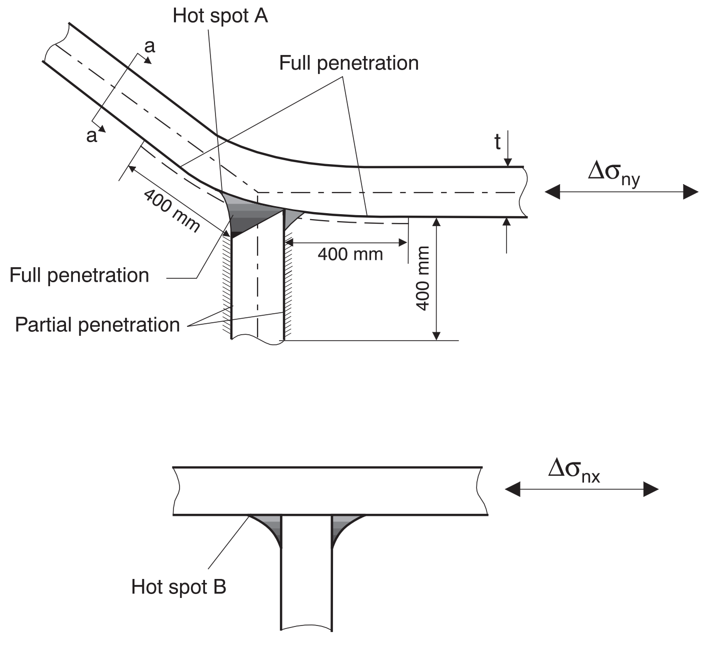
CONSTRUCTION:	NDE:
• Misalignment (median lines) between girder and sloping plate $\leq t_A / 3$. • Misalignment (median lines) between floor and hopper transverse web $\leq t_B / 3$.	The following NDE are required: • VE 100%, • UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirement:
  - sloping plate to be connected with partial penetration welding to inner bottom plating,
  - brackets to be connected with full penetration welding to inner bottom plating,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating on tank side.
- Material requirement:
  - the strake of inner bottom plating in way of the connection is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of prolonging brackets to be not less than those of the inner bottom plating.

Table 34 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Radiused construction	Sheet 4.3



Section a - a

Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY}$
- At hot spot B:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX} + K_{SYX} \cdot \Delta\sigma_{nY}$

t_A = minimum thickness between those of the girder and sloping plate,

t_B = minimum among:

- floor thickness,
- hopper transverse web thickness,
- girder thickness.

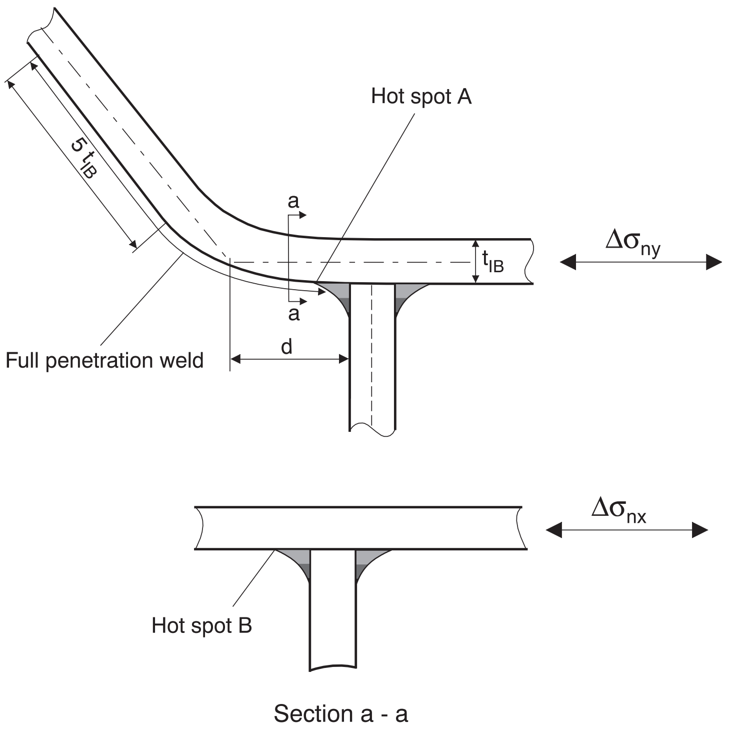
SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • Transverse brackets extended to the closest longitudinals to be fitted on each side of the girder, at mid-span between floors. • Thickness of these brackets, in mm ≥ 9 + 0,03 L_1 $k^{1/2}$.	Fatigue check to be carried out for L ≥ 170 m: K_{SY} = 3,15 K_{SX} = 1,30 K_{SYX} = 2,05
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between girder and sloping plate ≤ t_A / 3. • Misalignment (median lines) between floor and hopper transverse web ≤ t_B / 3. • In floor or transverse webs, in way of the bent area, scallops to be avoided or closed by collar plates.	The following NDE are required: • VE 100%, • UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirements:
  - floors to be connected (see sketches):
    - ♦ with full penetration welding to the inner bottom for a length ≥ 400 mm,
    - ♦ with partial penetration welding to the girder for a length ≥ 400 mm,
    - ♦ with continuous fillet welding in the remaining areas,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - welding procedures of longitudinal girder to the bent plate to be submitted to the Society for review, with evidence given that there is no risk of ageing after welding,
  - weld finishing of butt welds well faired to the inner bottom plating on ballast tank,
  - fair shape of fillet at hot spots.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.

Table 35 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Radiused construction	Sheet 4.4



Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY}$
- At hot spot B:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX} + K_{SYX} \cdot \Delta\sigma_{nY}$

t = minimum among:

- floor thickness,
- hopper transverse web thickness,
- girder thickness,

t_{IB} = inner bottom plating.

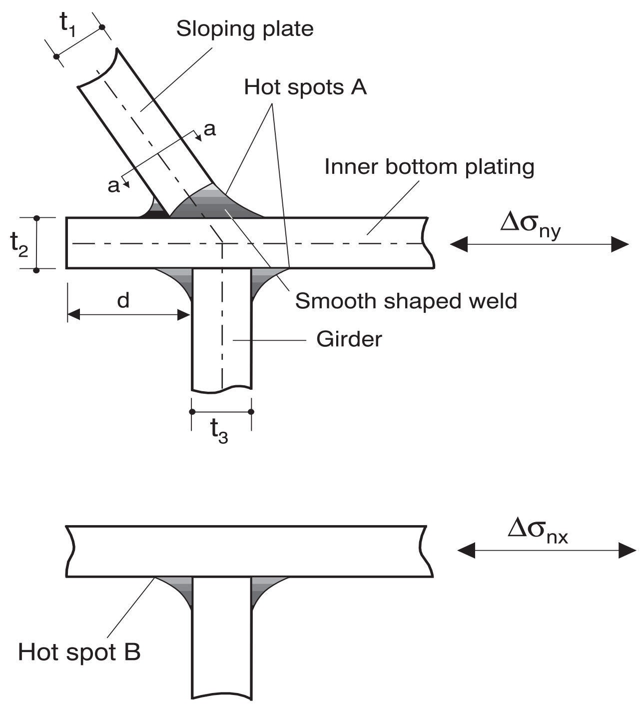
SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $d \leq 40$ mm. • Transverse brackets extended to the closest longitudinals to be fitted on each side of the girder, at mid-span between floors. • Thickness of these brackets, in mm $\geq 9 + 0{,}03\ L_1\ k^{1/2}$.	Fatigue check to be carried out for $L \geq 170$ m: K_{SY} = 3,85 K_{SX} = 1,30 K_{SYX} = 4,50
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between floor and hopper transverse web $\leq t / 3$. • In floor or transverse webs, in way of the bent area, scallops to be avoided or closed by collar plates.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - floors to be connected with full penetration welding to the inner bottom plating for a length $\geq 5\ t_{IB}$,
  - where girder is welded within the bent area, welding procedures to be submitted to the Society for review.
- Material requirements:
  - where girder is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.

Table 36 : LIQUEFIED GAS CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates	Sheet 4.5



Section a - a

Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY}$
- At hot spot B:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX} + K_{SYX} \cdot \Delta\sigma_{nY}$

t_A = min (t_1 , t_2 , t_3),
t_B = minimum among:

- floor thickness,
- hopper transverse web thickness,
- t_3.

SCANTLINGS:	FATIGUE:
d ≥ 50 mm.	Fatigue check to be carried out for L ≥ 170 m: K_{SY} = 3,85 where closed scallops 5,40 where open scallops K_{SX} = 1,30 K_{SYX} = 2,00

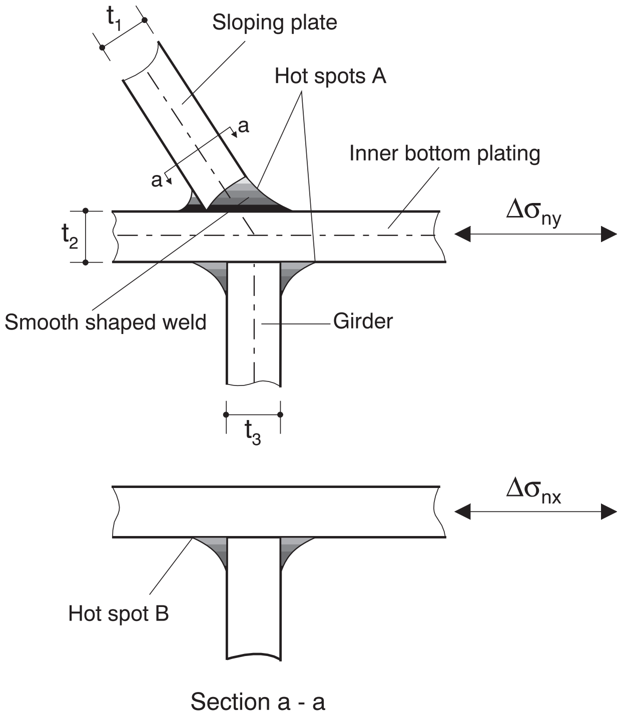
CONSTRUCTION:	NDE:
• Misalignment (median lines) between girder and sloping plate ≤ t_A / 3, max 6 mm. • Misalignment (median lines) between floor and hopper transverse web ≤ t_B / 3, max 6 mm.	The following NDE are required: • VE 100%, • UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

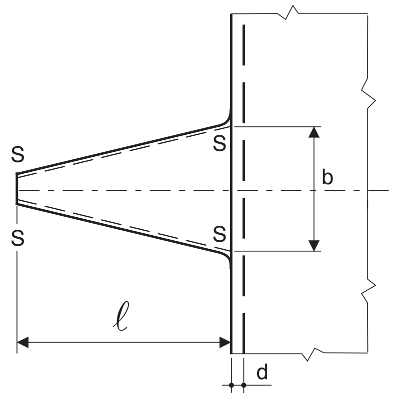
WELDING AND MATERIALS:

- Welding requirements:
  - sloping plate to be connected with full penetration welding to inner bottom plating, except in way of void spaces where partial penetration may be accepted,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating on tank side.
- Material requirements:
  - the strake of inner bottom plating in way of the connection is to be of Z25/ZH25 or of a steel of the same mechanical performances. In particular cases, grade E/EH low temperature steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review.

Table 37 : LIQUEFIED GAS CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Prolonging brackets	Sheet 4.6





Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY}$
- At hot spot B:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX} + K_{SYX} \cdot \Delta\sigma_{nY}$

$t_A = \min(t_1, t_2, t_3)$,
t_B = minimum among:

- floor thickness,
- hopper transverse web thickness,
- t_3.

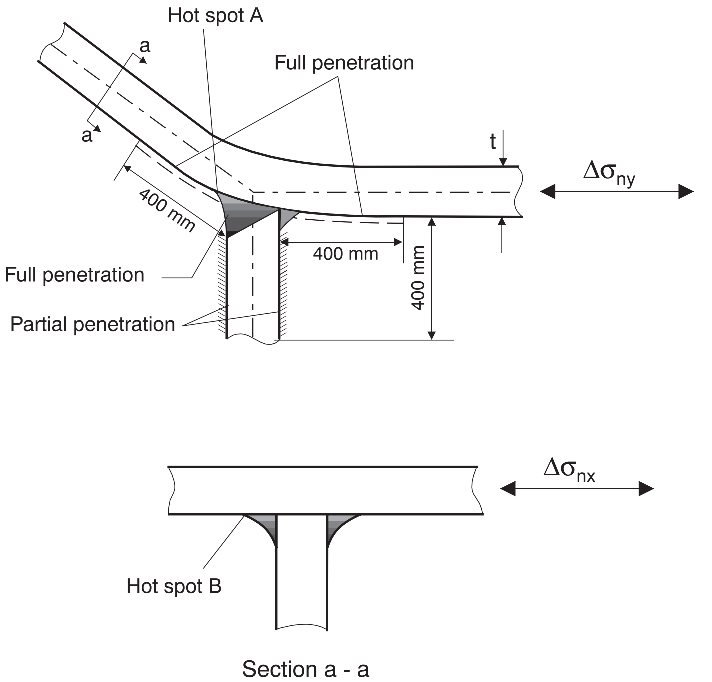
SCANTLINGS:	FATIGUE:
• Inner bottom plating to be prolonged within the hopper tank structure by brackets as shown in the sketch. • $d \geq 50$ mm. • Guidance values, to be confirmed by calculations carried out according to Ch 7, Sec 3: - thickness of the above brackets $\geq t_2$, - $b \geq 0{,}4$ times the floor spacing, - $\ell \geq 1{,}5\ b$.	Fatigue check to be carried out for $L \geq 170$ m: K_{SY} = 2,4 where closed scallops 3,4 where open scallops K_{SX} = 1,3 K_{SYX} = 1,5
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between girder and sloping plate $\leq t_A / 3$, max 6 mm. • Misalignment (median lines) between floor and hopper transverse web $\leq t_B / 3$, max 6 mm.	The following NDE are required: • VE 100%, • UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirements:
  - sloping plate to be connected with full penetration welding to inner bottom plating, except in way of void spaces where partial penetration may be accepted,
  - prolonging brackets to be connected with full penetration welding to inner bottom plating,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating on tank side.
- Material requirements:
  - the strake of inner bottom plating in way of the connection is to be of Z25/ZH25 or of a steel of the same mechanical performances. In particular cases, grade E/EH low temperature steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review,
  - material properties of prolonging brackets to be not less than those of the inner bottom plating.

Table 38 : LIQUEFIED GAS CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Radiused construction	Sheet 4.7



Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY}$
- At hot spot B:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX} + K_{SYX} \cdot \Delta\sigma_{nY}$

t_A = minimum thickness between those of the girder and sloping plate,
t_B = minimum among:
- floor thickness,
- hopper transverse web thickness,
- girder thickness.

SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • Transverse brackets extended to the closest longitudinals to be fitted on each side of the girder, at mid-span between floors. • Thickness of these brackets, in mm ≥ 9 + 0,03 L_1 $k^{1/2}$.	Fatigue check to be carried out for L ≥ 170 m: K_{SY} = 3,15 K_{SX} = 1,30 K_{SYX} = 2,05

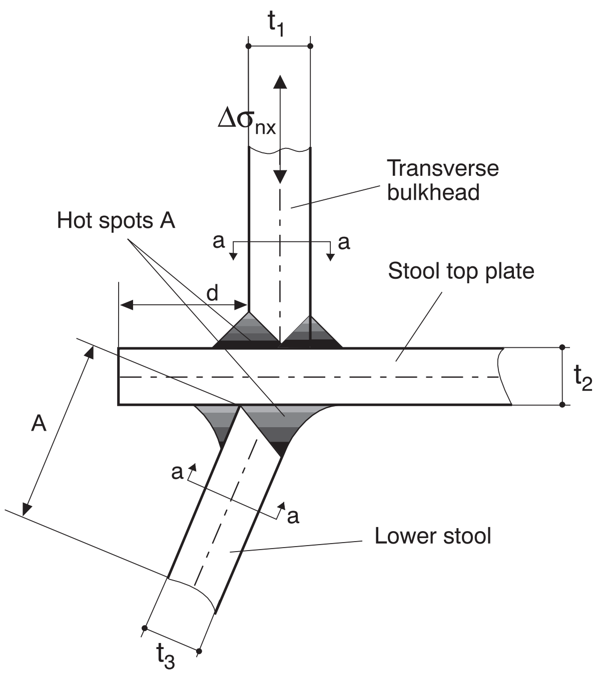
CONSTRUCTION:	NDE:
• Misalignment (median lines) between girder and sloping plate ≤ t_A / 3. • Misalignment (median lines) between floor and hopper transverse web ≤ t_B / 3. • In floor or transverse webs, in way of the bent area, scallops to be avoided or closed by collar plates.	The following NDE are required: • VE 100%, • UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

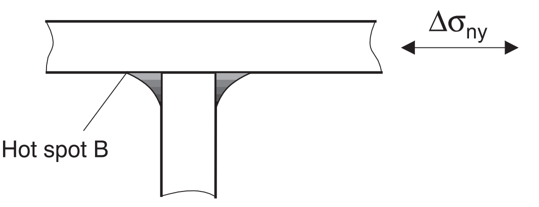
WELDING AND MATERIALS:

- Welding requirements:
  - floors to be connected (see sketches):
    - ♦ with full penetration welding to the inner bottom for a length ≥ 400 mm,
    - ♦ with partial penetration welding to the girder for a length ≥ 400 mm,
    - ♦ with continuous fillet welding in the remaining areas,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - welding procedures of longitudinal girder to the bent plate to be submitted to the Society for review, with evidence given that there is no risk of ageing after welding,
  - weld finishing of butt welds well faired to the inner bottom plating on ballast tank,
  - fair shape of fillet at hot spots.
- Material requirements:
  - the radiused construction may be accepted provided that the bent plate is of grade E or EH and the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.

Table 39 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads	Sheet 5.1





Section a - a

A = distance to be taken not less than the spacing of bulkhead vertical webs

Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min(t_1, t_2, t_3)$

t_B = minimum among:

- thickness of member above stool top plate,
- thickness of member below stool top plate,
- t_2 .

SCANTLINGS:	FATIGUE:
• $d \geq 1{,}5\ t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs.	Fatigue check to be carried out for L ≥ 170 m: K_{SX} = 3,85 K_{SY} = 1,30 K_{SXY} = 2,00

CONSTRUCTION:	NDE:
• Misalignment (median lines) between bulkhead plating and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between members above and below stool top plate $\leq t_B / 3$.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

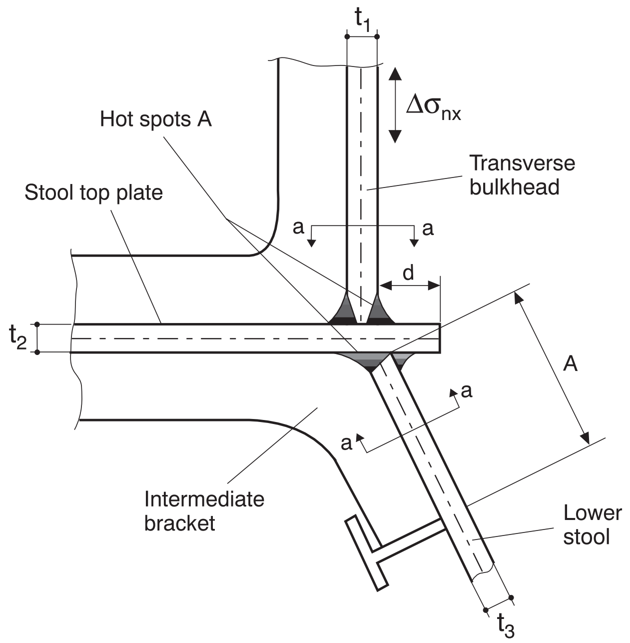
WELDING AND MATERIALS:

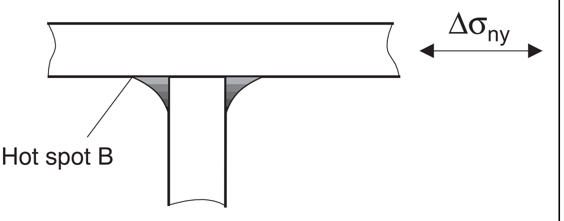
- Welding requirements:
  - bulkhead and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the stool top plate,
  - weld finishing well faired to the stool top plate.
- Material requirements:
  - the stool top plate is recommended to be Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - ♦ the stool top plate,
    - ♦ the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating.

Table 40 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads in way of intermediate brackets	Sheet 5.2





Section a - a

A = distance to be taken not less than the spacing of bulkhead vertical webs

Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min (t_1 , t_2 , t_3)$

t_B = minimum among:

- thickness of member above stool top plate,
- thickness of intermediate bracket,
- t_2 .

SCANTLINGS:	FATIGUE:
• $d \geq 1,5\ t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above stool top plate to be not less than that of bulkhead vertical webs.	Fatigue check to be carried out for $L \geq 170$ m: $K_{SX} = 3,55$ $K_{SY} = 1,30$ $K_{SXY} = 1,75$

CONSTRUCTION:	NDE:
• Misalignment (median lines) between bulkhead plating and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between intermediate bracket and member above stool top plate $\leq t_B / 3$. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the stool side plating and the stool top plate.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

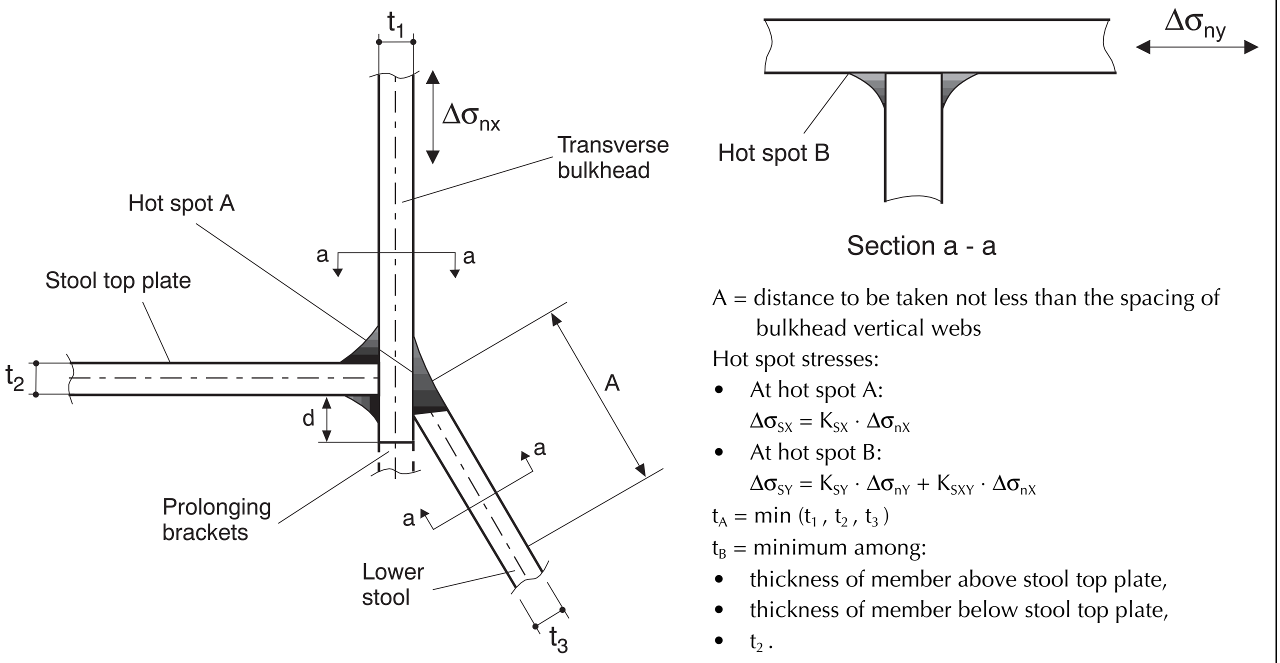
WELDING AND MATERIALS:

- Welding requirements:
  - bulkhead and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - brackets to be connected with continuous fillet welding to plating and stiffeners,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the stool top plate,
  - weld finishing well faired to the stool top plate.
- Material requirements:
  - the stool top plate is recommended to be Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - ♦ the stool top plate,
    - ♦ the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating.

Table 41 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	**Connection of lower stools with plane bulkheads - Prolonging brackets**	**Sheet 5.3**



A = distance to be taken not less than the spacing of bulkhead vertical webs

Hot spot stresses:
- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min(t_1, t_2, t_3)$

t_B = minimum among:
- thickness of member above stool top plate,
- thickness of member below stool top plate,
- t_2 .

SCANTLINGS:	**FATIGUE:**
• $d \geq 50$ mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of prolonging brackets $\geq t_1$. • Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs.	Fatigue check to be carried out for $L \geq 170$ m: $K_{SX} = 2{,}4$ $K_{SY} = 1{,}3$ $K_{SXY} = 1{,}5$
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between stool top plate and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between members above and below stool top plate $\leq t_B / 3$.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

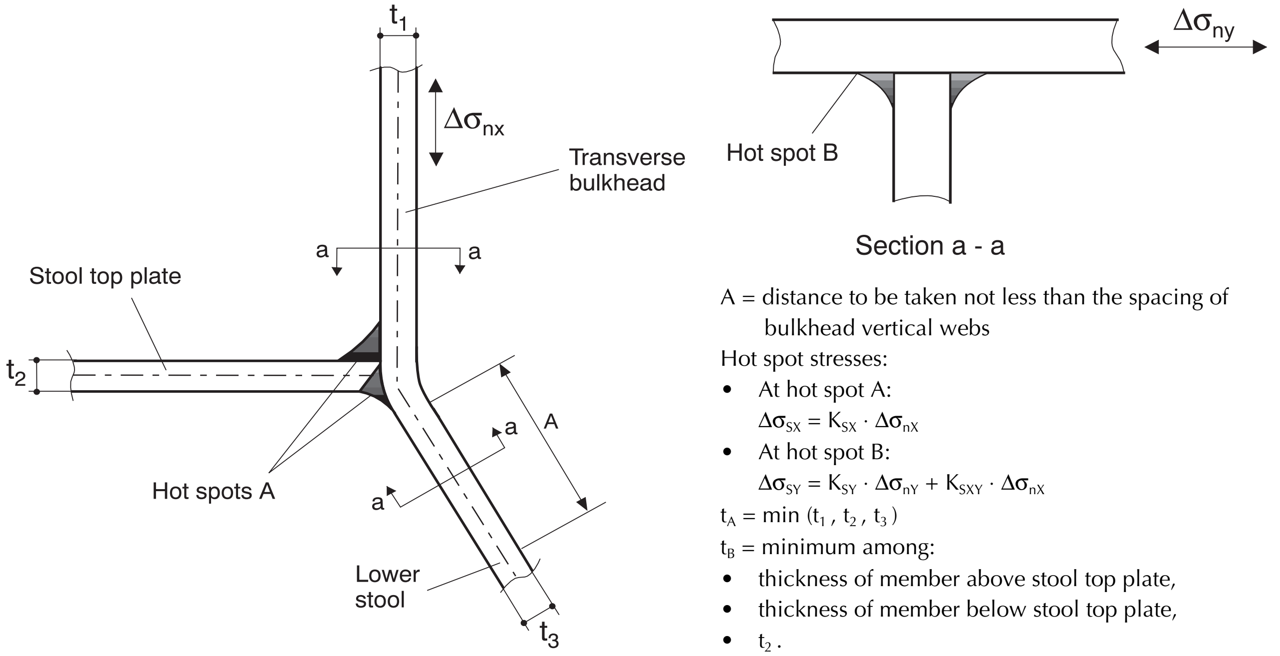
WELDING AND MATERIALS:

- Welding requirements:
  - stool side plating to be connected with full penetration welding to the bulkhead plating. Root gap to be checked along the production steps as appropriate,
  - brackets to be connected with full penetration welding to transverse bulkhead plating,
  - full penetration weld of stool side plating to bulkhead plating to be welded first,
  - welding sequence against the risk of lamellar tearing in the bulkhead plating is recommended.
- Material requirements:
  - the lower strake of transverse bulkhead plating is recommended to be Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the strake in way of the weld is required prior to and after welding,
  - material properties of:
    - ♦ the stool top plate,
    - ♦ the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating,
  - material properties of prolonging brackets to be not less than those of the bulkhead plating.

Table 42 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads - Radiused construction	Sheet 5.4



A = distance to be taken not less than the spacing of bulkhead vertical webs

Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min (t_1 , t_2 , t_3)$

t_B = minimum among:

- thickness of member above stool top plate,
- thickness of member below stool top plate,
- t_2 .

SCANTLINGS:

- Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs.

FATIGUE:

Fatigue check to be carried out for L ≥ 170 m:

K_{SX} = 3,30

K_{SY} = 1,30

K_{SXY} = 2,25

CONSTRUCTION:

- Misalignment (median lines) between stool top plate and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between members above and below stool top plate $\leq t_B / 3$.
- If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings.
- Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate.

NDE:

The following NDE are required:

- VE 100%,
- UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

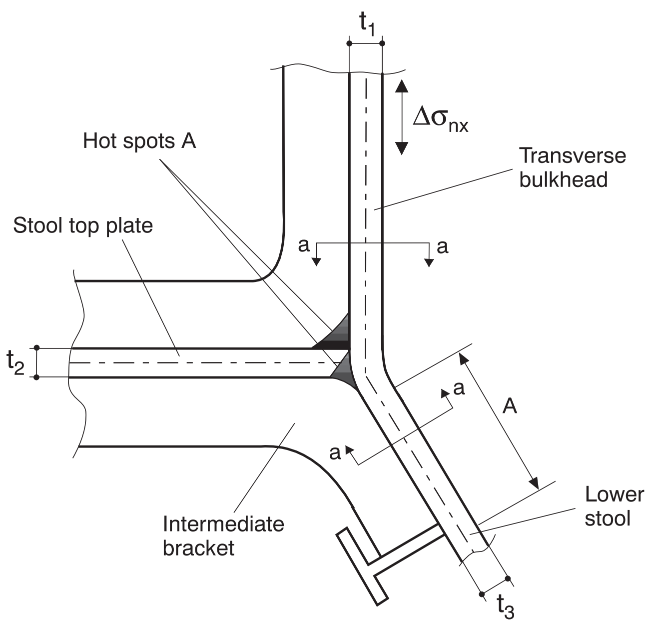
WELDING AND MATERIALS:

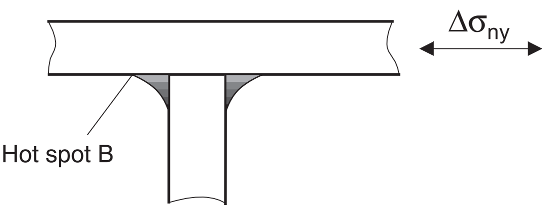
- Welding requirements:
  - welding sequence against the risk of lamellar tearing in the bulkhead plate is recommended,
  - weld finishing well faired to the bulkhead plating and stool side plating.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.
  - material properties of:
    - ♦ the stool top plate,
    - ♦ the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating.

Table 43 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads in way of intermediate brackets - Radiused construction	Sheet 5.5





Section a - a

A = distance to be taken not less than the spacing of bulkhead vertical webs

Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min (t_1 , t_2 , t_3)$

t_B = minimum among:

- thickness of member above stool top plate,
- thickness of intermediate bracket,
- t_2 .

SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above stool top plate to be not less than that of bulkhead vertical webs.	Fatigue check to be carried out for L≥170m: K_{SX} = 3,15 K_{SY} = 1,30 K_{SXY} = 2,05

CONSTRUCTION:	NDE:
• Misalignment (median lines) between stool top plate and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between intermediate bracket and member below stool top plate $\leq t_B / 3$. • If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the stool top plate and the bulkhead plating. • Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

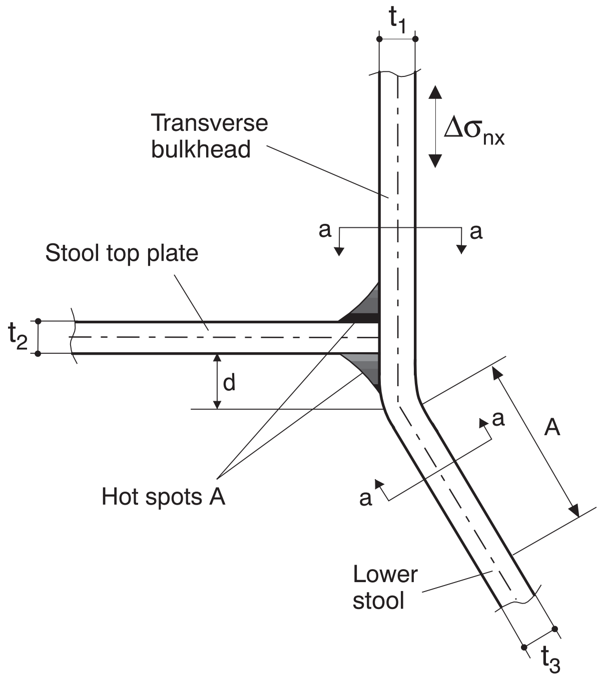
WELDING AND MATERIALS:

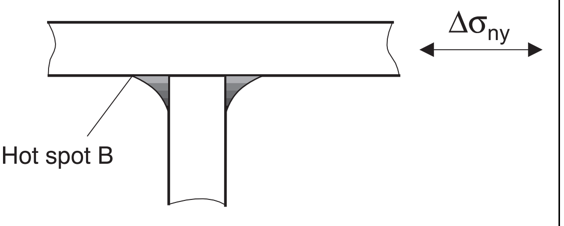
- Welding requirements:
  - brackets to be connected with continuous fillet welding to plating and stiffeners,
  - welding sequence against the risk of lamellar tearing in the bulkhead plate is recommended,
  - weld finishing well faired to the bulkhead plating and stool side plating.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation.
  - material properties of:
    - ♦ the stool top plate,
    - ♦ the portion A of the stool side plating,

    to be not less than those of the transverse bulkhead plating.

Table 44 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads - Radiused construction	Sheet 5.6





Section a - a

A = distance to be taken not less than the spacing of bulkhead vertical webs

Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

t = minimum among:

- thickness of member above stool top plate,
- thickness of member below stool top plate,
- t_2 .

SCANTLINGS:

- Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan.
- $d \leq 40$ mm.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs.

FATIGUE:

Fatigue check to be carried out for $L \geq 170$ m:

$K_{SX} = 4,50$
$K_{SY} = 1,30$
$K_{SXY} = 5,60$

CONSTRUCTION:

- Misalignment (median lines) between members above and below stool top plate $\leq t / 3$.
- If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings.
- Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate.

NDE:

The following NDE are required:

- VE 100%,
- UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

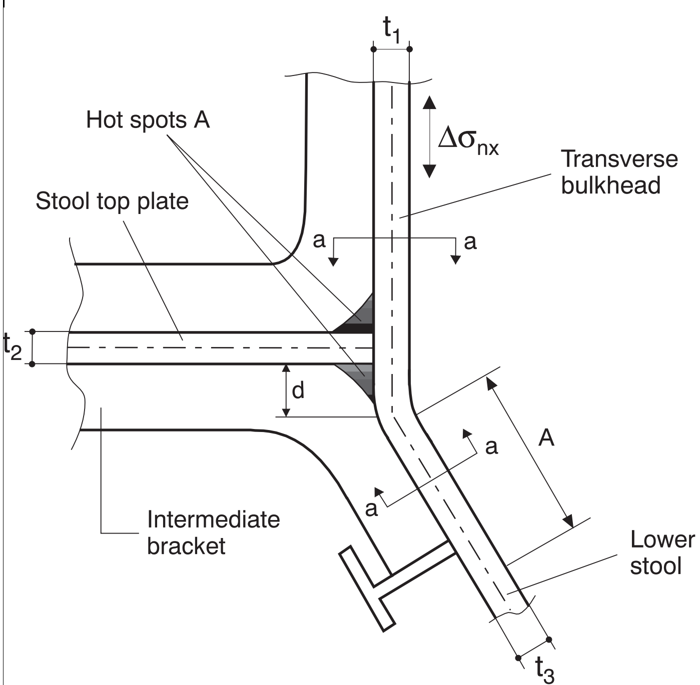
Material requirements:

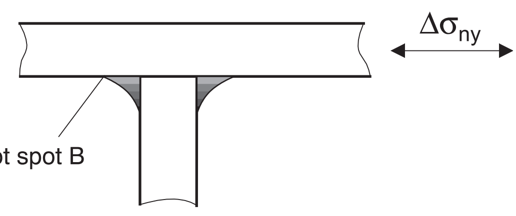
- where stool top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation,
- material properties of:
  - ♦ the stool top plate,
  - ♦ the portion A of the stool side plating,

  to be not less than those of the transverse bulkhead plating.

Table 45 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads in way of intermediate brackets - Radiused construction	Sheet 5.7





Section a - a

A = distance to be taken not less than the spacing of bulkhead vertical webs

Hot spot stresses:
- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

t = minimum among:
- thickness of member above stool top plate,
- thickness of intermediate bracket,
- t_2 .

SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $d \leq 40$ mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above stool top plate to be not less than that of bulkhead vertical webs.	Fatigue check to be carried out for $L \geq 170$ m: $K_{SX} = 3{,}85$ $K_{SY} = 1{,}30$ $K_{SXY} = 4{,}50$

CONSTRUCTION:	NDE:
• Misalignment (median lines) between intermediate bracket and member above stool top plate $\leq t / 3$. • If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the stool top plate and the bulkhead plating. • Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

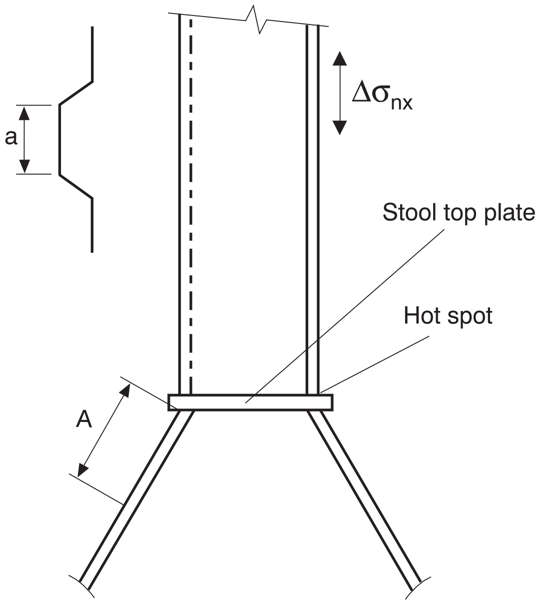
WELDING AND MATERIALS:

Material requirements:
- where stool top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation,
- material properties of:
  - ♦ the stool top plate,
  - ♦ the portion A of the stool side plating,

  to be not less than those of the transverse bulkhead plating.

Table 46 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads	Sheet 5.8



$A \geq a$

Hot spot stress:
$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,

$t = \min (t_F , t_T , t_S)$.

SCANTLINGS:	FATIGUE:
• $t_T \geq t_F$. • $t_S \geq t_F$ in portion A.	Fatigue check to be carried out for L ≥ 170 m: K_{SX} = 2,35
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between corrugation flanges and stool side plating ≤ t / 3. • Distance from the edge of the stool top plate to the surface of the corrugation flanges ≥ 1,5 t_F. • Corrugation radius according to Ch 4, Sec 7, [3.1.3].	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

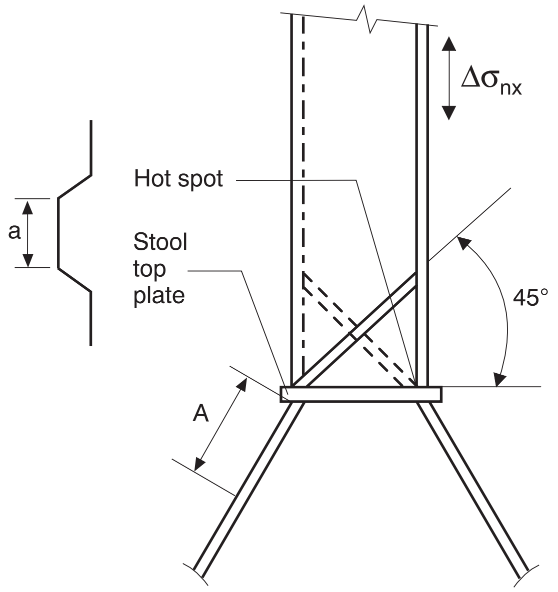
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - welding sequence against the risk of lamellar tearing,
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - ♦ the stool top plate,
    - ♦ the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 47 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Shedder plates 45°	Sheet 5.9



$A \geq a$

Hot spot stress:
$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_{SH} = shedder plate thickness,

$t_A = \min(t_F, t_T, t_S)$

$t_B = \min(t_{SH}, t_T, t_S)$.

SCANTLINGS:

- $t_T \geq t_F$.
- $t_S \geq t_F$ in portion A.
- $t_{SH} \geq 0{,}75\ t_F$.

FATIGUE:

Fatigue check to be carried out for $L \geq 170$ m:
$K_{SX} = 1{,}35$

CONSTRUCTION:

- Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$.
- Knuckled shedder plates are to be avoided.
- Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1{,}5\ t_F$.
- Corrugation radius according to Ch 4, Sec 7, [3.1.3].
- In ships with service notations **combination carrier**, **oil tanker** or **chemical tanker**, closed spaces to be filled with suitable compound compatible with the products carried.

NDE:

The following NDE are required:
- VE 100%,
- UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

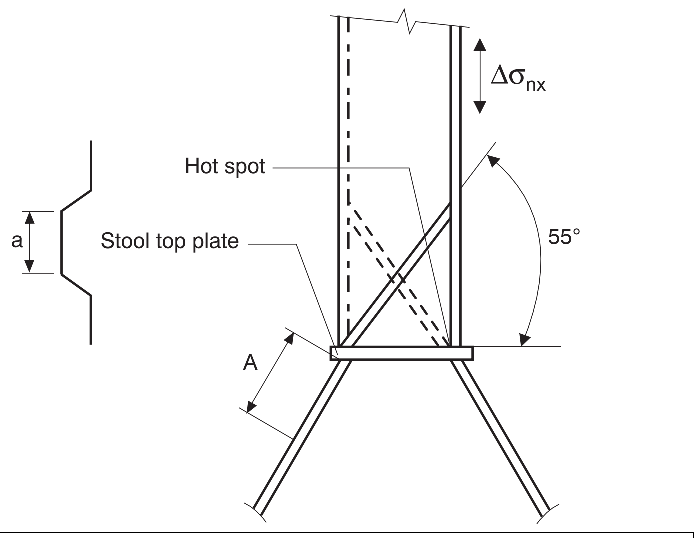
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate,
  - welding sequence against the risk of lamellar tearing,
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - ♦ the shedder plates,
    - ♦ the stool top plate,
    - ♦ the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 48 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Shedder plates 55°	Sheet 5.10



$A \geq a$

Hot spot stress:
$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_{SH} = shedder plate thickness,

$t_A = \min (t_F , t_T , t_S)$,

$t_B = \min (t_{SH} , t_T , t_S)$.

SCANTLINGS:

- $t_T \geq t_F$.
- $t_S \geq t_F$ in portion A.
- $t_{SH} \geq 0,75\ t_F$.

FATIGUE:

Fatigue check to be carried out for L ≥ 170 m:
$K_{SX} = 1,25$

CONSTRUCTION:

- Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$.
- Knuckled shedder plates are to be avoided.
- Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5\ t_F$.
- Corrugation radius according to Ch 4, Sec 7, [3.1.3].
- In ships with service notations **combination carrier**, **oil tanker** or **chemical tanker**, closed spaces to be filled with suitable compound compatible with the products carried.

NDE:

The following NDE are required:
- VE 100%,
- UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

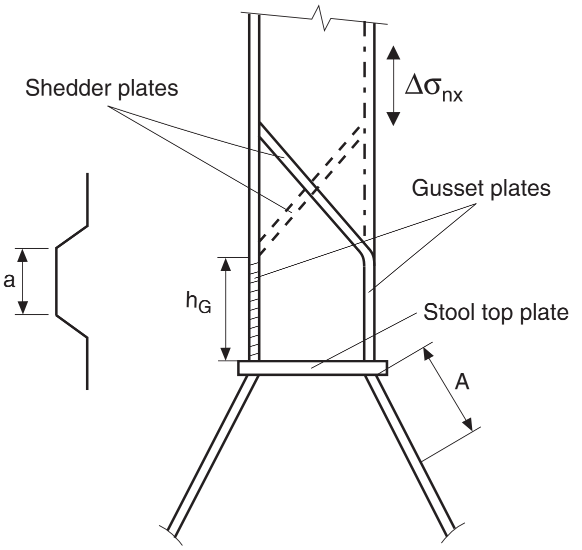
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate,
  - welding sequence against the risk of lamellar tearing,
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - the shedder plates,
    - the stool top plate,
    - the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 49 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Gusset and shedder plates	Sheet 5.11



$A \geq a$

Hot spot stress:
$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_G = gusset plate thickness,
t_{SH} = shedder plate thickness,

$t_A = \min (t_F , t_T , t_S)$,

$t_B = \min (t_G , t_T , t_S)$.

SCANTLINGS:	FATIGUE:
• $t_T \geq t_F$. • $t_S \geq t_F$ in portion A. • $t_G \geq t_F$. • $t_{SH} \geq 0{,}75\ t_F$. • $h_G \geq a / 2$.	Fatigue check not required.

CONSTRUCTION:	NDE:
• Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between lower edge of gusset plates and stool side plating $\leq t_B / 3$. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1{,}5\ t_F$. • Corrugation radius according to Ch 4, Sec 7, [3.1.3]. • In ships with service notations **combination carrier**, **oil tanker** or **chemical tanker**, closed spaces to be filled with suitable compound compatible with the products carried.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

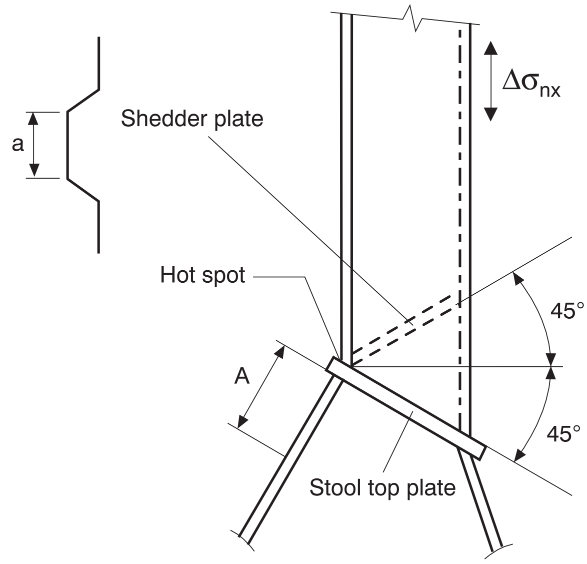
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - gusset plates generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings) and with one side penetration, or equivalent, to corrugations and shedder plates,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and gusset plates,
  - welding sequence against the risk of lamellar tearing,
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - ♦ the gusset plates,
    - ♦ the shedder plates,
    - ♦ the stool top plate,
    - ♦ the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 50 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Sloping stool top plate	Sheet 5.12



$A \geq a$

Hot spot stress:
$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_{SH} = shedder plate thickness,

$t_A = \min (t_F , t_T , t_S)$.

$t_B = \min (t_{SH} , t_T , t_S)$.

SCANTLINGS:	FATIGUE:
• $t_T \geq t_F$. • $t_S \geq t_F$ in portion A. • $t_{SH} \geq 0,75\ t_F$.	Fatigue check to be carried out for $L \geq 170$ m: $K_{SX} = 1,90$
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$. • Knuckled shedder plates are to be avoided. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5\ t_F$. • Corrugation radius according to Ch 4, Sec 7, [3.1.3]. • In ships with service notations **combination carrier**, **oil tanker** or **chemical tanker**, closed spaces to be filled with suitable compound compatible with the products carried.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

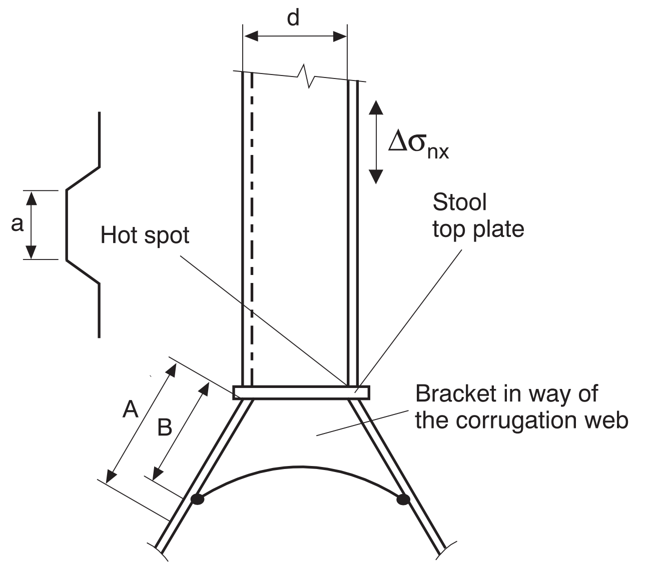
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate,
  - welding sequence against the risk of lamellar tearing
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - ♦ the shedder plates,
    - ♦ the stool top plate,
    - ♦ the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 51 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Brackets below stool top plate	Sheet 5.13



$A \geq a$,
B = bracket dimension.

Hot spot stress:
$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_W = corrugation web thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_B = bracket thickness,

$t_A = \min(t_F, t_T, t_S)$.

$t_B = \min(t_W, t_T, t_S)$.

SCANTLINGS:	FATIGUE:
• $t_T \geq t_F$ • $t_S \geq t_F$ in portion A • $t_B \geq t_W$ • $B \geq d$	Fatigue check to be carried out for $L \geq 170$ m: $K_{SX} = 1{,}95$

CONSTRUCTION:	NDE:
• Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between corrugation webs and brackets below stool top plate $\leq t_B / 3$. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1{,}5\ t_F$. • Corrugation radius according to Ch 4, Sec 7, [3.1.3].	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

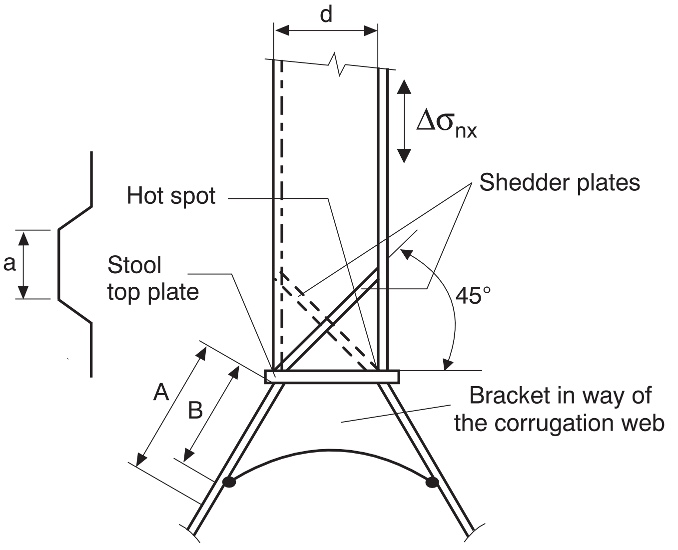
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - welding sequence against the risk of lamellar tearing,
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - ♦ the stool top plate,
    - ♦ the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 52 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Shedder plates 45° and brackets below stool top plate	Sheet 5.14



$A \geq a$,
B = bracket dimension.

Hot spot stress:
$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_W = corrugation web thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_{SH} = shedder plate thickness,
t_B = bracket thickness,

$t_A = \min (t_F , t_T , t_S)$
$t_B = \min (t_{SH} , t_T , t_S)$
$t_C = \min (t_W , t_T , t_B)$.

SCANTLINGS:	FATIGUE:
• $t_T \geq t_F$ • $t_S \geq t_F$ in portion A • $B \geq d$ • $t_{SH} \geq 0,75\ t_F$ • $t_B \geq t_W$	Fatigue check to be carried out for $L \geq 170$ m: $K_{SX} = 1,25$

CONSTRUCTION:	NDE:
• Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$. • Misalignment (median lines) between corrugation webs and brackets below stool top plate $\leq t_C / 3$. • Knuckled shedder plates are to be avoided. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5\ t_F$. • Corrugation radius according to Ch 4, Sec 7, [3.1.3]. • In ships with service notations **combination carrier**, **oil tanker** or **chemical tanker**, closed spaces to be filled with suitable compound compatible with the products carried.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

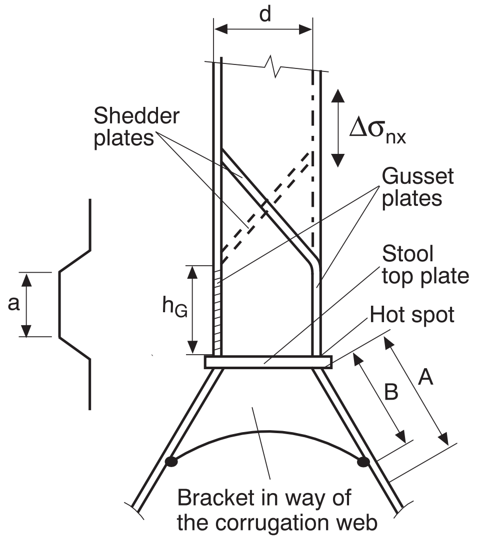
WELDING AND MATERIALS:

- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate,
  - welding sequence against the risk of lamellar tearing
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - ♦ the shedder plates,
    - ♦ the stool top plate,
    - ♦ the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 53 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Gusset and shedder plates and brackets below stool top plate	Sheet 5.15



$A \geq a$,
B = bracket dimension.

Hot spot stress:
$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$

t_F = corrugation flange thickness,
t_W = corrugation web thickness,
t_T = stool top plate thickness,
t_S = stool side plating thickness,
t_G = gusset plate thickness,
t_{SH} = shedder plate thickness,
t_B = bracket thickness,

$t_A = \min (t_F , t_T , t_S)$
$t_B = \min (t_G , t_T , t_S)$
$t_C = \min (t_W , t_T , t_B)$.

SCANTLINGS:

- $t_T \geq t_F$
- $t_S \geq t_F$ in portion A
- $t_G \geq t_F$
- $t_{SH} \geq 0,75\ t_F$
- $t_B \geq t_W$
- $h_G \geq a / 2$
- $B \geq d$

FATIGUE:

Fatigue check not required.

CONSTRUCTION:

- Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$.
- Misalignment (median lines) between lower edge of gusset plates and stool side plating $\leq t_B / 3$.
- Misalignment (median lines) between corrugation webs and brackets below stool top plate $\leq t_C / 3$.
- Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5\ t_F$.
- Corrugation radius according to Ch 4, Sec 7, [3.1.3].
- In ships with service notations **combination carrier**, **oil tanker** or **chemical tanker**, closed spaces to be filled with suitable compound compatible with the products carried.

NDE:

The following NDE are required:
- VE 100%,
- UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

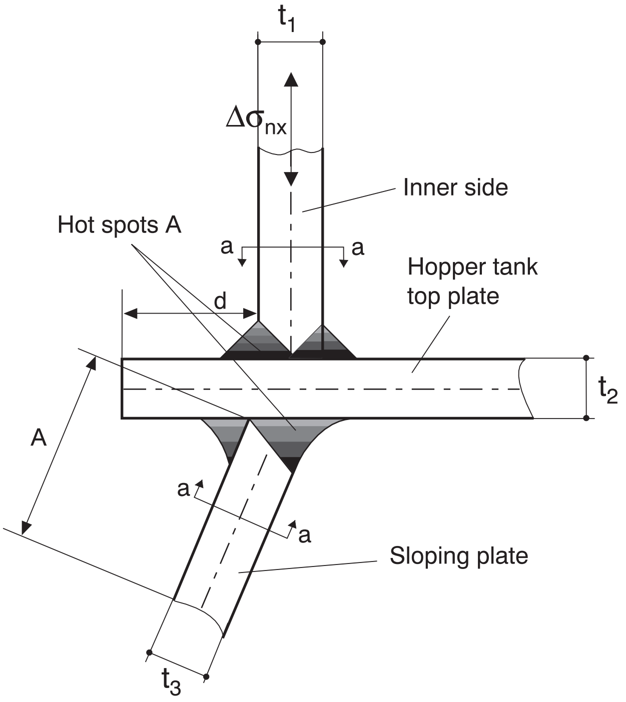
WELDING AND MATERIALS:

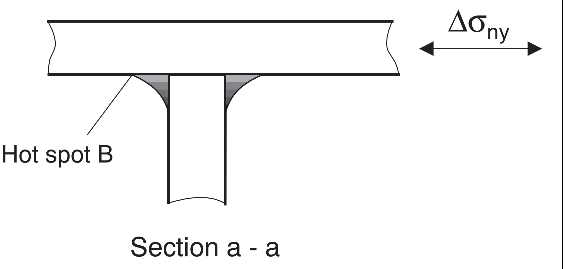
- Welding requirements:
  - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production,
  - gusset plates generally to be connected with full penetration to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings) and with one side penetration, or equivalent, to corrugations and shedder plates,
  - shedder plates to be connected with one side penetration, or equivalent, to corrugations and gusset plates,
  - welding sequence against the risk of lamellar tearing
  - start and stop welding away from the locations of corrugation bents,
  - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating.
- Material requirements:
  - the stool top plate is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of:
    - ♦ the gusset plates,
    - ♦ the shedder plates,
    - ♦ the stool top plate,
    - ♦ the portion A of the stool side plating,

    to be not less than those of the corrugation flanges.

Table 54 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side	Sheet 6.1





A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min (t_1, t_2, t_3)$

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of member below hopper tank top plate,
- t_2 .

SCANTLINGS:	FATIGUE:
• $d \geq 1,5\ t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out for $L \geq 170$ m: $K_{SX} = 3,85$ $K_{SY} = 1,30$ $K_{SXY} = 2,00$

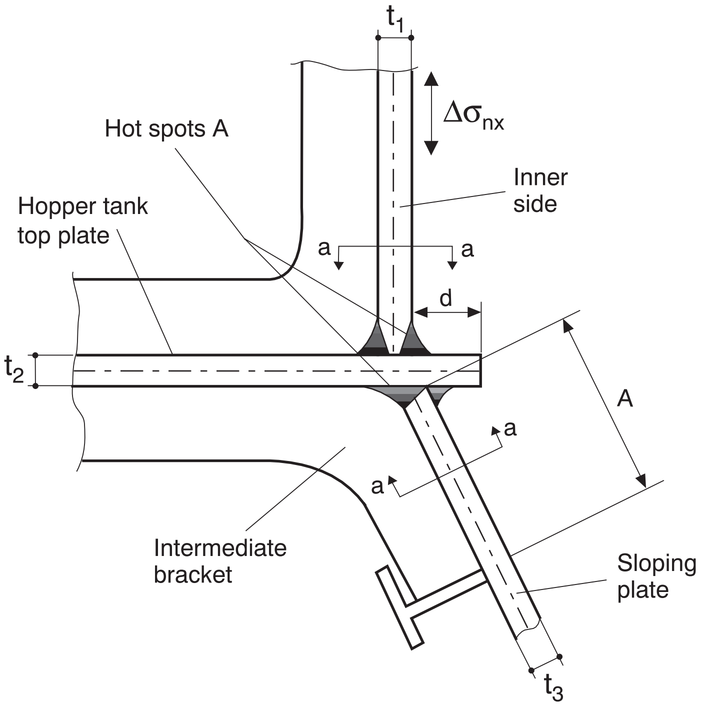
CONSTRUCTION:	NDE:
• Misalignment (median lines) between inner side plating and hopper tank sloping plate $\leq t_A / 3$. • Misalignment (median lines) between members above and below hopper tank top plate $\leq t_B / 3$.	The following NDE are required: • VE 100%, • UE 25% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

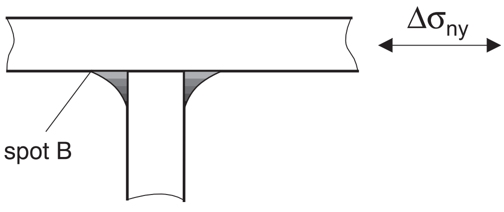
WELDING AND MATERIALS:

- Welding requirements:
  - inner side and hopper tank sloping plate generally to be connected with full penetration welding to hopper tank top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the hopper tank top plate,
  - weld finishing well faired to the hopper tank top plate.
- Material requirements:
  - the hopper tank top plate is recommended to be Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 55 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets	Sheet 6.2





Section a - a

A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min (t_1 , t_2 , t_3)$

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of intermediate bracket,
- t_2 .

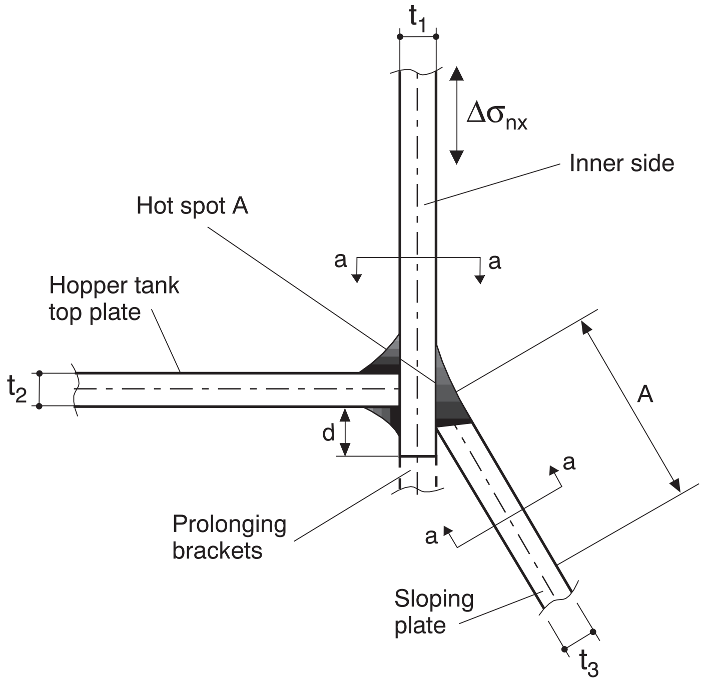
SCANTLINGS:	FATIGUE:
• $d \geq 1{,}5\ t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out for L ≥ 170 m: K_{SX} = 3,55 K_{SY} = 1,30 K_{SXY} = 1,75
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between inner side plating and hopper tank sloping plate $\leq t_A / 3$. • Misalignment (median lines) between intermediate bracket and member above hopper tank top plate $\leq t_B / 3$. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank sloping plate and the hopper tank top plate.	The following NDE are required: • VE 100%, • UE 25% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

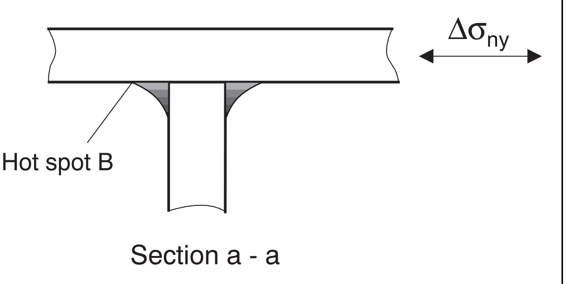
WELDING AND MATERIALS:

- Welding requirements:
  - inner side and hopper tank sloping plate generally to be connected with full penetration welding to hopper tank top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - brackets to be connected with continuous fillet welding to plating and stiffeners,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the hopper tank top plate,
  - weld finishing well faired to the hopper tank top plate.
- Material requirements:
  - the hopper tank top plate is recommended to be Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 56 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side - Prolonging brackets	Sheet 6.3





A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min (t_1 , t_2 , t_3)$

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of member below hopper tank top plate,
- t_2 .

SCANTLINGS:

- $d \geq 50$ mm.
- $t_2 \geq t_1$.
- $t_3 \geq t_1$ in portion A.
- Thickness of prolonging brackets $\geq t_1$.
- Thickness of members above and below hopper tank top plate to be not less than that of side transverses.

FATIGUE:

Fatigue check to be carried out for $L \geq 170$ m:

$K_{SX} = 2,40$

$K_{SY} = 1,30$

$K_{SXY} = 1,50$

CONSTRUCTION:

- Misalignment (median lines) between hopper tank top plate and hopper tank sloping plate $\leq t_A / 3$.
- Misalignment (median lines) between members above and below hopper tank top plate $\leq t_B / 3$.

NDE:

The following NDE are required:

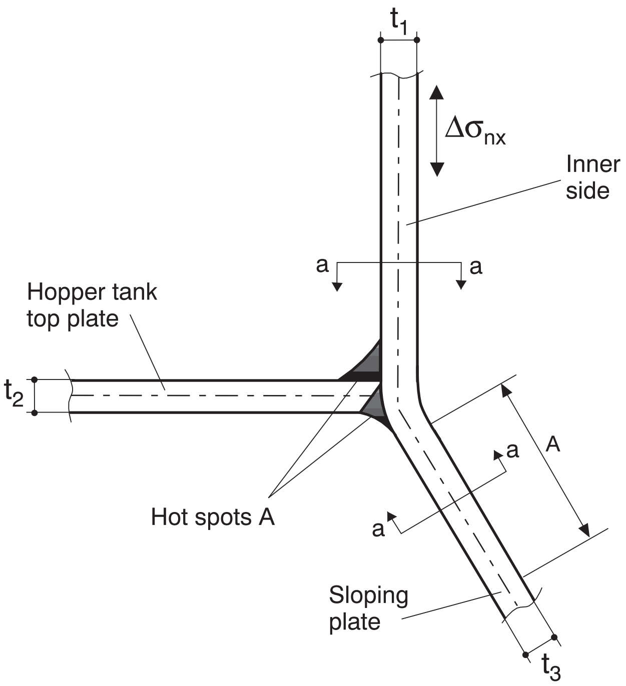
- VE 100%,
- UE 25% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

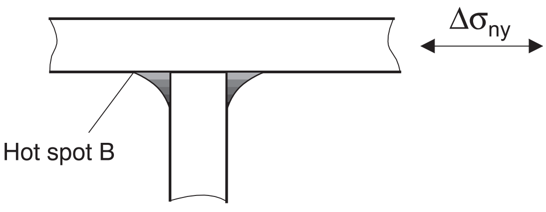
WELDING AND MATERIALS:

- Welding requirements:
  - hopper tank sloping plate to be connected with full penetration welding to the inner side plating. Root gap to be checked along the production steps as appropriate,
  - prolonging brackets to be connected with full penetration welding to inner side plating,
  - full penetration weld of hopper tank sloping plate to inner side plating to be welded first,
  - welding sequence against lamellar tearing in the inner side plating is recommended.
- Material requirements:
  - the lower strake of inner side plating is recommended to be Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the strake in way of the weld is required prior to and after welding,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating,
  - material properties of prolonging brackets to be not less than those of the inner side plating.

Table 57 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side - Radiused construction	Sheet 6.4





Section a - a

A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min(t_1, t_2, t_3)$

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of member below hopper tank top plate,
- t_2 .

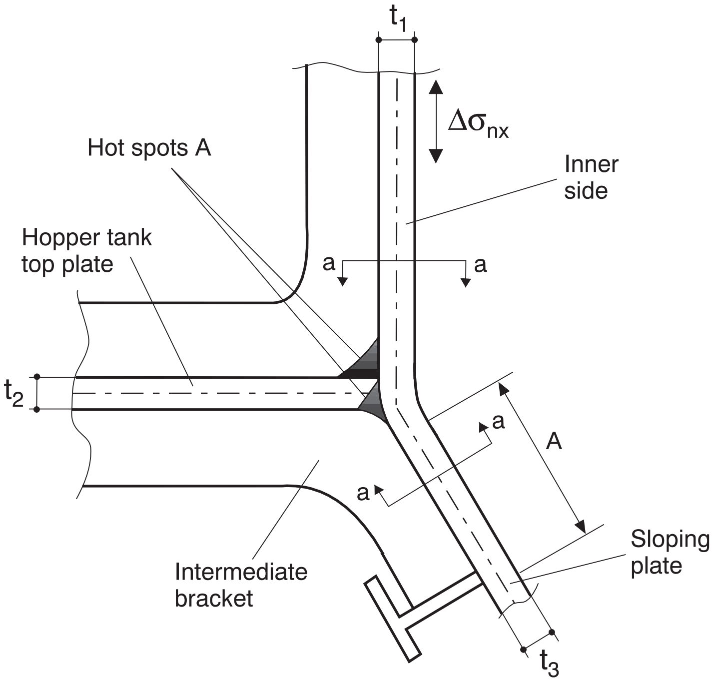
SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out for L ≥ 170 m: K_{SX} = 3,30 K_{SY} = 1,30 K_{SXY} = 2,25
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between hopper tank top plate and hopper tank sloping plate ≤ t_A / 3. • Misalignment (median lines) between members above and below hopper tank top plate ≤ t_B / 3. • If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings. • Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate.	The following NDE are required: • VE 100%, • UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

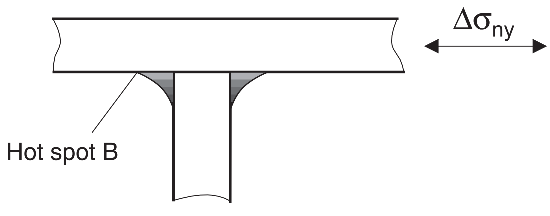
WELDING AND MATERIALS:

- Welding requirements:
  - welding sequence against the risk of lamellar tearing in the inner side plate is recommended,
  - weld finishing well faired to the inner side plating and hopper tank sloping plate.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 58 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets - Radiused construction	Sheet 6.5





Section a - a

A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

t_A = min (t_1 , t_2 , t_3)

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of intermediate bracket,
- t_2 .

SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out for L ≥ 170 m: K_{SX} = 3,15 K_{SY} = 1,30 K_{SXY} = 2,05

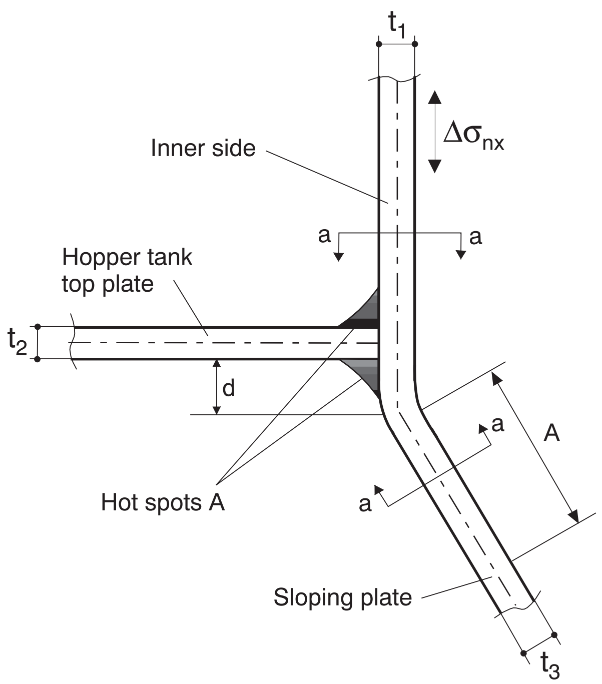
CONSTRUCTION:	NDE:
• Misalignment (median lines) between hopper tank top plate and hopper tank sloping plate ≤ t_A / 3. • Misalignment (median lines) between intermediate bracket and member above hopper tank top plate ≤ t_B / 3. • If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank top plate and the inner side plating. • Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate.	The following NDE are required: • VE 100%, • UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

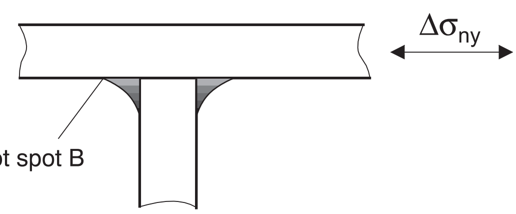
WELDING AND MATERIALS:

- Welding requirements:
  - brackets to be connected with continuous fillet welding to plating and stiffeners,
  - welding sequence against the risk of lamellar tearing in the inner side plate is recommended,
  - weld finishing well faired to the inner side plating and hopper tank sloping plate.
- Material requirements:
  - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 59 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side - Radiused construction	Sheet 6.6





Section a - a

A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

t = minimum among:

- thickness of member above hopper tank top plate,
- thickness of member below hopper tank top plate,
- t_2 .

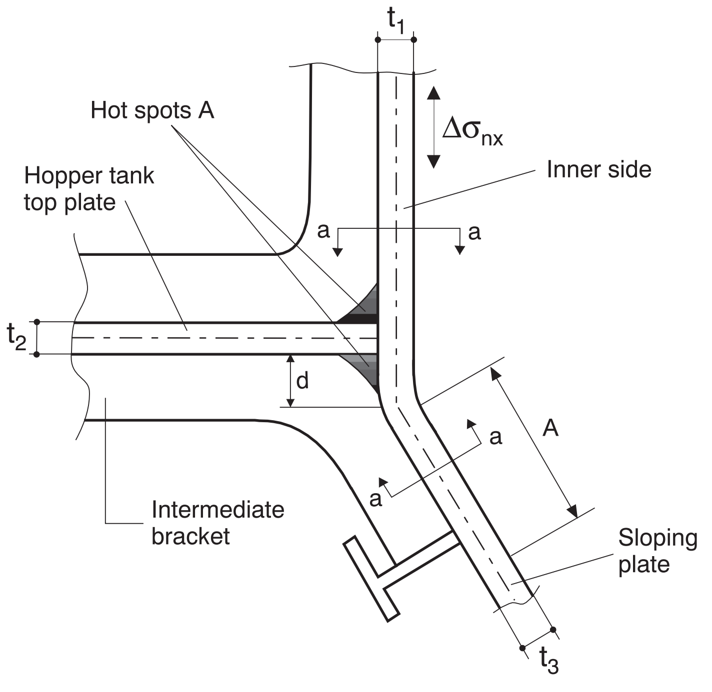
SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • d ≤ 40 mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out for L ≥ 170 m: K_{SX} = 4,50 K_{SY} = 1,30 K_{SXY} = 5,60

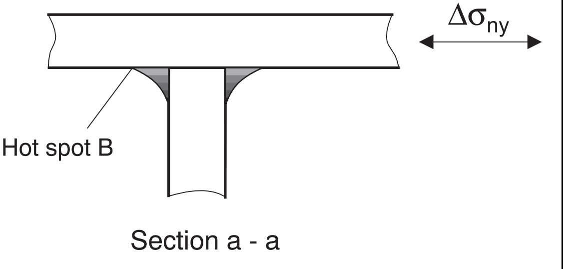
CONSTRUCTION:	NDE:
• Misalignment (median lines) between members above and below hopper tank top plate ≤ t / 3. • If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings. • Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate.	The following NDE are required: • VE 100%, • UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:
Material requirements: - where hopper tank top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation, - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 60 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets - Radiused construction	Sheet 6.7





A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:
- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

t = minimum among:
- thickness of member above hopper tank top plate,
- thickness of intermediate bracket,
- t_2 .

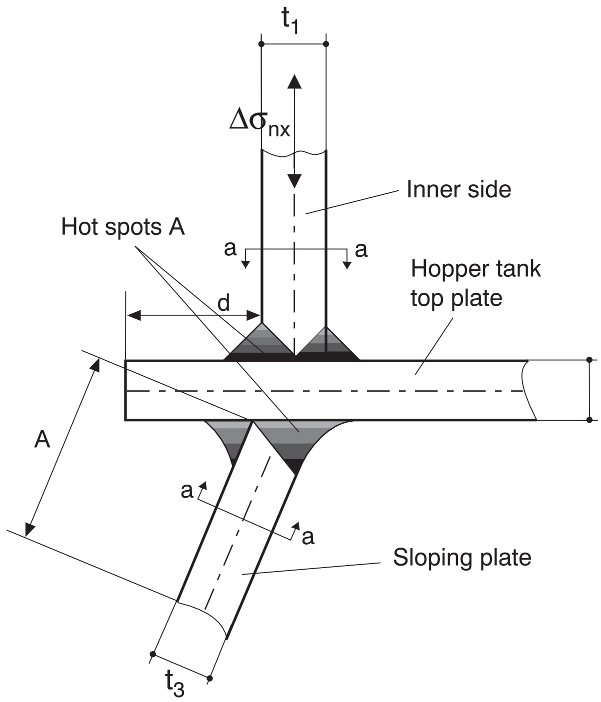
SCANTLINGS:	FATIGUE:
• Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • d ≤ 40 mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out for L ≥ 170 m: K_{SX} = 3,85 K_{SY} = 1,30 K_{SXY} = 4,50
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between intermediate bracket and member above hopper tank top plate ≤ t / 3. • If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank top plate and the inner side plating. • Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate.	The following NDE are required: • VE 100%, • UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears.

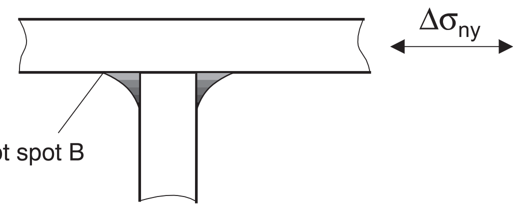
WELDING AND MATERIALS:

Material requirements:
- where hopper tank top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation,
- material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 61 : LIQUEFIED GAS CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side	Sheet 6.8





A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:
- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

$t_A = \min (t_1 , t_2 , t_3)$

t_B = minimum among:
- thickness of member above hopper tank top plate,
- thickness of member below hopper tank top plate,
- t_2 .

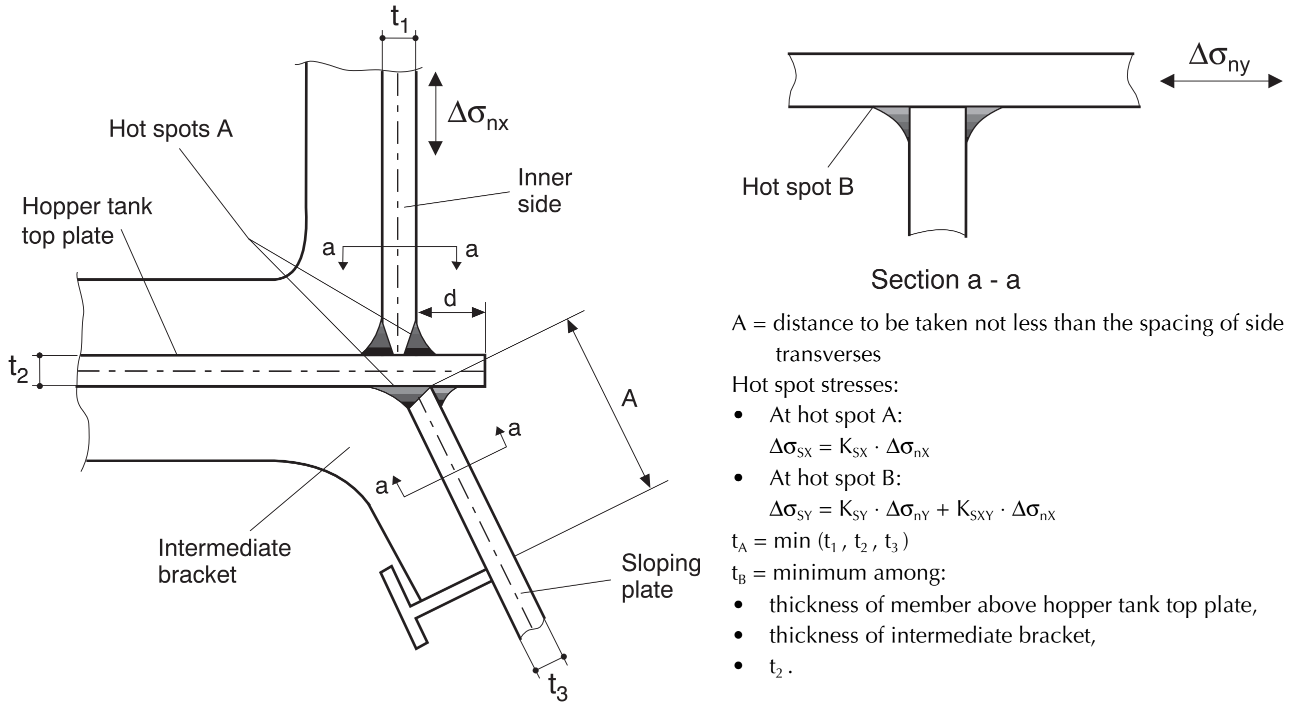
SCANTLINGS:	FATIGUE:
• $d \geq 1,5\ t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out for $L \geq 170$ m: $K_{SX} = 3,85$ $K_{SY} = 1,30$ $K_{SXY} = 2,00$
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between inner side plating and hopper tank sloping plate $\leq t_A / 3$, max 6 mm. • Misalignment (median lines) between members above and below hopper tank top plate $\leq t_B / 3$, max 6 mm.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirements:
  - inner side and hopper tank sloping plate to be connected with full penetration welding to hopper tank top plate, except in way of void spaces where partial penetration may be accepted,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the hopper tank top plate,
  - weld finishing well faired to the hopper tank top plate.
- Material requirements:
  - the hopper tank top plate is to be of Z25/ZH25 or of a steel of the same mechanical performances. In particular cases, grade E/EH low temperature steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

Table 62 : LIQUEFIED GAS CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets	Sheet 6.9



A = distance to be taken not less than the spacing of side transverses

Hot spot stresses:

- At hot spot A:
  $\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{nX}$
- At hot spot B:
  $\Delta\sigma_{SY} = K_{SY} \cdot \Delta\sigma_{nY} + K_{SXY} \cdot \Delta\sigma_{nX}$

t_A = min (t_1 , t_2 , t_3)

t_B = minimum among:

- thickness of member above hopper tank top plate,
- thickness of intermediate bracket,
- t_2 .

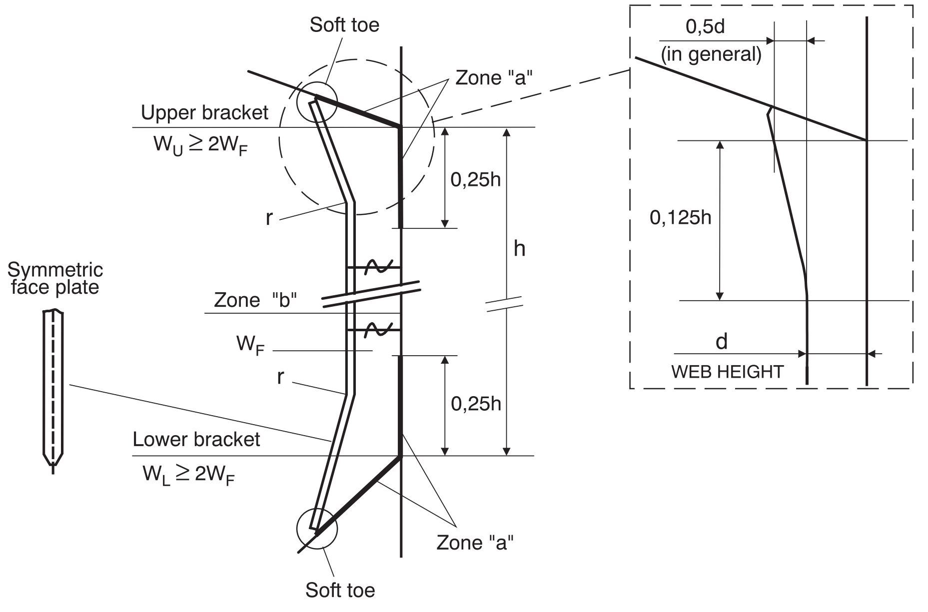
SCANTLINGS:	FATIGUE:
• $d \geq 1,5\ t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses.	Fatigue check to be carried out for L ≥ 170 m: K_{SX} = 3,55 K_{SY} = 1,30 K_{SXY} = 1,75

CONSTRUCTION:	NDE:
• Misalignment (median lines) between inner side plating and hopper tank sloping plate ≤ t_A / 3, max 6 mm. • Misalignment (median lines) between intermediate bracket and member above hopper tank top plate ≤ t_B / 3, max 6 mm. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank sloping plate and the hopper tank top plate.	The following NDE are required: • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirements:
  - inner side and hopper tank sloping plate to be connected with full penetration welding to hopper tank top plate, except in way of void spaces where partial penetration may be accepted,
  - brackets to be connected with continuous fillet welding to plating and stiffeners,
  - approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the hopper tank top plate,
  - weld finishing well faired to the hopper tank top plate.
- Material requirements:
  - the hopper tank top plate is to be of Z25/ZH25 or of a steel of the same mechanical performances. In particular cases, grade E/EH low temperature steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review,
  - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating.

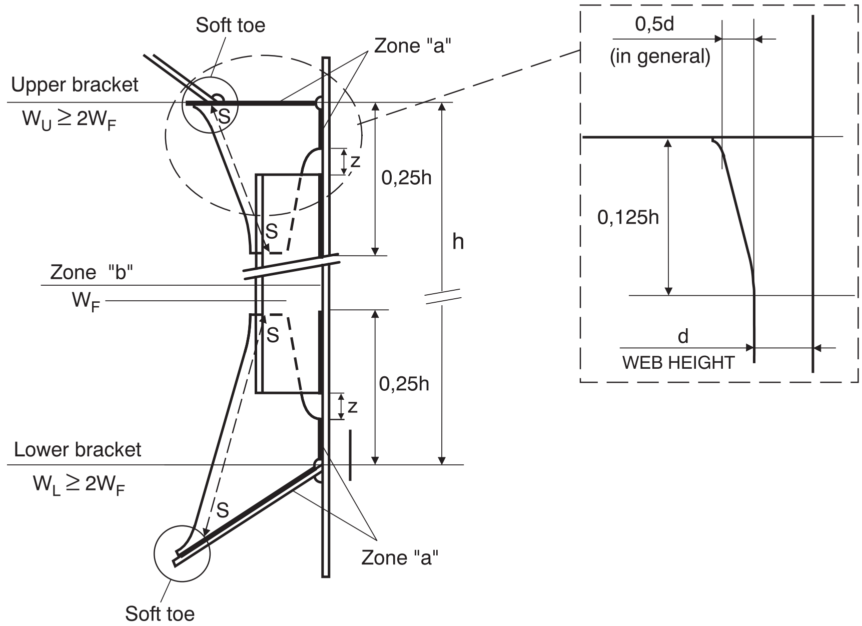
Table 63 : BULK CARRIERS

<table>
<tr><td>AREA 7: Side frames</td><td colspan="2">Connection of side frames with hopper and topside tanks - Symmetric face plate frame with integral brackets</td><td>Sheet 7.1</td></tr>
<tr><td colspan="4">

t_w = fitted thickness, in mm, of side frame web $t_{w,min}$ = (7,0 + 0,03 L_1) mm
b_F = bracket flange width, in mm t_F = bracket flange thickness, in mm.</td></tr>
<tr><td colspan="3">SCANTLINGS:</td><td>FATIGUE:</td></tr>
<tr><td colspan="3">• Thickness of lower bracket, in mm, ≥ max (t_w , $t_{w, min}$ + 2).
• Thickness of upper bracket, in mm, ≥ max (t_w , $t_{w, min}$).
• Section modulus of the frame with the upper or lower bracket, at the locations shown in the sketch, to be not less than twice the section modulus required for the frame mid-span area.
• Dimensions of lower and upper brackets to be not less than those shown in the sketch.
• Structural continuity with the upper and lower end connections of side frames is to be ensured within hopper tanks and upper wing tanks by connecting brackets.
• Frame flange to be curved (not knuckled) at the connection with the end brackets, $r \geq 0,4\, b_F^2 / t_F$.
• Ends of flange to be sniped.</td><td>Fatigue check not required.</td></tr>
<tr><td colspan="2">CONSTRUCTION:</td><td colspan="2">NDE:</td></tr>
<tr><td colspan="2">• Misalignment between frame web and the connecting brackets inside hopper tank and upper wing tank ≤ t / 3, where t is the minimum thickness among those of the connected elements.
• Soft toe: tapering of frame flange at ends: thickness 1:3, width 1:5.</td><td colspan="2">The following NDE are required:
• VE 100%, with particular care for fillet shape and undercuts on the plating at the soft toes,
• ME or dye penetrant depending on the results of VE.</td></tr>
<tr><td colspan="4">WELDING AND MATERIALS:</td></tr>
<tr><td colspan="4">Welding requirements:
- frames and brackets to be connected with continuous fillet welding to side plating, hopper tank and upper wing tank plating, with throat thickness to be not less than:
  ♦ 0,45 t in “zone a”,
  ♦ 0,40 t in “zone b”,
  where t is the minimum thickness between those of the two connected elements,
- welding sequence to minimise restraints at the frame butt joints, i.e.:
  ♦ leaving about 200 mm unwelded, each side of butt joint, of the connections between frame web and side plating and between frame web and flange,
  ♦ performing the frame butt joints,
  ♦ completing the fillet welding,
- turn the fillet weld all around the end of integral brackets and scallops giving an elongated shape, well faired to the plating,
- avoid burned notches at the scallops, if existing, in way of frame flange butt joints; if scallops not adopted, care to be taken to avoid end defects at web butt joints.</td></tr>
</table>

Table 64 : BULK CARRIERS

AREA 7: Side frames	Connection of side frames with hopper and topside tanks - Non symmetric face plate frame with separate brackets	Sheet 7.2



This solution is permitted only for ships less than 190 m in length with side frames built in normal strength steel.

t_w = fitted thickness, in mm, of side frame web

b_F = bracket flange width, in mm

$t_{w,min} = (7,0 + 0,03\ L_1)$ mm

t_F = bracket flange thickness, in mm.

SCANTLINGS:	FATIGUE:
• Thickness of lower bracket, in mm, ≥ max (t_w , $t_{w,\ min}$ + 2). • Thickness of upper bracket, in mm, ≥ max (t_w , $t_{w,\ min}$). • Section modulus of the frame with the upper or lower bracket, at the locations shown in the sketch, to be not less than twice the section modulus required for the frame mid-span area. • Dimensions of lower and upper brackets to be not less than those shown in the sketch. • Structural continuity with the upper and lower end connections of side frames is to be ensured within hopper tanks and upper wing tanks by connecting brackets. • Ends of flange to be sniped. • z ≤ 50 mm.	Fatigue check not required.

CONSTRUCTION:	NDE:
• Misalignment between frame brackets and the connecting brackets inside hopper tank and upper wing tank ≤ t / 3, where t is the minimum thickness among those of the connected elements. • Bracket overlap: ≥ 1,5 d, in mm. • Soft toe: tapering of frame flange at ends: thickness 1:3, width 1:5.	The following NDE are required: • VE 100%, with particular care for fillet shape and undercuts on the plating at the soft toes, • ME or dye penetrant depending on the results of VE.

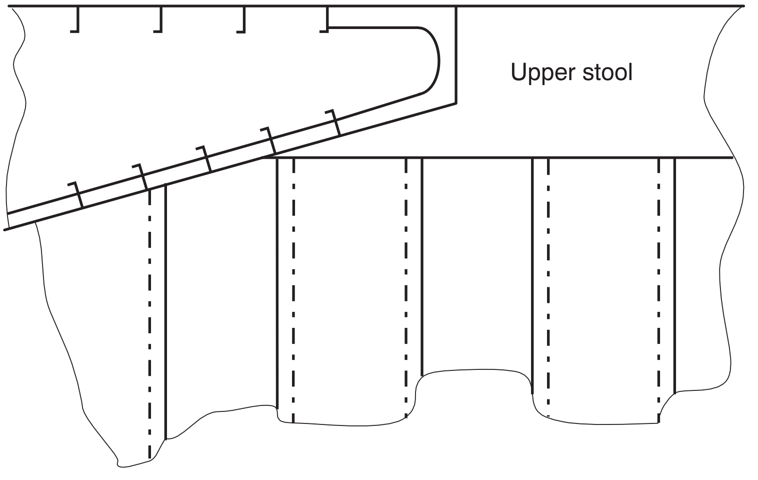
WELDING AND MATERIALS:

Welding requirements:

- frames and brackets to be connected with continuous fillet welding to side plating, hopper tank and upper wing tank plating, with throat thickness to be not less than:
  - ♦ 0,45 t in “zone a”,
  - ♦ 0,40 t in “zone b”,

  where t is the minimum thickness between those of the two connected elements,
- brackets to be connected with continuous fillet welding to frames, with throat thickness to be not less than half thickness of brackets,
- welding procedure of frame butt joint, if any, to be approved with particular care for the welding of the bulbs and of the corner in case of L sections,
- welding sequence to minimise restraints at the frame butt joints, i.e.:
  - ♦ leaving about 200 mm unwelded, each side of butt joint, of the connections between frame web and side plating and between frame web and flange,
  - ♦ performing the frame butt joints,
  - ♦ completing the fillet welding,
- turn the fillet weld all around the end of integral brackets and scallops giving an elongated shape, well faired to the plating,
- avoid burned notches at fillet welds of overlapped joints and at scallops.

Table 65 : BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

<table>
<tr><td>AREA 8: Topside tanks</td><td>Connection of transverse corrugated bulkheads with topside tanks</td><td>Sheet 8.1</td></tr>
<tr><td colspan="3">

t = minimum thickness among those of the connected elements.</td></tr>
</table>

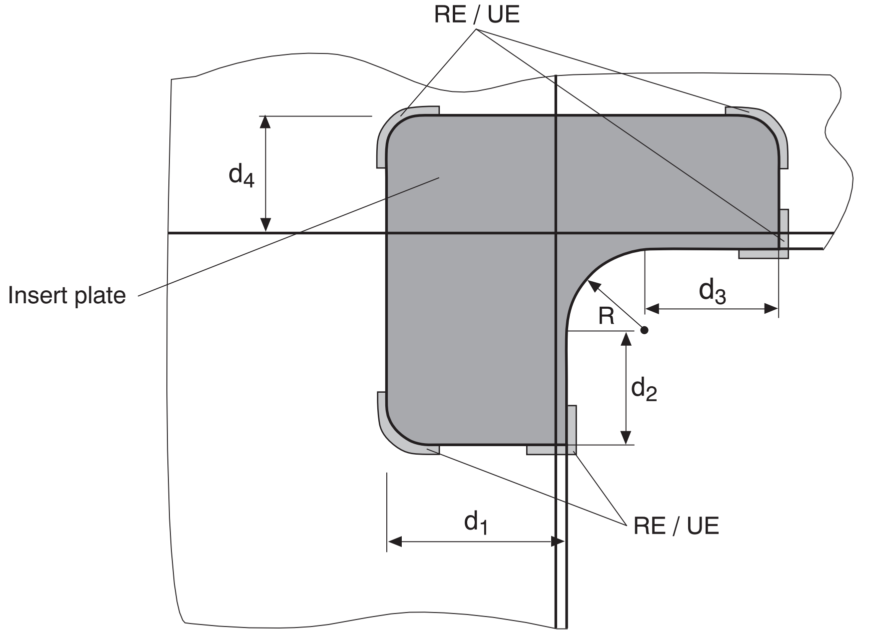
SCANTLINGS:	FATIGUE:
A transverse web or an intercostal reinforcement is to be fitted inside the topside tank in line with the flanges of corrugation and the upper stool side plating. Its arrangement is to be indicated in the approved plan.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
Misalignments between: - transverse web or intercostal reinforcement fitted inside the upper wing tank and corrugation flanges, - transverse web or intercostal reinforcement fitted inside the upper wing tank and upper stool side plating, - upper stool side plating and corrugation flanges, are to be ≤ t / 3.	The following NDE are required: • VE 100%, with particular care for fillet shape and undercuts on the plating, • UE 100% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

Welding requirements:
- bulkhead plating to be connected with continuous fillet welding to topside plating and upper stool plating, full penetration weld is recommended in way of corner of vertical and inclined plating of upper wing tank,
- throat thickness = 0,45 t, where t is the minimum thickness between those of the two connected elements,
- gap at T joint reduced to the minimum,
- welding sequence to minimise restraints.

Table 66 : BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 10: Hatch corners	Deck plating in way of hatch corners	Sheet 10.1

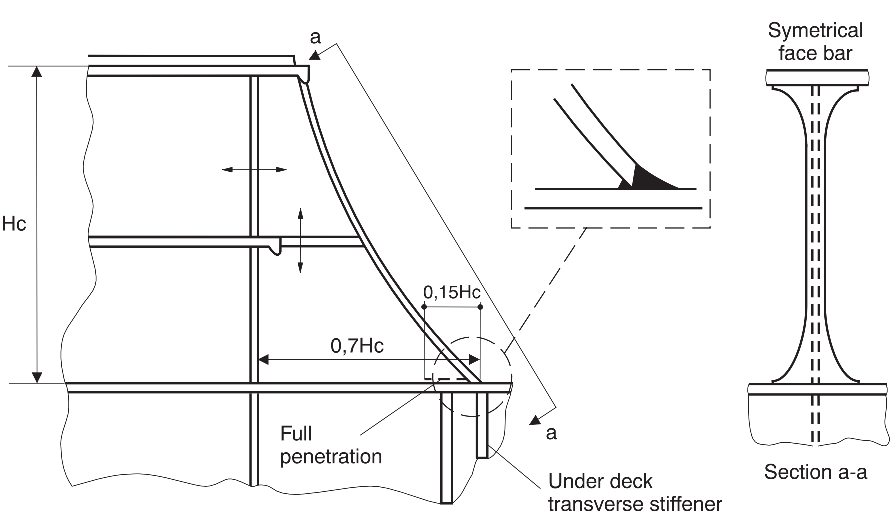


SCANTLINGS:	FATIGUE:
• Insert plates with circular profiles in general to be fitted in way of corners of hatchways located within the cargo area. The radius of circular corners to be in accordance with Ch 4, Sec 6, [6.2.1]. • Insert plates not required in way of corners of hatchways located in the above positions, where corners have an elliptical or parabolic profile according to Ch 4, Sec 6, [6.2.2]. • Where insert plates are required, their thickness to be defined according to Ch 4, Sec 6, [6.2.3] and their extension to be such that d_1 , d_2 , d_3 and $d_4 \geq s$, s being the ordinary frame spacing.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Corners of insert plates to be rounded, unless corresponding to joints of deck strakes. • Insert cut edges to be carefully executed.	The following NDE are required: • VE 100%, • RE / UE in areas indicated in the sketch.

WELDING AND MATERIALS:

- Welding requirements:
  - welds recommended to be continued on auxiliary pieces temporarily fitted at the free end of each joint, to be cut away; the joint ends are to be carefully ground.
- Materials requirements:
  - insert plate material of same or higher quality than the adjacent deck plating, depending on the insert thickness according to Ch 4, Sec 1, [2].

Table 67 : BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

<table>
<tr><td>AREA 10: Hatch corners</td><td>Ends of longitudinal hatch coamings - Bracket welded to deck plating</td><td>Sheet 10.2</td></tr>
<tr><td colspan="2">
</td><td>t_A = minimum among:
- thickness of bracket flange at lower end,
- deck plating thickness,
- under deck transverse stiffener web thickness,

t_B = minimum among:
- bracket web thickness,
- deck plating thickness,
- thickness of the under deck longitudinal member.</td></tr>
</table>

SCANTLINGS:	**FATIGUE:**
An additional under deck transverse stiffener is to be fitted in way of termination bracket toe, where the toe is clear of normal stiffener.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Misalignment between bracket flange and under deck transverse stiffener $\leq t_A / 3$. • Misalignment between bracket and under deck longitudinal $\leq t_B / 3$.	The following NDE are required: • VE 100%, with particular care for the weld shape and undercuts on deck plating at the bracket flange connection, • UE 100% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

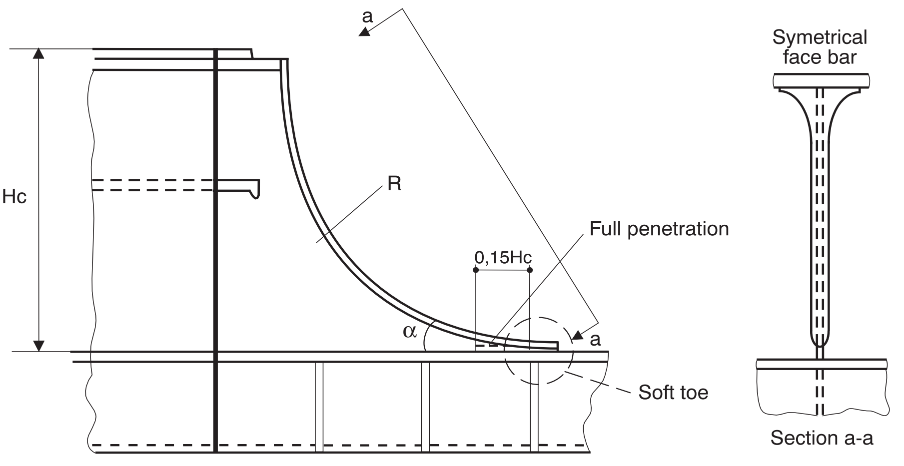
WELDING AND MATERIALS:

Welding requirements:

- bracket flange to be connected with full penetration welding to deck plating, with half V bevel and weld shape elongated on deck plating (see sketch),
- ends of bracket webs to be connected with full penetration welding to deck plating for the extension shown in the sketch, with half X bevel,
- under deck transverse stiffener to be connected with full penetration welding to deck plating in way of the bracket flange,
- care is to be taken to ensure soundness of the crossing welds at the bracket toe, if the case, adopting small scallop to be closed by welding.

Table 68 : BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 10: Hatch corners	Ends of longitudinal hatch coamings - Bracket sniped at deck plating	Sheet 10.3



t = minimum among:
- bracket web thickness,
- deck plating thickness,
- thickness of the under deck longitudinal member.

SCANTLINGS:	FATIGUE:
$R \geq 500$ mm. $\alpha \leq 30°$.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Misalignment between bracket and under deck longitudinal $\leq t_B / 3$. • Soft toe: tapering of bracket flange at ends: thickness 1:3, width 1:5.	The following NDE are required: • VE 100%, with particular care for the weld shape and undercuts on deck plating, • UE 100% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

Welding requirements:
- ends of bracket webs to be connected with full penetration welding to deck plating for the extension shown in the sketch, with half X bevel.

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