Rules for the Classification of Inland Navigation Vessels

PART B – Hull Design and Construction

Chapters 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8

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 the above listed being relieved from any of their expressed or implied obligations as a result of the interventions of the Society.

1.4 Only the Society 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 ("Applicable Referential"), 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 (or Certification as defined in clause 2.2) 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 and/or Applicable Referential 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 (available online on veristar.com), guidance notes 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 Rules and/or 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, and/or to the Applicable Referential, 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 nor on its content in the event of the actual issuance of a Certificate. This opinion shall only be an appraisement 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, involves, for the part carried out, the payment of fees thirty (30) 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, interest 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 resolve 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-cent (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 The Services shall be automatically and immediately terminated in the event the Client can no longer establish any form of interest in the Unit (e.g. sale, scrapping).

9.3 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, or immediately in the event of termination under clause 9.2, subject to compliance with clause 4.1 and 6 above.

9.4 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, will be 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, other 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 in accordance with and governed by the laws of England and Wales.

15.2 Any dispute shall be finally 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.

15.3 Notwithstanding clause 15.2, disputes relating to the payment of the Society's invoices may be submitted by the Society to the *Tribunal de Commerce de Nanterre*, France, or to any other competent local Court, at the Society's entire discretion.

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 and, when applicable, Business Partner Code of Conduct both available at https://group.bureauveritas.com/group/corporate-social-responsibility/operational-excellence.
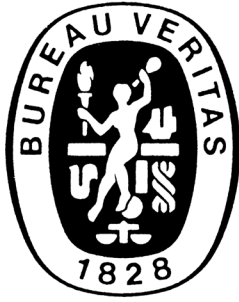
RULES FOR INLAND NAVIGATION VESSELS

Part B
Hull Design and Construction

Chapters **1 2 3 4 5 6 7 8**

June 2021

These Rules apply to inland navigation vessels for which contracts for construction are signed on or after June 1st, 2021.

The English version of these Rules takes precedence over editions in other languages.

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Part B

Hull Design and Construction

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Chapter 1

GENERAL

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SECTION 1 APPLICATION

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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 inland navigation vessels as well as vessels operated in restricted maritime stretches of water, of displacement type, of normal form, speed and proportions, having a rule length:

- L ≤ 135 m for vessels made of steel or aluminium alloy

- L < 40 m for vessels made of composite material or plywood.

These requirements are to be integrated with those specified in Part D, for any individual vessel type, depending on the class notations assigned to the vessels.

1.1.2 The requirements of Part B and Part D need to be complemented by applicable requirements of the Society's Rule Notes:

- NR561 Hull in Aluminium alloys, for vessels assigned additional service feature **A**

- NR546 Hull in Composite Materials and Plywood, for vessels assigned additional service feature **C** or **W**.

1.1.3 Vessels with rule length exceeding the limits specified in [1.1.1] and vessels 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 vessels constructed and maintained according to the Rules is sufficient for the scantling draught considered when applying the Rules.

1.1.5 For vessels with high design speed and/or where high trim angles are expected or for dynamically supported vessels, other applicable Society's Rules are to be complied with.

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 vessel'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 vessel's structure are considered as fixed parts.

1.2.2 The fixed parts of lifting appliances and their connections to the vessel's structure are covered by the Rules, even when the certification of lifting appliances is not required.

2 Rule application

2.1 Vessel parts

2.1.1 General

For the purpose of application of the Rules, the vessel is considered as divided into the following four parts:

- fore part

- central part

- machinery space, where applicable

- aft part.

2.1.2 Fore part

The fore part includes the structures of the stems and those:

- located in the part before the cargo zone in the case of vessels with a separated cargo zone (separated by bulkheads)

- located in the part extending over 0,1L behind the stem in all other cases unless otherwise mentioned.

2.1.3 Central part

The central part includes the structures within the greater of:

- the region extending over 0,5L through the midship section

- the region located between the fore part and:
  - the machinery space, if located aft
  - the aft part, otherwise.

2.1.4 Aft part

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

2.2 Vessels made of metallic materials

2.2.1 Rules applicable to various vessel parts

For vessels made of metallic materials, the various Chapters and Sections of Part B are to be applied to vessel parts according to Tab 1.

Ch 5, Sec 6 applies, as an alternative to the relevant requirements of Part B, Chapter 5, to vessels of rule length L < 40 m.

2.2.2 Rules applicable to other vessel items

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

Table 1 : Application to vessel parts - Metallic hulls

Part	Applicable Chapters and Sections	
	General	Specific
Fore part	Part B, Chapter 1 Part B, Chapter 2 Part B, Chapter 3 Part B, Chapter 4 Part B, Chapter 6 **(1)**, excluding: • Ch 6, Sec 1 • Ch 6, Sec 2 Part B, Chapter 8	Ch 6, Sec 1
Central part All vessels		Ch 5, Sec 1 to Ch 5, Sec 5
Central part L < 40 m		Ch 5, Sec 6 **(2)**
Aft part		Ch 6, Sec 2
(1) See also Tab 2. **(2)** Ch 5, Sec 6 applies, as an alternative to the relevant requirements of Part B, Chapter 5, to vessels of rule length L < 40 m.		

Table 2 : Application to other items - Metallic hulls

Item	Applicable Chapters and Sections
Machinery space	Ch 6, Sec 3
Superstructures and deckhouses	Ch 6, Sec 4
Hatch covers	Ch 6, Sec 5
Movable decks and ramps	Ch 6, Sec 6
Miscellaneous fittings	Ch 6, Sec 7
Helicopter decks and platforms	Ch 6, Sec 8
Rudders	Ch 7, Sec 1
Other hull outfitting	Part B, Chapter 7

2.3 Vessels assigned additional service feature C or W (plywood)

2.3.1 The requirements listed in Tab 3 apply also to vessels assigned additional service feature **C** or **W** (plywood).

Table 3 : Application to vessels assigned additional service features C or W

Item	Applicable requirements
General arrangement design	Part B, Chapter 1
Stability	Ch 2, Sec 2
Materials	Ch 2, Sec 3, [4]
Strength criteria- structural items in composite material or plywood	Ch 2, Sec 6
Design loads	Part B, Chapter 3
Sidescuttles, windows and sky-lights	Ch 6, Sec 7, [1]
Helicopter decks and platforms	Ch 6, Sec 8
Rudders	Ch 7, Sec 1
Other hull outfitting	Part B, Chapter 7
Construction and testing	Ch 8, Sec 1

3 Rounding off of scantlings - Metallic hulls

3.1 General

3.1.1 Plate thicknesses
The rounding off of plate thicknesses on metallic hulls is to be obtained from the following procedure:

a) the net thickness (see Ch 2, Sec 5, [2.1]) is calculated in accordance with the rule requirements

b) corrosion addition t_C (see Ch 2, Sec 5, [3.1]) is added to the calculated net thickness, and this gross thickness is rounded off to the nearest half-millimeter

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

Symbols

L   :   Rule length, in m, defined in [2.1]

B   :   Breadth, in m, defined in [2.2]

D   :   Depth, in m, defined in [2.3]

T   :   Scantling draught, in m, defined in [2.4]

L_{OA} :   Length overall, in m, defined in [2.5]

L_{WL} :   Length of waterline, in m, defined in [2.6]

Δ :   Displacement, in tons, at scantling draught T

ρ :   River/sea water density, in t/m^3

C_B :   Block coefficient:

$$C_B = \frac{\Delta}{\rho L B T}$$

1   Units

1.1

1.1.1   Unless otherwise specified, the units used in the Rules are as indicated in Tab 1.

Table 1 : Units

Designation	Usual symbol	Units
Vessel's dimensions	see [2.1]	m
Hull girder section modulus	Z	cm³
Density	ρ	t/m³
Concentrated loads	P	kN
Linearly distributed loads	q	kN/m
Surface distributed loads (pressure)	p	kN/m²
Thickness	t	mm
Span of ordinary stiffeners and primary supporting members	ℓ	m
Spacing of ordinary stiffeners and primary supporting members	s, S	m
Bending moment	M	kN.m
Stresses	σ, τ	N/mm²
Section modulus of ordinary stiffeners and primary supporting members	w	cm³
Sectional area of ordinary stiffeners and primary supporting members	A	cm²
Vessel speed	V	km/h

2   Definitions

2.1   Rule length

2.1.1   The rule length L is the distance, in m, measured on the waterline at the scantling draught, 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% of the extreme length on the waterline at the scantling draught.

In the case of vessels having neither a rudder post (e.g. vessels fitted with azimuth thrusters) nor a rudder (e.g. pushed barges) the rule length L is to be taken equal to the length of the load waterline.

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

2.2   Breadth

2.2.1   The breadth B is the greatest moulded breadth, in m, measured amidships at the scantling draught.

2.3   Depth

2.3.1   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 vessel 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.

2.4   Scantling draught

The scantling draught T is the distance, in m, measured vertically on the midship transverse section, from the moulded base line to the waterline at which the strength

requirements for the scantlings of the vessels are met. It represents the full load condition and is to be not less than that corresponding the assigned freeboard.

In the case of vessels with a solid bar keel, the moulded base line is to be taken as defined in [2.3].

2.5 Length overall

2.5.1 The length overall is the extreme length of the vessel, in m, measured from the foremost point of the stem to the aftermost part of the stern.

2.6 Length of waterline

2.6.1 The length of waterline is the length of the hull, in m, measured at the maximum draught.

2.7 Ends of rule length and midship

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

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

Figure 1 : Ends and midship
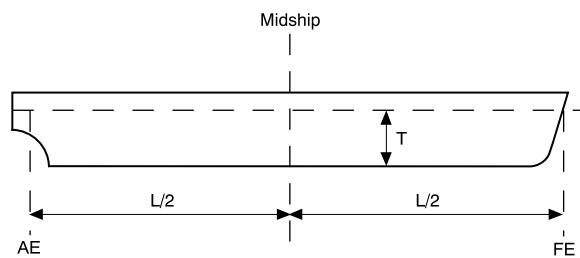
2.8 Superstructure

2.8.1 A superstructure is a decked structure connected to the strength deck defined in [2.10], extending from side to side of the vessel or with the side plating not being inboard of the shell plating more than 0,04B.

2.9 Deckhouse

2.9.1 A deckhouse is a decked structure other than a superstructure, located on the strength deck defined in [2.10] or above.

2.10 Strength deck

2.10.1 The strength deck (main deck) is the uppermost continuous deck contributing to the hull girder longitudinal strength.

2.11 Weather deck

2.11.1 The weather deck is the uppermost continuous exposed deck.

2.12 Bulkhead deck

2.12.1 The bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads and the shell are carried.

2.13 Cofferdam

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

2.14 Inner side

2.14.1 The inner side is the longitudinal bulkhead which limits the inner hull for vessels fitted with double hull.

2.15 Weathertight

2.15.1 "Weathertight" is the term used to a closure or structure which prevents water from penetrating into the vessel under any service conditions. Weathertight designates structural elements or devices which are so designed that the penetration of water into the inside of the vessel is prevented:

- for one minute when they are subjected to a pressure corresponding to a 1 m head of water, or

- for ten minutes when they are exposed to the action of a jet of water with a minimum pressure of 1 bar in all directions over their entire area.

Following constructions are regarded as weathertight:

- weathertight doors complying with ISO 6042

- ventilation flaps complying with ISO 5778

- airpipe heads of automatic type and of approved design.

Weathertightness shall be proven by hose tests or equivalent tests accepted by the Society before installing.

2.16 Watertight

2.16.1 "Watertight" designates structural elements or devices which meet all the conditions stated for weathertightness and also remain tight at the anticipated internal and external pressure.

Watertightness should be proven by workshop testing and where applicable by type approvals in combination with construction drawings (e.g. watertight sliding doors, cable penetrations through watertight bulkheads).

3 Reference co-ordinate system

3.1 General

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

- Origin: at the intersection among the longitudinal plane of symmetry of vessel, 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.

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

Figure 2 : Reference co-ordinate system
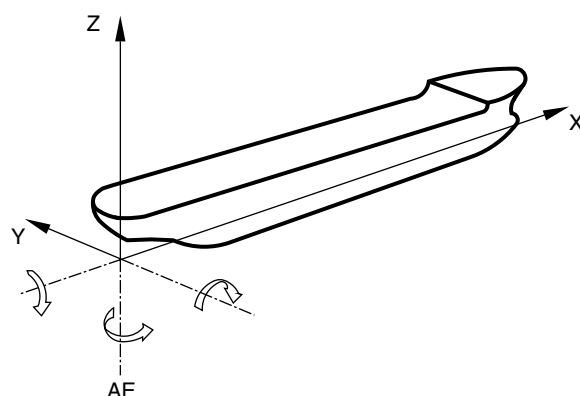
SECTION 3   DOCUMENTATION TO BE SUBMITTED

1   Documentation to be submitted for all vessels

1.1   Vessels surveyed by the Society during the construction

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

Structural plans are to show details of connections of the various parts and, in general, are to specify the materials used, including their manufacturing processes, welding procedures and heat treatments.

Furthermore, considered values of corrosion margin are to be provided for structural design of increased corrosion addition with respect to minimum values stipulated under Ch 2, Sec 5, [3].

1.1.2 The Society reserves the right to ask for further documents and drawings considered necessary.

Irrespective of this, the Rules of construction also apply to components and details not shown in the submitted drawings.

1.1.3 Any deviation from reviewed drawings is subject to the Society's approval before work is commenced.

1.1.4 The application of the Society's construction Rules does not exclude any patent claims.

1.1.5   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 Rules requirements, they are to be submitted to the Society.

Table 1 : Plans and documents to be submitted for review for all vessels

Plan or document	Containing also information on
Midship section Transverse sections Longitudinal sections Shell expansion Decks and profiles Double bottom Pillar arrangements Framing plan Welding table	Class characteristics Main dimensions Maximum draught Block coefficient for the length between perpendiculars at the maximum draught Frame spacing Contractual service speed Density of cargoes Setting pressure of safety relief valves, if any Assumed loading and unloading procedure Design loads on decks and double bottom Material specifications (steel grades, aluminium alloys, etc.) 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 Details related to welding
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

Plan or document	Containing also information on
Machinery space structures Foundations of propulsion machinery	Type, power and r.p.m. of propulsion machinery Mass and centre of gravity of machinery and boilers, if any Mass of liquids contained in the engine room
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)
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 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 main 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 **(1)**	Maximum ahead service speed
Sternframe or sternpost, sterntube Propeller shaft boss and brackets **(1)**	
River/sea chests	
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 watertight doors and scheme of relevant manoeuvring devices	Manoeuvring devices Electrical diagrams of power control and position indication circuits
Stability documentation	See Ch 2, Sec 2, [2.1]
Equipment	List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes
(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted.	

2 Further documentation to be submitted for vessels with specific notations

2.1 General

2.1.1 Depending on the service notation and, possibly, the additional service feature and additional class notation assigned to the vessel, other plans or documents may be required to be submitted to the Society, in addition to those in [1.1].

2.2 Service notations

2.2.1 The additional plans or documents to be submitted to the Society for review or for information are specified in relevant sections of Part D, Chapter 1.

2.3 Additional class notations

2.3.1 The additional plans or documents to be submitted to the Society for review or for information are specified in relevant sections of Part D, Chapter 2 and Part D, Chapter 3.

HULL AND STABILITY PRINCIPLES

SECTION 1   GENERAL ARRANGEMENT DESIGN

Symbols

z_{hc} :   Z co-ordinate, in m, of the top of hatch coaming

z_{LE} :   Z co-ordinate, in m, of the lower edge of opening

h_2 :   Reference value, in m, of the relative motion in the inclined vessel condition in Ch 3, Sec 3, [2.2.1].

1   Subdivision arrangement

1.1   Number of watertight bulkheads

1.1.1 All vessels are to have at least the following transverse watertight bulkheads:

- a collision bulkhead
- an after peak bulkhead
- two bulkheads forming the boundaries of the machinery space in vessels with machinery amidships, and one bulkhead forward of the machinery space in vessels with machinery aft. In the case of vessels with an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulkheads.

1.1.2   Additional bulkheads

In the cargo space of single hull open deck vessels, additional transverse bulkheads may be recommended in order to ensure an efficient support to the topside structure.

Additional bulkheads may be required also for vessels having to comply with damage stability criteria.

In the cargo space of double hull vessels, transverse bulkheads are to be fitted in the side tanks in way of watertight floors.

1.2   Collision bulkhead

1.2.1 The collision bulkhead is to be positioned aft of the fore perpendicular at a distance d_C, in m, such that:

$$0,04 \ L_{WL} \leq d_c \leq 0,04 \ L_{WL} + 2$$

1.2.2 The Society may, on a case by case basis, accept a distance from the collision bulkhead to the forward perpendicular different from that specified in [1.2.1], on the basis of stability calculations.

1.2.3 The collision bulkhead is to extend up to the bulkhead deck.

1.3   After peak and machinery space bulkheads

1.3.1   Extension

These bulkheads are to extend up to the bulkhead deck.

1.3.2   Stern tube

The after peak bulkhead is to enclose the sterntube and the rudder trunk in a watertight compartment. Other measures to minimize the danger of water penetrating into the vessel in the case of damage to stern tube arrangements may be taken at the discretion of the Society.

For vessels less than 40 m, where the after peak bulkhead is not provided in way of the sterntube stuffing box, the stern tubes are to be enclosed in watertight spaces of moderate volume.

1.4   Tank bulkheads

1.4.1 The number and location of transverse and longitudinal watertight bulkheads in vessels intended for the carriage of liquid cargoes (tankers and similar) are to comply with the stability requirements to which the vessel is subject.

1.4.2 In general, liquid compartments extending over the full breadth of the vessel are to be fitted with at least one longitudinal bulkhead, whether watertight or not, where the mean compartment breadth is at least equal to 2B/3, where B is the vessel breadth defined in Ch 1, Sec 2, [2.2].

As a rule, where the bulkhead is perforated, the total area of the holes is generally to be about 5% of the total area of the bulkhead.

1.5   Height of transverse watertight bulkheads

1.5.1 Transverse watertight bulkheads are to extend up to the bulkhead deck.

1.5.2 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.

1.6   Openings in watertight bulkheads

1.6.1   Collision bulkheads

Openings may not be cut in the collision bulkhead below the bulkhead deck.

The number of openings in the collision bulkhead above the bulkhead deck is to be kept to the minimum compatible with the design and proper working of the vessel.

All such openings are to be fitted with means of closing to weathertight standards.

No doors or manholes are permitted in the collision bulkhead below the bulkhead deck.

No bilge cock or similar device is to be fitted on the collision bulkhead.

A maximum of two pipes may pass through the collision bulkhead below the bulkhead deck, unless otherwise justified. Such pipes are to be fitted with suitable valves operable from above the bulkhead deck. The valve chest is to be secured at the bulkhead inside the fore peak. Such valves may be fitted on the after side of the collision bulkhead provided that they are easily accessible and the space in which they are fitted is not a cargo space.

1.6.2   Bulkheads other than collision bulkheads

Certain openings below the bulkhead deck are permitted in bulkheads other than the collision bulkhead, but these are to be kept to a minimum compatible with the design and proper working of the vessel and to be provided with watertight doors having strength such as to withstand the head of water to which they may be subjected.

1.7   Watertight doors

1.7.1   Doors cut out in watertight bulkheads are to be fitted with watertight closing appliances. The arrangements to be made concerning these appliances are to be approved by the Society.

1.7.2   The thickness of watertight doors is to be not less than that of the adjacent bulkhead plating, taking account of their actual framing spacing.

1.7.3   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.

1.7.4   Watertight doors required to be open during navigation are to be of the sliding type and capable of being operated both at the door itself, on both sides, and from an accessible position above the bulkhead deck.

Means are to be provided at the latter position to indicate whether the door is open or closed, as well as arrows indicating the direction in which the operating gear is to be operated.

1.7.5   Watertight doors may be of the hinged type if they are always intended to be closed during navigation.

Such doors are to be framed and capable of being secured watertight by handle-operated wedges which are suitably spaced and operable at both sides.

2   Compartment arrangement

2.1   Cofferdams

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)
- 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 from lubricating oil tanks
- lubricating oil tanks from compartments intended for fresh water or boiler feed water
- lubricating oil tanks from those intended for the carriage of liquid foam for fire extinguishing.

may not be required when deemed impracticable or unreasonable by the Society in relation to the characteristics and dimensions of the spaces containing such tanks, provided that:
- the thickness of common boundary plates of adjacent tanks is increased, with respect to the thickness obtained according to Ch 5, Sec 5, [2] 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 3, Sec 4, [5.1].

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

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

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

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

2.2   Compartments forward of the collision bulkhead

2.2.1   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.

3   Access arrangement

3.1   Double bottom

3.1.1   Inner bottom manholes

Inner bottom manholes are to be not less than 0,40 m x 0,40 m. Their number and location are to be so arranged as to provide convenient access to any part of the double bottom.

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.

3.1.2 Floor and girder manholes

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

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.

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.

3.2 Access to tanks

3.2.1 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.

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

3.2.2 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 0,36 m² and its length 0,50 m.

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 so arranged as to facilitate the access of persons wearing breathing apparatus or carrying a stretcher with a patient.

3.3.2 Manholes

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

3.4 Access to side tanks

3.4.1 Where openings allowing access to side tanks are cut in the stringer plate, they are to be arranged clear of the hatch corners and shall be of even-deck design, without obstacles causing stumbling. In order to assure the continuity of the strength, they are to be cut smooth along a well rounded design and are to be strengthened by thick plates, by doubling plates or by other equivalent structure.

3.5 Access to cargo hold

3.5.1 As far as practicable, permanent or movable means of access stored on board are to be provided to ensure proper survey and maintenance of cargo holds.

4 Freeing ports

4.1 General provisions

4.1.1 Where bulwarks on weather decks form wells, provisions are to be made for rapidly freeing the decks from water and draining them.

A well is any area on the deck exposed to the weather, where water may be entrapped.

5 Machinery space openings

5.1 Skylight hatches

5.1.1 Engine room skylights are to be fitted with weathertight hatch covers made of metallic material or any other equivalent material. The hatch covers are to be permanently secured to the sides where the lower edge of the opening is at a height above the load waterline of less than 1 m for range of navigation **IN(x ≤ 2)**, or 0,5 m for the range of navigation **IN**.

5.2 Closing devices

5.2.1 Openings in machinery space casings are to be surrounded by a metallic casing of efficient construction. The openings of the casings exposed to the weather are to be fitted with strong and weathertight doors.

5.3 Position of non-weathertight openings

5.3.1 In any case, the distance, in m, of the lower edge of a non-weathertight opening to the load waterline is to be such that:

$$z_{LE} \geq T + h_2$$

5.4 Entrances

5.4.1 The height, in m, of entrances to machinery space, h_C, above the deck is not to be less than the values given in Tab 1.

Furthermore, this height h_C, above the deck, is to be such that:

$$z_{hc} \geq T + h_2 + 0,15$$

Table 1 : Height of entrances to machinery space

Vessel type	Range of navigation	h_C, in m
Carriage of dangerous goods	All	0,5
Other vessels	**IN**	0,3
	IN(x ≤ 2)	0,5

6 Companionway

6.1 General

6.1.1 Companions leading under the bulkhead deck are to be protected by a superstructure or closed deckhouse, or by a companionway having equivalent strength and tightness.

6.1.2 Companion sill height

The sill height above the deck is not to be less than 0,15 m.

Furthermore, this height h_C, above the deck, is to be such that:

$z_{hC} \geq T + h_2 + 0,15$

7 Ventilators

7.1 General

7.1.1 Ventilator openings below main deck are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck.

7.1.2 Coamings

In vessels assigned other range of navigation, the coaming height above the deck is not to be less than 0,30 m and this height is to be such that:

$z_{hC} \geq T + h_2 + 0,15$.

SECTION 2 STABILITY

1 General

1.1 Application

1.1.1 All vessels may be assigned class only after it has been demonstrated that their intact stability is adequate. Adequate intact stability means compliance with the relevant Society's rule requirements or with standards laid down by the relevant Administration, taking into account the vessel's size and type.

1.1.2 Approval of the Administration

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

1.2 Definitions

1.2.1 Plane of maximum draught

Plane of maximum draught is the water plane corresponding to the maximum draught at which the vessel is authorised to navigate.

1.2.2 Bulkhead deck

Bulkhead deck is defined in Ch 1, Sec 2, [2.12].

1.2.3 Freeboard

Freeboard is the distance between the plane of maximum draught and a parallel plane passing through the lowest point of the gunwale or, in the absence of a gunwale, the lowest point of the upper edge of the vessel's side.

1.2.4 Residual freeboard

Residual freeboard is the vertical clearance available, in the event of the vessel heeling over, between the water level and the upper surface of the deck at the lowest point of the immersed side or, if there is no deck, the lowest point of the upper surface of the vessel's side shell.

1.2.5 Safety clearance

Safety clearance is the distance between the plane of maximum draught and the parallel plane passing through the lowest point above which the vessel is no longer deemed to be watertight.

1.2.6 Residual safety clearance

Residual safety clearance is the vertical clearance available, in the event of the vessel heeling over, between the water level and the lowest point of the immersed side, beyond which the vessel is no longer regarded as watertight.

1.2.7 Weathertight

"Weathertight" is defined in Ch 1, Sec 2, [2.15].

1.2.8 Watertight

"Watertight" is defined in Ch 1, Sec 2, [2.16].

1.2.9 Lightship

The lightship is a vessel complete in all respects, but without consumables, stores, cargo, and crew and effects, owners supply and without liquids on board except for machinery and piping fluids, such as lubricants and hydraulics, which are at operating levels.

1.2.10 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 vessel. By using this information and applying basic naval architecture principles, the vessel's vertical centre of gravity (VCG or KG) is determined.

1.2.11 Lightweight check

The lightweight check is a procedure which involves auditing all items which are to be added, deducted or relocated on the vessel at the time of the inclining test so that the observed condition of the vessel 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 vessel at the time of the inclining test as determined by verifying draught marks of the vessel, the vessel's hydrostatic data and the water density.

2 Examination procedure

2.1 Documents to be submitted

2.1.1 List of information

The following information is to be included in the documents to be submitted:

- general description of the vessel

- linesplan / hull definition such as offset table

- 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 vessel's perpendiculars

- hydrostatic curves or tables corresponding to the design trim and, if significant trim angles are foreseen during the normal operation of the vessel, curves or tables corresponding to such a range of trim are to be introduced

- 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 buoyant

- tank sounding tables or curves showing capacities, centres of gravity, and free surface data for each tank

- lightship data from the inclining test, 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 clearly indicated, and a copy of the approved inclining test report relevant to this sister ship is to be included

- standard loading conditions and examples for developing other acceptable loading conditions using the information contained in the trim and stability 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 reporting a comparison between the actual and the required values) are to be available for each of the above-mentioned operating conditions

- 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.

The Society may require any other necessary guidance for the safe operation of the vessel.

2.2 Displacement and centre of gravity

2.2.1 The lightship displacement and the location of the centre of gravity shall be determined either by means of an inclining experiment (see [3]) or by detailed mass and moment calculation.

In this latter case the lightweight of the vessel shall be checked by means of a lightweight test with a tolerance limit of about 5% between the mass determined by calculation and the displacement determined by the draught readings. A tolerance limit of 0,5% between the values of the longitudinal centre of gravity may not be exceeded.

The weight and centre of gravity calculation has to be submitted before the lightweight survey will be performed.

2.3 Effects of free surfaces of liquids in tanks

2.3.1 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.

2.3.2 Free surface effects are to be considered for any filling level of the tank. Free surface effects need not be considered where a tank is nominally full.

3 Inclining test and lightweight check

3.1 General

3.1.1 Any vessel 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 [3.1.3].

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.

3.1.2 Inclining test

The inclining test is required in the following cases:

- any new vessel, after its completion, except for the cases specified in [3.1.3]

- any vessel, if deemed necessary by the Society, where any alterations are made so as to materially affect the stability.

3.1.3 Lightweight check

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

- an individual vessel, provided basic stability data are available from the inclining test of a sister ship and a lightweight check is performed in order to prove that the sister ship corresponds to the leader ship. In such a case the Society is satisfied when the result of the lightweight check shows a deviation from the displacement (Δ) and a deviation from the longitudinal centre of gravity (LCG) of the leader ship not greater than the values specified in Tab 1.

    The final stability data to be considered for the sister ship in terms of displacement and position of the centre of gravity are those of the leader.

- special types of vessel, such as pontoons, provided that the vertical centre of gravity is considered at deck level.

- special types of vessel, such as catamarans, provided that:

    - a detailed list of weights and the positions of their centres of gravity is submitted

    - the lightweight check is showing accordance between the estimated values and those determined

    - adequate stability is demonstrated in all the loading conditions.

Table 1 : Maximum deviations, in %

	L ≤ 50 m	50 < L ≤ 135 m
Δ	2 **(1)**	$2,455 - \dfrac{L}{110}$
LCG	0,5 **(1)**	0,5
(1)	Greater values may be accepted by the Society on a case by case basis.	

3.2 Detailed procedure

3.2.1 General conditions of the vessel

Prior to the test, the Society's Surveyor is to be satisfied of the following:

- the weather conditions are to be favourable

- the vessel is to be moored in a quiet, sheltered area free from extraneous forces, such as to allow unrestricted heeling. The vessel is to be positioned in order to minimise the effects of possible wind and stream

- the vessel is to be transversely upright and hydrostatic data and sounding tables are to be available for the actual trim

- 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

- preferably, all tanks are to be empty and clean, or completely full. The number of tanks containing liquids is to be reduced to a minimum taking into account the above-mentioned trim. The shape of the tank is to be such that the free surface effect can be accurately determined and remain almost constant during the test. All cross connections are to be closed

- the weights necessary for the inclination are to be already on board, located in the correct place

- all work on board is suspended and crew or personnel not directly involved in the inclining test shall not be on board

- the vessel 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

- initial heeling angle shall not be greater than 0,5° prior to the start of the inclining test.

3.2.2 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 vessels provided that the requirement on pendulum deflection or U-tube difference in height specified in [3.2.4] 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, shall be available during the inclining test to shift weights on the deck in an expeditious and safe manner. Water ballast is generally not acceptable as an inclining weight.

3.2.3 Water ballast as inclining weight

Where the use of solid weights to produce the inclining moment is demonstrated to be impracticable, the movement of ballast water may be permitted as an alternative method. This acceptance would be granted for a specific test only, and approval of the test procedure by the Society is required prior to the test. 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 structural members that create air pockets

- tanks are to be directly opposite to maintain vessel's trim

- specific gravity of ballast water is to be measured and recorded

- pipelines to inclining tanks are to be full. If the vessel'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 leaking 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 vessel'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 changing environmental conditions over long periods of time.

3.2.4 Pendulums

The use of three pendulums is recommended but a minimum of two are to be used to allow identification of bad readings at each pendulum station. However, for vessels of a length equal to or less than 30 m, only one pendulum can be accepted. Each is 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 from upright, of at least 10 cm. To ensure recordings from individual instruments, it is suggested that the pendulums shall be physically located as far apart as practical.

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

3.2.5 Means of communications

Efficient two-way communication 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 shall have complete control over all personnel involved in the test.

3.2.6 Documentation

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

- 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 thickness and draught mark corrections (if available).

3.2.7 Determination of the displacement

The Society's Surveyor shall carry out all the operations necessary for the accurate evaluation of the displacement of the vessel at the time of the inclining test, as listed below:

- 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 vessel'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

- 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 vessel's trim and the position of air pipes, and also taking into account the provisions of [3.2.1]

- it is to be checked that the bilge is dry, and an evaluation of the liquids (not included in the lightship which cannot be pumped, remaining in the pipes, boilers, condenser, etc., is to be carried out

- the entire vessel is to be surveyed in order to identify all items which need to be added, removed or relocated to bring the vessel 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.

3.2.8 The incline

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

The weights are to be transversely shifted, so as not to modify the vessel'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.

Figure 1 : Weight shift procedure
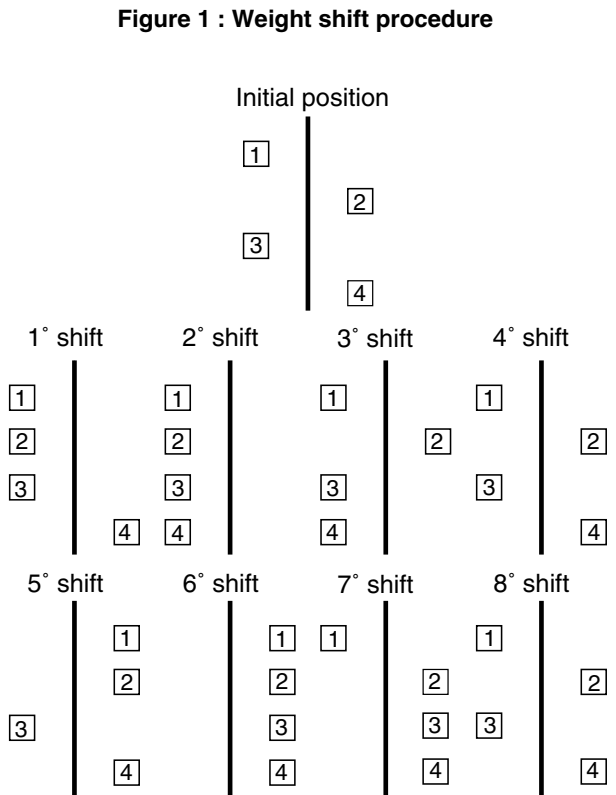
After each weight movement, the shifting distance (centre to centre) is to be measured and the heeling moment calculated by multiplying the distance by the amount of weight moved. The tangent is calculated for each pendulum by dividing the deflection by the length of the pendulum. The resultant tangents are plotted on the graph as shown in Fig 2.

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

During the reading, no movements of personnel are allowed.

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

Figure 2 : Graph of resultant tangents
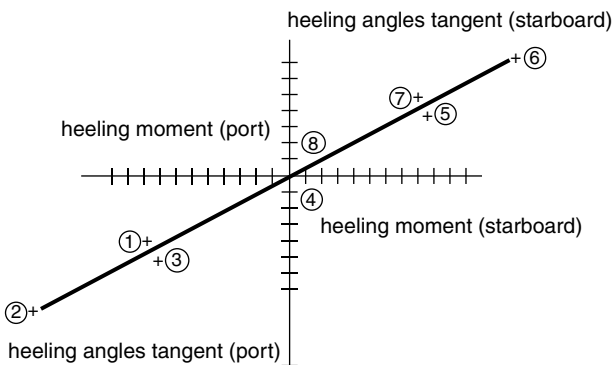
4 Intact stability design criteria

4.1 General intact stability criteria

4.1.1 The intact stability criteria specified in [4.1.2], [4.1.3] and [4.1.4] are to be complied with for all intended loading and unloading conditions, bearing in mind the influence of all free surfaces in tanks.

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 vessel, its equipment and to safe carriage of the cargo.

4.1.2 GZ curve area

The surface of the positive area of the righting lever curve up to immersion of the first unprotected (non-weathertight) opening and in any event up to an angle of heel of 27°, shall not be less than 0,024 m.rad.

4.1.3 Minimum righting lever

In the positive area of the righting lever curve up to immersion of the first non-weathertight opening, there shall be a righting lever (GZ) of not less than 0,10 m.

4.1.4 Initial metacentric height

The initial metacentric height GM_0 shall not be less than 0,10 m.

SECTION 3 MATERIALS

1 General

1.1 Characteristics of materials

1.1.1 The characteristics of the materials to be used in the construction of vessels 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.

1.4 Dimensional tolerances

1.4.1 Plates and wide flats

For plates and wide flats, an under thickness tolerance of 0,3 mm is permitted.

1.4.2 Sections and bars

For sections and bars, the under thickness tolerance is to be in accordance with the requirements of a recognized international or national standard.

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 inland navigation vessels.

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 yield stress R_{eH} greater than 235 N/mm² are used, hull scantlings are to be determined by taking into account the material factor k defined in [2.3].

2.1.4 When no other information is available, the minimum yield stress R_{eH} and the Young's modulus E of steels used at temperatures between 90°C and 300°C 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 yield stress at ambient temperature

E_0 : Value of the Young's modulus at ambient temperature

θ : Service temperature, 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].

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.

Table 1 : Mechanical properties of hull steels

Steel grades (t ≤ 100 mm)	Minimum yield stress R_{eH}, in N/mm²	Ultimate minimum tensile strength R_m, in N/mm²
A - B - D	235	400 - 520
A32 - D32	315	440 - 570
A36 - D36	355	490 - 630
A40 - D40 **(1)**	390	510 - 660
(1) t ≤ 50 mm		

Table 2 : Material factor k

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

2.3 Material factor k

2.3.1 General

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

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

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

2.4 Grades of steel

2.4.1 Normal strength grades A, B and D

The distribution of the steel grades used in the different regions of the vessel is indicated in Tab 3.

Steel of grade D may be required for structural members consisting in plates more than 20 mm thick in areas liable to important static or dynamic stress concentrations.

**Table 3 : Distribution of steel grades
in midship and holds or tanks regions**

	t ≤ 15	15 < t ≤ 20	t > 20
Bilge and topside structure **(1)**	A	B	D
Side shell	A	A	A
Deck and bottom	A	A	B
Deck plates at the corners of hatches	A	B	D
Note 1:			
t : Structural member gross thickness, in mm.			
(1) Sheerstrake, stringer plate, longitudinal hatch coaming of open deck vessels, trunk longitudinal bulkhead.			

2.4.2 High tensile strength structural steel grades AH and DH

The distribution of the steel grades used in the midship, holds or tanks regions, according to the type of vessel concerned is given in Tab 4.

Outside these regions, the thickness of high tensile strength steel must be kept unchanged until the region where the thickness of ordinary steel is the same for the vessel considered.

**Table 4 : Distribution of steel grades
in midship and holds or tanks regions**

	t ≤ 20	t > 20
Bilge and topside structure **(1)**	AH	DH
Side shell	AH	AH
Deck and bottom	AH	DH
Deck plates at the corners of long hatches	AH	DH
Note 1:		
t : Structural member gross thickness, in mm.		
(1) Sheerstrake, stringer plate, longitudinal hatch coaming of open deck vessels, trunk longitudinal bulkhead		

2.4.3
For strength members not mentioned in these tables, grade A / AH may generally be used.

2.4.4
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 2, Sec 5.

2.4.5 Vessels carrying corrosive liquids

Where corrosive liquids are to be carried, the plates and sections of the hull of vessels with built-in cargo tanks and the independent cargo tanks are to be built in a material approved by the Society.

2.4.6 Vessels with ice strengthening

For vessels with ice strengthening, shell strakes in way of ice strengthening area plates are to be of a minimum grade B/AH.

2.5 Grades of steel for structures exposed to low air temperatures

2.5.1
The selection of steel grades to be used for the structural members exposed to low temperatures (–20°C or below) is to be in compliance with applicable requirements of NR216 Materials and Welding.

3 Aluminium alloys for hull structure

3.1 General

3.1.1
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]).

3.1.2
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.

3.1.3
Unless otherwise agreed, the Young's modulus for aluminium alloys is equal to 70000 N/mm² and the Poisson's ratio equal to 0,33.

3.1.4 Use of aluminium alloys on tankers

The use of aluminium alloys is authorized for wheelhouses located aft of the aft cofferdam or forward of the fore cofferdam.

3.2 Extruded plating

3.2.1
Extrusions with built-in plating and stiffeners, referred to as extruded plating, may be used.

3.2.2
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.

3.2.3
Extruded plating is preferably to be oriented so that the stiffeners are parallel to the direction of main stresses.

3.2.4
Connections between extruded plating and primary members are to be given special attention.

3.3 Mechanical properties of weld joints

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

3.3.2 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.

3.3.3 The as-welded properties of aluminium alloys of series 6000 are to be agreed by the Society.

3.4 Minimum yield stress

3.4.1 The minimum yield stress of aluminium R_y, in N/mm², used for the scantling criteria of the hull structure is to be taken, unless otherwise specified, equal to:

$R_y = R'_{lim}$

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, η_2 : Coefficients defined in Tab 5.

Table 5 : 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 6.		
Note 1:		
$R'_{p0,2}$: Minimum specified yield stress, in N/mm², of material in welded condition (see [3.3])		
R'_m : Minimum specified tensile stress, in N/mm², of material in welded condition (see [3.3]).		

Table 6 : 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

3.5 Material factor

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

$$k = \frac{100}{R'_{lim}}$$

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

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

4 Composite materials and plywood for hull structure

4.1 Characteristics and testing

4.1.1 The characteristics of the composite materials and plywood and their testing and manufacturing process are to comply with the applicable requirements of NR546 Composite Ships, in particular for the:

- raw materials

- laminating process

- mechanical tests and raw material homologation.

4.2 Application

4.2.1 Attention is drawn to the use of composite and/or plywood materials from the point of view of structural fire protection. Regulations of the country where the vessel is registered may entail in some cases a limitation in the use of composite and/or plywood materials.

5 Other materials

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, derricks, accessories and wire ropes are generally to comply with the applicable requirements of NR216 Materials and Welding.

5.1.2 Materials used in welding processes are to comply with the applicable requirements of NR216 Materials and Welding.

SECTION 4 STRUCTURAL DETAIL PRINCIPLES

Symbols

w : Section modulus, in cm³, of an ordinary stiffener or primary supporting member, as the case may be, with an attached plating of width b_p

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

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

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

s : Spacing, in m, of ordinary stiffeners

S : Spacing, in m, of primary supporting members

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

I : Moment of inertia, in cm⁴, of an ordinary stiffener or a primary supporting member, as the case may be, without attached plating, around its neutral axis parallel to the plating

I_B : Moment of inertia, in cm⁴, of an ordinary stiffener or a primary supporting member, as the case may be, with bracket and without attached plating, around its neutral axis parallel to the plating, calculated at mid-length of the bracket

k : Material factor defined in:
- Ch 2, Sec 3, [2.3] for steel
- Ch 2, Sec 3, [3.5] for aluminium alloys

R_y : Minimum yield stress, in N/mm², of the material to be taken equal to:
- $R_y = 235/k$ N/mm² for steel
- $R_y = 100/k$ N/mm² for aluminium alloys

unless otherwise specified

1 General

1.1 Application

1.1.1 Metallic structures

The requirements of the present Section apply to longitudinally or transversely framed structure arrangement of hulls built in metallic materials.

Any other arrangement may be considered, on a case-by-case basis.

Additional structure design principles in relation to specific notations are defined in Part D.

1.1.2 Composite and plywood structure

Equivalent arrangement for hulls built in composite materials and/or plywood is defined in NR546 Composite Ships.

2 General strength principles

2.1 Structural continuity

2.1.1 The variation in scantlings between the midship region and the fore and aft parts is to be gradual.

2.1.2 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 and machinery space
- in way of ends of superstructures.

2.1.3 Longitudinal members contributing to the hull girder longitudinal strength, according to Ch 4, Sec 1, [2.1], are to extend continuously for a sufficient distance towards the ends of the vessel 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.

2.1.4 Where stress concentrations may occur in way of structural discontinuities, adequate compensation and reinforcements are to be provided.

2.1.5 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.

2.1.6 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.

2.2 Structural continuity - Multihull platform

2.2.1 Attention is to be paid to the structural continuity of the primary transverse cross structure of the platform ensuring the global transverse resistance of the multihull.

The primary transverse cross structure of catamaran is generally to be continuous when crossing float structures. The general continuity principles defined in [2.1] apply also to the primary transverse cross structure of the platform.

2.3 Connections with higher strength steel

2.3.1 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.

2.4 Connections between steel and aluminium

2.4.1 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).

2.4.2 Any heterogeneous jointing system is considered by the Society on a case by case basis.

2.4.3 The use of transition joints made of aluminium/steel clad plates or profiles is considered by the Society on a case by case basis.

3 Plating

3.1 Insert plates and doublers

3.1.1 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.

3.1.2 On tankers for oil or chemical cargoes, doubling plates are not allowed to be fitted within the cargo tank area, i.e. from the aftermost to the foremost cofferdam bulkhead.

3.1.3 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 8, Sec 2, [2.6].

3.1.4 When doublers fitted on the outer shell and strength deck within 0,5 L 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 [3.1.3]. Outside this area, the possibility of fitting doublers requiring slot welds will be considered by the Society on a case by case basis.

4 Ordinary stiffeners

4.1 General

4.1.1 Stiffener not perpendicular to the attached plating

Where the stiffener is not perpendicular to the attached plating, the actual net section modulus w, in cm³, and net shear area A_{sh}, in cm², and net moment of inertia I, in cm⁴, 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 cm³, of the stiffener assumed to be perpendicular to the plating

A_0 : Actual net shear area, in cm², of the stiffener assumed to be perpendicular to the plating

I_0 : Net moment of inertia, in cm⁴, 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 midspan of the stiffener.

4.1.2 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:

$h_w = h_w' - \dfrac{h_w'}{9,2} + 2$

$t_w = t_w'$

$b_f = \alpha \left[t_w' + \dfrac{h_w'}{6,7} - 2 \right]$

$t_f = \dfrac{h_w'}{9,2} - 2$

where:

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

α : Coefficient equal to:

for $h_w' \le 120$: $\alpha = 1,1 + \dfrac{(120 - h_w')^2}{3000}$

for $h_w' > 120$: $\alpha = 1,0$

Figure 1 : Bulb section and its equivalent angle
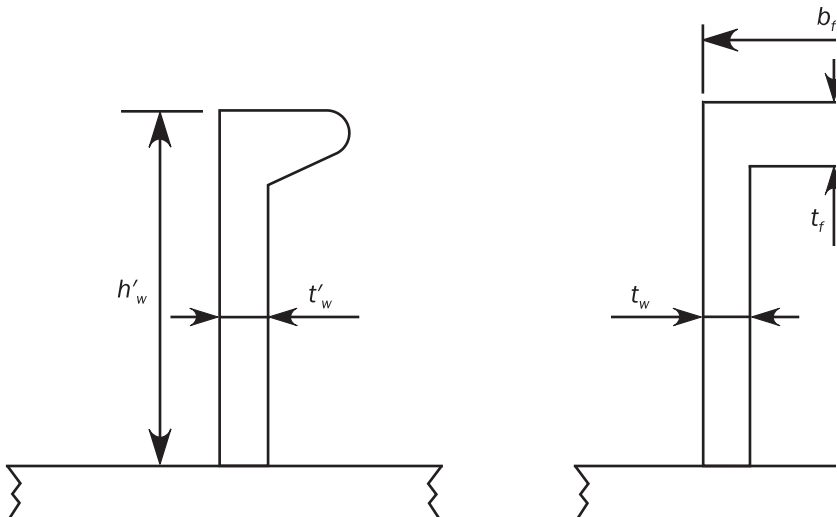
Figure 2 : Ordinary stiffener without brackets
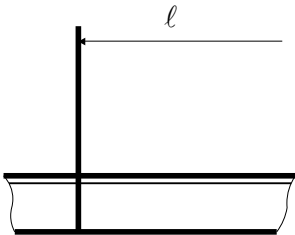
Figure 3 : Ordinary stiffener with a stiffener at one end
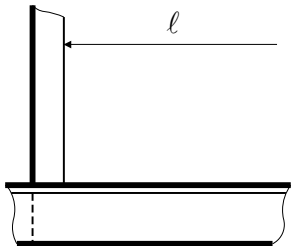
Figure 4 : Ordinary stiffener with end bracket
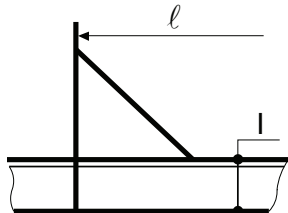
Figure 5 : Ordinary stiffener with a bracket and a stiffener at one end
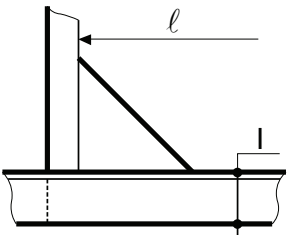
4.2 Span of ordinary stiffeners

4.2.1 General

The span ℓ of ordinary stiffeners is to be measured as shown in Fig 2 to Fig 5.

4.3 Width of attached plating

4.3.1 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):

  $b_P = 0,5\ s$

4.3.2 Buckling check

The attached plating to be considered for the buckling check of ordinary stiffeners is defined in Ch 2, Sec 7, [3.1].

4.4 Geometric properties

4.4.1 Built sections

The geometric properties of built sections as shown in Fig 6 may be calculated as indicated in the following formulae.

The shear sectional area of a built section with attached plating is to be obtained, in cm², from the following formula:

$$A_{Sh} = \frac{h_w t_w}{100}$$

The section modulus of a built section with attached plating of sectional area A_a, in mm², 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 mid-plate thickness of 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 moment of inertia of a built section with attached plating is to be obtained, in cm⁴, from the following formula:

$$I = w \cdot v$$

These formulae are applicable provided that:

$$A_a \geq t_f b_f$$

$$\frac{h_w}{t_p} \geq 10$$

$$\frac{h_w}{t_f} \geq 10$$

Figure 6 : Dimensions of a built section
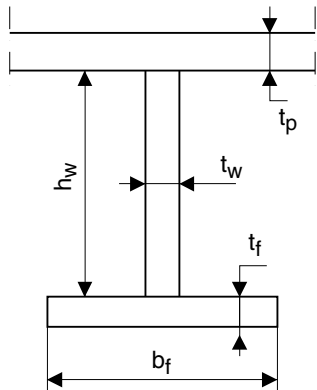
4.4.2 Corrugations

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
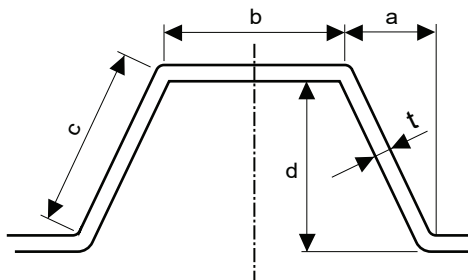
4.5 End connections

4.5.1 Continuous ordinary stiffeners

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 7 to Fig 11. In the case of high values for the design loads, additional stiffening is required.

Connection details other than those shown in Fig 7 to Fig 11 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.

Figure 8 : End connection of ordinary stiffener Without collar plate
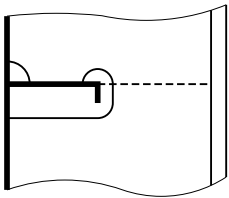
Figure 9 : End connection of ordinary stiffener Collar plate
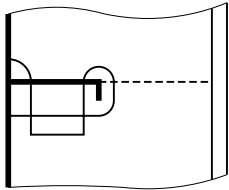
Figure 10 : End connection of ordinary stiffener One large collar plate
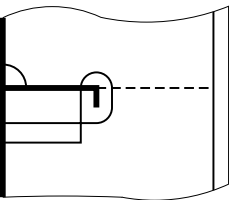
Figure 11 : End connection of ordinary stiffener Two large collar plates
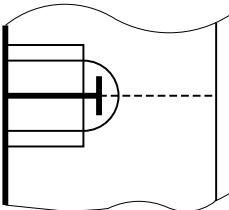
4.5.2 Intercostal ordinary stiffeners

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

All brackets for which:

$$\frac{\ell_b}{t} > 60$$

where:

ℓ_b :   Length, in mm, of the free edge of the bracket

t   :   Bracket net thickness, in mm,

are to be flanged or stiffened by a welded face plate.

The sectional area, in cm², of the flange or the face plate is to be not less than $0.01 \, \ell_b$.

The width of the face plate, in mm, is to be not less than 10 t.

4.5.3 Sniped ends of stiffeners

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

$$t = c \sqrt{\frac{ps(\ell - 0.5s)}{R_y}}$$

where:

p   :   Stiffener design load, in kN/m², to be determined in compliance with Ch 3, Sec 4

c   :   Coefficient to be taken equal to:

- 12,7 for watertight bulkheads
- 15,7 for all other components.

5 Primary supporting members

5.1 General

5.1.1 Primary supporting member not perpendicular to the attached plating

Where the primary supporting member is not perpendicular to the attached plating, the actual section modulus may be obtained, in accordance with [4.1.1].

5.2 Span of primary supporting members

5.2.1 The span of primary supporting members is to be determined in compliance with [4.2].

5.3 Width of attached plating

5.3.1 General

The width of the attached plating of primary supporting members is to be obtained according to [5.3.2] or [5.3.3], depending on the type of loading, where:

S_0 : $S_0 = S$, for plating extending on both sides of the primary supporting member

            $S_0 = 0.5 \, S$, for plating extending on one side of the primary supporting member

S_1 : $S_1 = 0.2 \, \ell$, for plating extending on both sides of the primary supporting member

            $S_1 = 0.1 \, \ell$, for plating extending on one side of the primary supporting member.

5.3.2 Loading type 1

Where the primary supporting members are subjected to uniformly distributed loads or else by not less than 6 equally spaced concentrated loads, the width of the attached plating is to be obtained, in m, from the following formulae:

- for $\ell / S_0 \leq 4$:

$$b_P = 0.36 S_0 \left(\frac{\ell}{S_0} \right)^{0.67}$$

- for $\ell / S_0 > 4$:

$$b_P = \text{MIN} \, (S_0 \, ; \, S_1)$$

5.3.3 Loading type 2

Where the primary supporting members are subjected to less than 6 concentrated loads, the width of the attached plating is to be obtained, in m, from the following formulae:

- for $\ell / S_0 < 8$:

$$b_P = 0.205 S_0 \left(\frac{\ell}{S_0} \right)^{0.72}$$

- for $\ell / S_0 \geq 8$:

$$b_P = 0.9 \, S_0$$

5.3.4 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 [5.3.2] and [5.3.3] 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.

5.4 Geometric properties

5.4.1 Standard roll sections

The geometric properties of primary supporting members made of standard roll sections may be determined in accordance with [4.4.1], reducing the web height hw by the depth of the cut-out for the passage of ordinary stiffeners, if any (see [5.7.1]).

5.4.2 Built sections

The geometric properties of primary supporting members (including primary supporting members of double hull structures, such as double bottom floors and girders) are generally determined in accordance with [4.4.1], reducing the web height h_w by the depth of the cut-outs for the passage of the ordinary stiffeners, if any (see [5.7.1]).

Figure 12 : Bracket dimensions
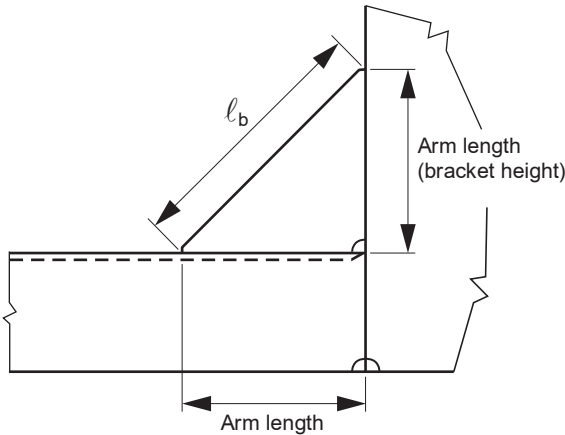
5.5 Bracketed end connections

5.5.1 Arm lengths of end brackets are to be equal, as far as practicable (see Fig 12).

The height of end brackets is to be not less than that of the weakest primary supporting member.

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

5.5.3 The bracket web thickness is to be not less than that of the weakest primary supporting member.

5.5.4 The face plate of end brackets is to have a width not less than the width of the primary supporting member face-plates.

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

5.5.5 In addition to the above requirements, the scantlings of end brackets are to comply with the applicable requirements given in Ch 5, Sec 1 to Ch 5, Sec 5.

5.6 Bracketless end connections

5.6.1 In the case of bracketless end connections between primary supporting members, the strength continuity is to be obtained as schematically shown in Fig 13 or by any other method which the Society may consider equivalent.

5.6.2 In general, the continuity of the face plates is to be ensured.

5.7 Cut-outs and holes

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

In general, the height of cut-outs is to be not greater than 50% of the height of the primary supporting member. Other cases are to be covered by calculations submitted to the Society.

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

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

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

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

Figure 13 : Connection of two primary supporting members
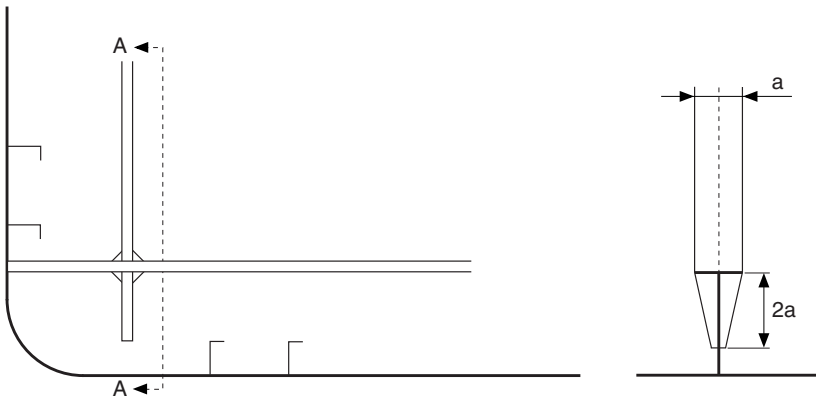
5.7.5 In the case of large openings as shown in Fig 14, the secondary stresses in primary supporting members are to be considered for the reinforcement of the openings.

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:

$$F = \frac{M_A + M_B}{2\,d}$$

$$m_1 = \left|\frac{M_A - M_B}{2}\right| K_1$$

$$m_2 = \left|\frac{M_A - M_B}{2}\right| K_2$$

$$\sigma_{F1} = 10\frac{F}{S_1}$$

$$\sigma_{F2} = 10\frac{F}{S_2}$$

$$\sigma_{m1} = \frac{m_1}{w_1}10^3$$

$$\sigma_{m2} = \frac{m_2}{w_2}10^3$$

$$\tau_1 = 10\frac{K_1 Q_T}{S_{w1}}$$

$$\tau_2 = 10\frac{K_2 Q_T}{S_{w2}}$$

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 2, Sec 8, [2.3] or Ch 2, Sec 8, [2.4], 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 15 to Fig 17:

- continuous face plate (solution 1): see Fig 15

- straight face plate (solution 2): see Fig 16

- compensation of the opening (solution 3): see Fig 17

- combination of the above solutions.

Other arrangements may be accepted provided they are supported by direct calculations submitted to the Society for review.

Figure 14 : Large openings in primary supporting members - Secondary stresses
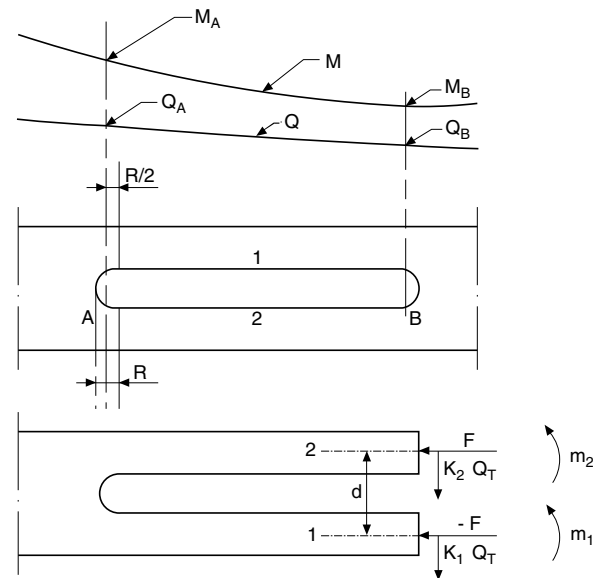
Figure 15 : Stiffening of large openings in primary supporting members - Solution 1
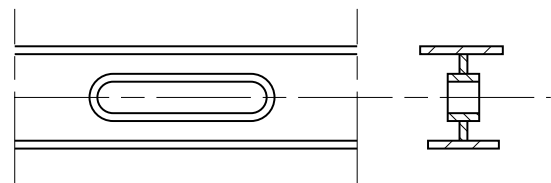
Figure 16 : Stiffening of large openings in primary supporting members - Solution 2
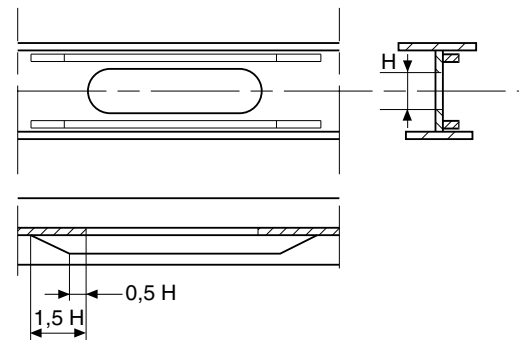
Figure 17 : Stiffening of large openings in primary supporting members - Solution 3

Inserted plate
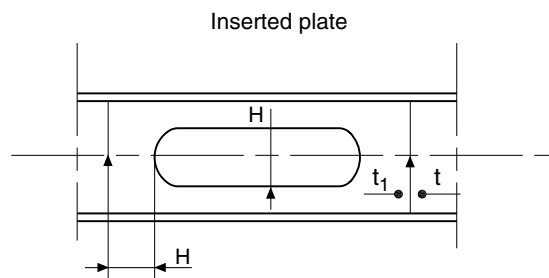
5.8 Stiffening arrangement

5.8.1 Webs of primary supporting members are generally to be stiffened where the height, in mm, is greater than 100 t, 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 110 t.

5.8.2 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:

$$A = 0,1 k_1 ps \ell$$

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 8)

- $k_1 = 0,225$ for connections with a collar plate (see Fig 9)

- $k_1 = 0,20$ for connections with one or two large collar plates (see Fig 10 and Fig 11)

p : Design pressure, in kN/m², acting on the ordinary stiffener, defined in Ch 3, Sec 4.

5.8.3 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 18):

$$I = C \ell^2 A \frac{R_{eH}}{235}$$

- for web stiffeners normal to the flange of the primary supporting members (see Fig 19):

$$I = 11,4 \, s t_w (2,5 \, \ell^2 - 2 s^2) \frac{R_{eH}}{235}$$

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 18 : Web stiffeners parallel to the flange
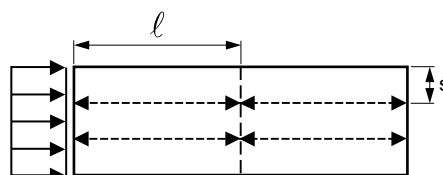
Figure 19 : Web stiffeners normal to the flange
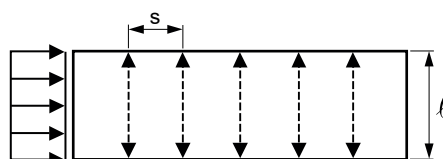
5.8.4 Tripping brackets (see Fig 20) welded to the face plate are generally to be fitted:

- every fourth spacing of ordinary stiffeners, without exceeding 4 m

- 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.

5.8.5 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 [5.8.4].

5.8.6 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 (see Fig 20)

s_t : Spacing, in m, of tripping brackets

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

Figure 20 : Primary supporting member: web stiffener in way of ordinary stiffener
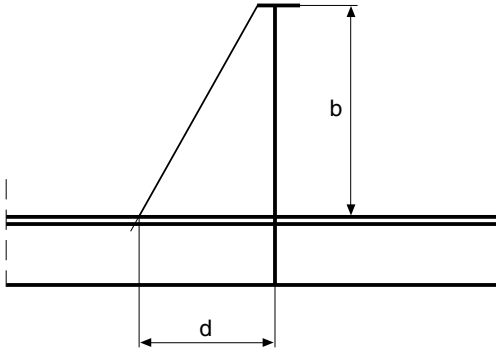
5.8.7 Tripping brackets with a net thickness, in mm, less than $15 \, L_b$ (where L_b is the length, in m, of the free edge of the bracket) are to be flanged or stiffened by a welded face plate.

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

6 Structural modeling

6.1 Calculation point

6.1.1 General

The calculation point is to be considered with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [3.1].

6.1.2 Plating

The elementary plate panel is the smallest unstiffened part of plating.

Unless otherwise specified, the loads 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 the strake.

6.1.3 Ordinary stiffeners

a) Lateral pressure

Unless otherwise specified, the loads are to be calculated at mid-span of the ordinary stiffener considered

b) 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.

6.1.4 Primary supporting members

a) Lateral pressure

Unless otherwise specified, the loads are to be calculated at mid-span of the primary supporting member considered

b) 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 neutral axis of the primary supporting member with attached plating.

6.2 Span correction coefficients

6.2.1 Ordinary stiffeners

These Rules apply to ordinary stiffeners without end brackets, with a bracket at one end or with two equal end brackets.

The span correction coefficients β_b and β_s of ordinary stiffeners are to be determined using the following formulae:

$$\beta_b = \left(1 - \sum_{i=1}^{n} \frac{\ell_{bi}}{\ell}\right)^2$$

$$\beta_s = \left(1 - \sum_{i=1}^{n} \frac{\ell_{bi}}{\ell}\right)$$

where:

ℓ : Span, in m, of ordinary stiffener, defined in [4.2]

$\ell_{bi} = 0,5 \, \ell_b$

$\ell_b = \text{MIN} \, (d \, ; b)$

d, b : Length, in m, of bracket arms

n : Number of end brackets.

6.2.2 Primary supporting members

Conventional parameters of end brackets are given in Fig 21. Special consideration is to be given to conditions different from those shown.

The span correction coefficients β_b and β_s of primary supporting members are to be determined using the following formulae:

$$\beta_b = \left(1 - \sum_{i=1}^{n} \frac{\ell_{bi}}{\ell}\right)^2$$

$$\beta_s = \left(1 - \sum_{i=1}^{n} \frac{\ell_{bi}}{\ell}\right)$$

where:

ℓ : Span, in m, of primary supporting member, defined in [5.2.1]

$\ell_{bi} = \ell_b - 0,25 \, h_W$

$\ell_b = \text{MIN} \, (d \, ; b)$

d, b : Lengths, in m, of bracket arms, defined in Fig 21

h_W : Height, in m, of the primary supporting member (see Fig 21)

n : Number of end brackets.

6.3 Coefficients for pressure distribution correction

6.3.1 The scantlings of non-horizontal structural members are to be determined using the coefficients for pressure distribution correction λ_b and λ_s defined as follows:

$$\lambda_s = 2\,\lambda_b - 1$$

$$\lambda_b = 1 + 0.2 \left| \frac{p_d - p_u}{p_d + p_u} \right|$$

where:

p_u	:	Pressure, in kN/m^2, at the upper end of the structural member considered
		$p_u = p_{su} + p_{wu}$
p_d	:	Pressure, in kN/m^2, at the lower end of the structural member considered
		$p_d = p_{sd} + p_{wd}$
p_{su}, p_{wu}	:	Still water pressure and wave pressure respectively, in kN/m^2, at the upper end of the structural member considered
p_{sd}, p_{wd}	:	Still water pressure and wave pressure respectively, in kN/m^2, at the lower end of the structural member considered.

Figure 21 : Characteristics of primary supporting member brackets
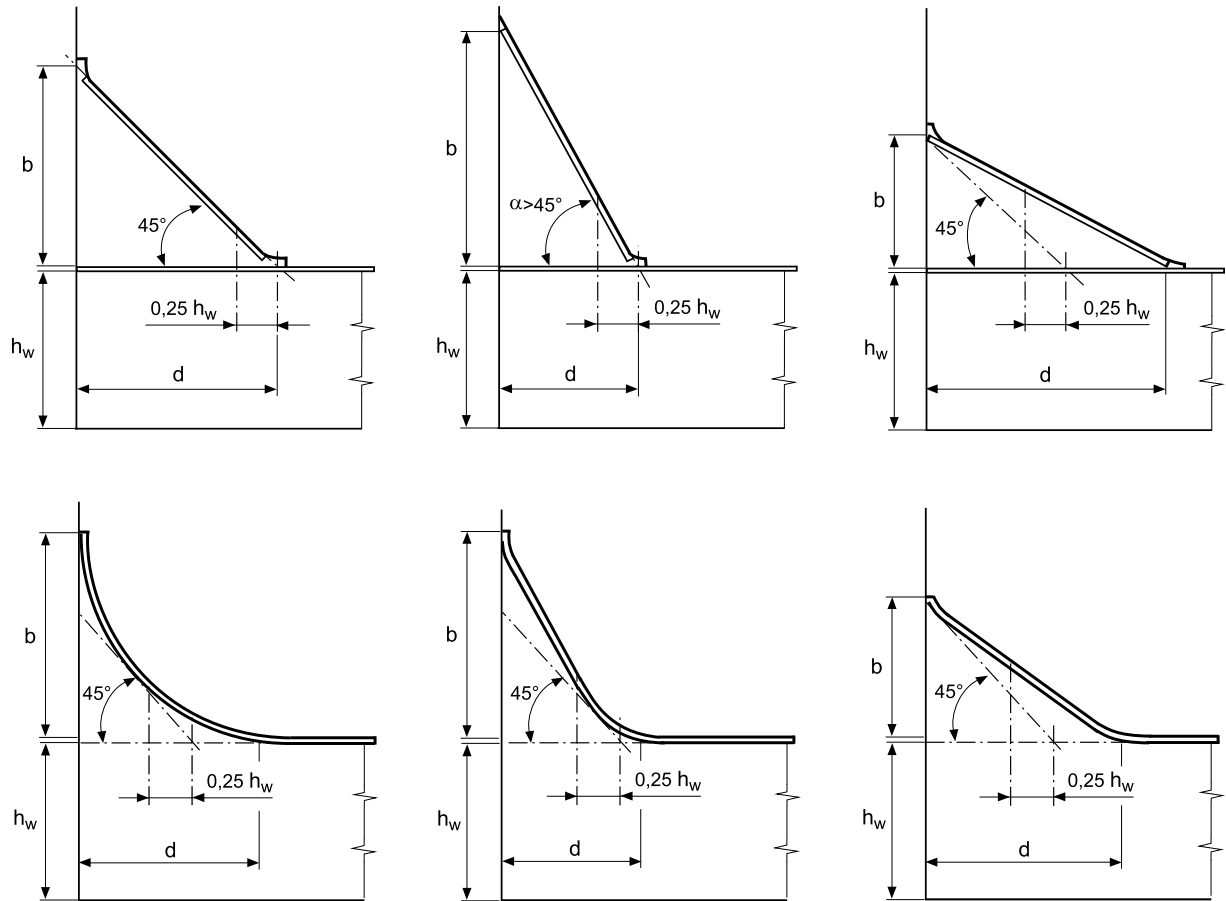
SECTION 5 NET SCANTLING APPROACH

1 Application criteria

1.1 General

1.1.1 The scantlings of metallic hull structural members obtained by applying the criteria specified in these Rules 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 of:

- rudder structures and hull appendages in Part B, Chapter 7
- massive pieces made of steel forgings, steel castings or iron castings.

1.1.2 The required strength characteristics are:

- thickness, for plating including that which constitutes primary supporting members
- section modulus, shear sectional 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 single moment for the hull girder.

1.1.3 The vessel is to be built at least with the gross scantlings obtained by reversing the procedure described in [2.1].

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, the structural checks are to be carried out on the basis of the net strength characteristics, derived as specified in [2.1.2] to [2.1.5].

2.1.2 Plating

The net thickness is to be obtained by deducting the corrosion addition t_c from the gross thickness.

2.1.3 Ordinary stiffeners

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

The net strength characteristics are to be calculated for the net transverse section. As an alternative, the net section modulus of bulb profiles may be obtained from the following formula:

$$w = w_G (1 - \alpha t_C) - \beta t_C$$

where:

w_G : Stiffener gross section modulus, in cm^3

α, β : Coefficients defined in Tab 1.

Table 1 : Coefficients α and β for bulb profiles

Range of w_G	α	β
$w_G \leq 200\ cm^3$	0,070	0,4
$w_G > 200\ cm^3$	0,035	7,4

2.1.4 Primary supporting members

The net transverse section is to be obtained by deducting the corrosion addition 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 Hull girder

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].

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 [3.1].

2.2.2 Hull girder net strength characteristic calculation

For the hull girder, the net hull girder transverse sections are to be considered as being constituted by plating and stiffeners having the net scantlings proposed by the designer.

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 corrosion protection measures prescribed in Ch 8, Sec 3, [1].

The designer may define values of corrosion additions greater than those specified in [3.1.2] and [3.1.3].

3.1.2 Corrosion additions for steel other than stainless steel

The corrosion addition for each of the two sides, t_{C1} or t_{C2}, of a structural member is specified in Tab 2.

The total corrosion addition t_C, in mm, for both sides of a structural member, is equal to:

- for a plating with a gross thickness greater than 10 mm:

  $t_C = t_{C1} + t_{C2}$

- for a plating with a gross thickness less than or equal to 10 mm:
  - $t_C = 20\%$ of the gross thickness of the plating, or
  - $t_C = t_{C1} + t_{C2}$

  whichever is smaller.

For an internal member within a given compartment, the total corrosion addition t_C is to be determined as follows:

- for a plating or a stiffener plating with a gross thickness greater than 10 mm:

  $t_C = 2\ t_{C1}$

- for a plating or a stiffener plating with a gross thickness less than or equal to 10 mm:
  - $t_C = 20\%$ of the gross thickness of the plating considered, or
  - $t_C = 2\ t_{C1}$

  whichever is smaller,

where t_{C1} is the value of the corrosion addition specified in Tab 2 for one side exposure to that compartment.

3.1.3 Corrosion additions for stainless steel and aluminium alloys

For structural members made of stainless steel or aluminium alloys, the corrosion addition is to be taken equal to 0,25 mm, for one side exposure ($t_{C1} = t_{C2} = 0,25$ mm).

Table 2 : Corrosion additions, in mm, for one side exposure (t_{C1} or t_{C2}) - steel other than stainless steel

Compartment type		Corrosion addition **(1)**
Ballast tank		1,00
Cargo tank and fuel oil tank	Plating of horizontal surfaces	0,75
	Plating of non-horizontal surfaces	0,50
	Ordinary stiffeners Primary supporting members	0,75
Dry bulk cargo hold	General	1,00
	Inner bottom plating Side plating for single hull vessel Inner side plating for double hull vessel Transverse bulkhead plating	1,75
	Frames Ordinary stiffeners Primary supporting members	1,00
Hopper well of dredging vessels		2,00
Accommodation space		0,00
Compartment and area other than those mentioned above		0,50
(1) Corrosion additions are applicable to all the members of the considered item.		

SECTION 6   STRENGTH CRITERIA - STRUCTURAL ITEMS IN COMPOSITE MATERIAL OR PLYWOOD

Symbols

M_H : Design still water bending moment in hogging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_S : Design still water vertical bending moment in sagging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_{WV} : Vertical wave bending moment, in kN.m, defined in Ch 3, Sec 2, [3.2]

p_{SE} : External still water pressure, in kN/m², defined in Ch 3, Sec 4, [2.1.1]

p_S : Still water pressure, in kN/m², defined in Ch 3, Sec 4, [3]

p_{WE} : External wave pressure, in kN/m², defined in Ch 3, Sec 4, [2.1.2]

p_W : Inertial pressure, in kN/m², defined in Ch 3, Sec 4, [3]

p_{ST} : Test pressure, in kN/m², defined in Ch 3, Sec 4, [5.1.1]

p_E : External design pressure, in kN/m²

$p_E = p_{SE} + \gamma_{W2} \, p_{WE}$

p_C : Cargo design pressure, in kN/m²

$p_C = p_S + \gamma_{W2} \, p_W$

p_B : Ballast design pressure, in kN/m²

$p_B = p_S + \gamma_{W2} \, p_W$

p_D : External design pressure, in kN/m²

$p_D = p_S + \gamma_{W2} \, p_W$

p_{WD} : Wind pressure, in kN/m², defined in Ch 3, Sec 4, [2.1.3]

γ_{W1} : Partial safety factor covering uncertainties regarding wave hull girder loads

- $\gamma_{W1} = 1,0$ for **IN**
- $\gamma_{W1} = 1,15$ for **IN(x ≤ 2)**

γ_{W2} : Partial safety factor covering uncertainties regarding wave local loads

- $\gamma_{W2} = 1,0$ for **IN**
- $\gamma_{W2} = 1,2$ for **IN(x ≤ 2)**

I_Y : Moment of inertia, in cm⁴, of the hull girder transverse section defined in Ch 4, Sec 1, [2.1], about its horizontal neutral axis

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section

z : Z co-ordinate, in m, of the calculation point of a structural element.

1 General

1.1 Application

1.1.1 The requirements of the present Section define the strength criteria to be considered for the strength check of structural items in composite material or plywood.

The hull strength check is to be carried out according to the applicable requirements of NR546 Composite Ships.

1.2 Gross scantling approach

1.2.1 The scantlings obtained by applying the criteria specified in the present Rules for composite structures include a rule partial safety factor C_V which takes into account the ageing effect on the laminate mechanical characteristics.

2 Local scantling analysis

2.1 Application

2.1.1 The local scantling of panels, secondary and primary stiffeners is to be reviewed according to:

- local loads as defined in [2.3] and [2.4]
- rule analysis as defined in NR546, Sec 6 for panels and in NR546, Sec 7 for stiffeners
- minimum rule safety factors as defined in [4.3] for laminates and in [5.2] for plywood structure.

2.2 Local load calculation point

2.2.1 Unless otherwise specified, the local loads are to be calculated:

- for plate panels:
  - at the lower edge of the plate panels for monolithic, and
  - at the middle of the plate panels for sandwich.
- for horizontal stiffeners: at mid-span of the stiffeners
- for vertical stiffeners: at the lower and upper vertical points of the stiffeners.

2.2.2 Superstructures and deckhouses

For superstructures and deckhouses, the lateral pressures are to be calculated, for all type of materials:

- for plating: at mid-height of the bulkhead
- for horizontal and vertical stiffeners: at mid-span of the stiffeners.

2.3 Design lateral pressure

2.3.1 The design lateral pressure, p, to be used for hull scantling is defined in Tab 1.

2.4 Forces induced by wheeled and dry unit cargoes

2.4.1 The force transmitted to the hull structure by wheeled cargoes and dry unit cargoes are given by the formula:

$$F = F_S + \gamma_{W2}F_W$$

where:

F_S, F_W : Still water and wave forces defined in Ch 3, Sec 4, [3].

3 Global strength scantling analysis

3.1 Application

3.1.1 Global hull girder longitudinal strength

As a rule, the global hull girder longitudinal strength of vessels assigned the range of navigation **IN(x ≤ 2)**, is to be examined for monohull vessels and for floats of catamarans, in the following cases:

- vessels with length greater than 30 m, or

- vessels having large openings in decks or significant geometrical structure discontinuity at bottom or deck, or

- vessels with a transverse framing system, or

- vessels with deck structure made of panels with small thicknesses and stiffeners with large spacings, or

- vessels with important deadweight, or

- where deemed appropriate by the Society.

The hull girder longitudinal strength of vessels not covered by the above cases is considered satisfied when the local scantlings are in accordance with the requirements defined in [2].

For vessels assigned the range of navigation **IN**, the global hull girder longitudinal strength will be examined on a case by case basis, where deemed appropriate by the Society.

3.1.2 Global strength and local scantling analysis

When deemed necessary by the Society, the hull scantling may be checked taking into account a combination between the global hull girder and local stresses.

3.1.3 Global transverse strength of catamaran

As a rule, the global transverse strength of catamaran is to be examined for all types of catamaran.

3.1.4 Finite element calculation

The global strength analysis may also be examined with a Finite Element Analysis submitted by the designer. In this case and where large openings are provided in side shell and/or in transverse cross bulkhead of catamaran, a special attention is to be paid to ensure a realistic modeling of the bending and shear strengths of the window jambs between windows.

3.2 Vertical overall longitudinal bending moment

3.2.1 The vertical overall longitudinal bending moment M_V to be considered for the scantling analysis is to be obtained from the following formulae:

- In sagging condition

  $$M_V = M_S + \gamma_W \gamma_{W1} C_{FV} M_{WV}$$

- In hogging condition

  $$M_V = M_H + \gamma_W \gamma_{W1} C_{FV} M_{WV}$$

where:

γ_W : Coefficient defined as follows:

- for global hull girder longitudinal strength analysis (see [3.1.1]): $\gamma_W = 1{,}0$

- for global strength and local scantling analysis (see [3.1.2]):

  - $\gamma_W = 1{,}0$ for **IN**

  - $\gamma_W = 0{,}625$ for **IN(x ≤ 2)**

C_{FV} : Combination factors defined in Tab 2

Table 1 : Design lateral pressure, p, in kN/m²

	Structure	In service conditions	In testing conditions	In flooding conditions
In general	Shell structure	p_E $p_C - p_{Em}$ $p_B - p_{Em}$	p_{ST} $p_{ST} - p_{SE}$ **(1)**	–
	Deck structure	p_E **(2)** p_C p_B p_D	p_{ST}	–
	Hatch coaming	$2+p_{WD}$	–	–
	Internal structure	p_C p_B	p_{ST}	p_{FL}
Superstructures & deckhouses	Wall structure	p_{WE}	–	–
	Deck structure	p_D	–	–
(1) Testing afloat				
(2) External deck pressure defined in Ch 3, Sec 4, [2.2.1]				

Table 2 : Combination factors C_{FV}

Load case	C_{FV}
"a"	0
"b"	1,0
"c"	Except vessels assigned a range of navigation **IN(x ≤ 2)**, the hull girder wave loads in inclined condition may generally be disregarded.
"d"	

4 Structural items in composite material

4.1 Application

4.1.1 The requirements of the present Article define the permissible stresses considered for the strength check of composite structures.

4.2 General

4.2.1 Principle of design review

The design review of composite structures is based on safety factors which are to be in compliance with the following criteria:

- minimum stress criteria in layers:

$$\frac{\sigma_{bri}}{\sigma_{iapp}} \geq SF$$

- critical buckling stress criteria:

$$\frac{\sigma_c}{\sigma_A} \geq SF_B$$

- combined stress criteria in layers:

$$SF_{CS} \geq SF_{CSiapp}$$

where:

σ_{bri} : In-plane theoretical individual layer breaking stresses defined in NR546 Composite Ships, Sec 5, [5]

σ_C : Critical buckling stress of the composite element considered calculated as defined in NR546, Composite Ships, Sec 6, [4].

σ_{iapp} : In-plane individual layer applied stresses

σ_A : Compressive stress applied to the whole laminate considered

SF, SF_B, SF_{CS} : Rule safety factors defined in [4.3.3]

SF_{CSiapp} : Actual combined stress applied in layer as calculated in NR546 Composite ships, Sec 2, [1.3.3].

Note 1: The breaking stresses directly deduced from mechanical tests (as requested in NR546 Composite Ships) may be taken over from the theoretical breaking stresses if the mechanical test results are noticeably different from the expected values.

4.2.2 Types of stress considered

The following different types of stress are considered, corresponding to the different loading modes of the fibres:

a) Principal stresses in the individual layers

- stress σ_1

These stresses, parallel to the fibre (longitudinal direction), may be tensile or compressive stresses and are mostly located as follows:

- in 0° direction of unidirectional tape or fabric reinforcement systems

- in 0° and 90° directions of woven roving.

- stress σ_2

These stresses, perpendicular to the fibre (transverse direction), may be tensile or compressive stresses and are mostly located as follows:

- in 90° direction of unidirectional tape or combined fabrics when the fibres of the set are stitched together without criss-crossing.

- shear stress τ_{12} (in the laminate plane)

These shear stresses, parallel to the fibre, may be found in all type of reinforcement systems

- shear stresses τ_{13} and τ_{23} (through the laminate thickness)

These shear stresses, parallel or perpendicular to the fibre, are the same stresses than the interlaminar shear stresses τ_{IL2} and τ_{IL1}

- combined stress (Hoffman criteria).

b) Stresses in the whole laminate

- compressive and shear stresses in the whole laminate inducing buckling.

4.2.3 Theoretical breaking criteria

Three theoretical breaking criteria are used in the present Rules:

a) the maximum stress criteria leading to the breaking of the component resin/fibre of one elementary layer of the full lay-up laminate

b) the Hoffman combined stress criteria with the hypothesis of in-plane stresses in each layer

c) the critical buckling stress criteria applied to the laminate.

The theoretical breaking criteria defined in items a) and b) are to be checked for each individual layer.

The theoretical breaking criteria defined in item c) is to be checked for the global laminate.

4.2.4 First ply failure

It is considered that the full lay-up laminate breaking strength is reached as soon as the lowest breaking strength of any elementary layer is reached. This is referred to as "first ply failure".

4.3 Rule safety factors

4.3.1 General

a) General consideration:

The rule safety factors to be considered for the composite structure check are defined in [4.3.3], according to the partial safety factors defined in [4.3.2].

b) Additional considerations:

Rule safety factors other than those defined in [4.3.3] may be accepted for one elementary layer when the full lay-up laminate exhibits a sufficient safety margin between the theoretical breaking stress of this elementary layer and the theoretical breaking stress of the other elementary layers.

Finite Element Model analyses are examined on a case by case basis by the Society. As a rule, when the structure is checked with a Finite Element Model, the rule safety factors defined in [4.3.3] and [4.3.4] may be reduced by ten per cent.

4.3.2 Partial safety factors

As a general rule, the minimum partial safety factors considered are to be as follows:

a) Ageing effect factor C_V

C_V takes into account the ageing effect of the composites and is generally taken equal to:

$C_V = 1,2$ for monolithic laminates (or for face-skins laminates of sandwich)

$C_V = 1,1$ for sandwich core materials

b) Fabrication process factor C_F

C_F takes into account the fabrication process and the reproducibility of the fabrication and is generally taken equal to:

$C_F = 1,10$ in case of a prepreg process

$C_F = 1,15$ in case of infusion and vacuum process

$C_F = 1,25$ in case of a hand lay-up process

$C_F = 1,00$ for the core materials of sandwich composite

c) Type of load factor C_i

C_i takes into account the type of loads and is generally taken equal to:

$C_i = 1,0$ for local external pressures and internal pressures or concentrated forces

$C_i = 0,8$ for test pressures and flooding loads

d) Type of stress factor C_R

C_R takes into account the type of stress in the fibres of the reinforcement fabrics and the cores and is generally taken equal to:

1) For fibres of the reinforcement fabrics

• for tensile or compressive stress parallel to the continuous fibre of the reinforcement fabric:

$C_R = 2,1$ for unidirectional tape, bi-bias, three-unidirectional fabric

$C_R = 2,4$ for woven roving

• for tensile or compressive stress perpendicular to the continuous fibre of the reinforcement fabric:

$C_R = 1,25$ for unidirectional tape, bi-bias, three-unidirectional fabric

• for shear stress parallel to the fibre in the elementary layer and for interlaminar shear stress in the laminate:

$C_R = 1,6$ for unidirectional tape, bi-bias, three-unidirectional fabric

$C_R = 1,8$ for woven roving

• for mat layer:

$C_R = 2,0$ for tensile or compressive stress in the layer

$C_R = 2,2$ for shear stress in the layer and for interlaminar shear stress

2) For core materials

• for tensile or compressive stress for cores:

- in the general case:

$C_R = 2,1$ for tensile or compressive stress

- for balsa:

$C_R = 2,1$ for tensile or compressive stress parallel to the wood grain

$C_R = 1,2$ for tensile or compressive stress perpendicular to the wood grain

• for shear stress, whatever the type of core material:

$C_R = 2,5$

3) For wood materials for strip planking

$C_R = 2,4$ for tensile or compressive stress parallel to the continuous fibre of the strip planking

$C_R = 1,2$ for tensile or compressive stress perpendicular to the continuous fibre of the strip planking

$C_R = 2,2$ for shear stress parallel to the fibre and for interlaminar shear stress in the strip planking.

4.3.3 Rule safety factors

The rule safety factors SF, SF_{CS} and SF_B to be considered for the composite structure check are defined according to the type of hull structure calculation, as follows:

a) For structure checked under local loads:

1) Minimum stress criterion in layers:

$SF = C_V C_F C_R C_i$

with:

C_V, C_F, C_R, C_i: Partial safety factors defined in [4.3.2]

2) Combined stress criterion in layers:

$SF_{CS} = C_{CS} C_V C_F C_i$

with:

C_{CS} : Partial safety factor, to be taken equal to:

• $C_{CS} = 1,7$ for unidirectional tape, bi-bias, three-unidirectional fabric

• $C_{CS} = 2,1$ for the other types of layer

C_V, C_F, C_i: Partial safety factors defined in [4.3.2]

b) For structure element contributing to the global strength checked under global hull girder loads:

The minimum stress criterion in layers and the combined stress criterion in layers are to be taken as defined in a) with a value of C_i equal to 1,4.

The critical buckling stress criterion is to be taken equal to:

$SF_B = C_{buck} C_V C_F C_i$

with:

C_{buck} : Partial safety factors to be taken equal to 1,45

C_V, C_F : Partial safety factors defined in [4.3.2]

C_i : Partial safety factors to be taken equal to 1,2

c) For structure element contributing to the global strength checked under global loads combined with local loads:

The minimum stress criterion in layers and the combined stress criterion in layers are to be taken as defined in a) with a value of C_i equal to 0,8.

The critical buckling stress criterion is to be taken as defined in b) with a value of C_i equal to 0,8.

4.3.4 Rule safety factor for structural adhesive joints

The structural adhesive characteristics are to be as defined in NR546 Composite Ships.

As a general rule, the rule safety factor SF considered in the present Rules and applicable to the maximum shear stress in adhesive joints is to be calculated as follows:

$SF = 2,4 \, C_F \, C_i$

where:

C_F : Factor taking into account the gluing process and generally taken as follows:
- $C_F = 1,4$ in case of a vacuum process with rising curing temperature
- $C_F = 1,5$ in case of vacuum process
- $C_F = 1,7$ in the other cases.

5 Structural items in plywood

5.1 General

5.1.1 Principle of design review

As a rule, plywood structures are checked according to an homogeneous material approach, or by a "ply by ply" approach as defined in NR546 Composite Ships.

5.2 Rule safety factors

5.2.1 Homogeneous material approach

As a general rule, the rule safety factor SF to be taken into account in the global formula used to determine the plating thickness or the permissible stress in stiffeners is to be equal to, or greater than, 4,0.

5.2.2 Ply by ply approach

As a general rule, the rule safety factor SF applicable to the maximum stress in each layer of the plywood is to be calculated as follows:

a) Minimum stress criterion in layers

$SF = C_R \, C_i \, C_V$

with:

C_R : Factor taking into account the type of stress in the grain of the plywood layer. Generally:
- $C_R = 3,7$

  for a tensile or compressive stress parallel to the grain of the ply considered
- $C_R = 2,4$

  for tensile or compressive stress perpendicular to the grain of the ply considered
- $C_R = 2,9$

  for a shear stress parallel to the grain of the ply considered

C_i : Factor taking into account the type of loads. Generally:
- $C_i = 1,0$

  for local external pressures and internal pressures or concentrated forces
- $C_i = 0,8$

  for test pressures and flooding loads

C_V : Factor taking into account the ageing effect of the plywood, to be taken at least equal to 1,2

b) Critical buckling stress criterion

As a general rule, the rule safety factor SFB applicable to the critical buckling stress criterion is to be calculated as follows:

$SF_B = C_{buck} \, C_V \, C_i$

with:

C_{buck}, C_V : Partial safety factors, to be taken equal to:
- $C_{buck} = 1,45$ and $C_V = 1,2$

  for the check of the structure under local loads
- $C_{buck} = 1,35$ and $C_V = 1,0$

  for the check of the global hull girder structure, if required.

C_i : Partial safety factor defined in [4.3.2].

SECTION 7 — BUCKLING AND ULTIMATE STRENGTH OF ORDINARY STIFFENERS AND STIFFENED PANELS

Symbols

a : Length of single or partial plate field, in mm (see Fig 1)

b : Breadth of single plate field, in mm (see Fig 1)

In general, the ratio plate field breadth to plate thickness shall not exceed $b / t = 100$

E : Young's modulus, in N/mm²:
- $E = 2,06 \cdot 10^5$ for steel, in general
- $E = 1,95 \cdot 10^5$ for stainless steel
- $E = 7,00 \cdot 10^4$ for aluminium alloys

F_1 : Correction factor for boundary condition of stiffeners on the longer side of elementary plate panels:
- $F_1 = 1,00$ for stiffeners sniped at both ends
- $F_1 = 1,05$ for flat bar
- $F_1 = 1,10$ for bulb sections
- $F_1 = 1,20$ for angle or T-sections
- $F_1 = 1,30$ for girders of high rigidity (e.g. bottom transverses).

K : Buckling factor according to Tab 1.

k : Material factor defined in:
- Ch 2, Sec 3, [2.3] for steel
- Ch 2, Sec 3, [3.5] for aluminium alloys

k_0 : Coefficient to be taken equal to:
- $k_0 = 1$ for steel
- $k_0 = 2,35$ for aluminium alloys

I_Y : Moment of inertia, in cm⁴, of the hull girder transverse section defined in Ch 4, Sec 1, [2.1], about its horizontal neutral axis

I_z : Net moment of inertia, in cm⁴, of the hull transverse section defined in Ch 4, Sec 1, [2.1] around the vertical neutral axis

M_H : Design still water bending moment in hogging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_S : Design still water vertical bending moment in sagging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_{WV} : Vertical wave bending moment, in kN.m, defined in Ch 3, Sec 2, [3.2]

M_{WH} : Horizontal wave bending moment, in kN.m, to be determined according to Ch 3, Sec 2, [3.3]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section

n_S : Number of single plate field breadths within the partial or total plate field

p_B : Ballast design pressure, in kN/m²
$p_B = p_S + \gamma_{WB} p_W$

p_C : Cargo design pressure, in kN/m²
$p_C = p_S + \gamma_{WB} p_W$

p_D : External design pressure, in kN/m²
$p_D = p_S + \gamma_{WB} p_W$

p_E : External design pressure, in kN/m²
$p_E = p_{SE} + \gamma_{WB} p_{WE}$

p_S : Still water pressure, in kN/m², defined in Ch 3, Sec 4, [3]

p_{SE} : External still water pressure, in kN/m², defined in Ch 3, Sec 4, [2.1.1]

p_{ST} : Test pressure, in kN/m², defined in Ch 3, Sec 4, [5.1.1]

p_W : Inertial pressure, in kN/m², defined in Ch 3, Sec 4, [3]

p_{WD} : Wind pressure, in kN/m², defined in Ch 3, Sec 4, [2.1.3]

p_{WE} : External wave pressure, in kN/m², defined in Ch 3, Sec 4, [2.1.2]

R_{eH} :
- for hull structural steels:
  Minimum yield stress, in N/mm²
- for aluminium alloys:
  - in general
    Minimum yield stress of the parent metal in delivery condition $R_{P0,2}$, in N/mm²
  - for buckling of pillars
    Minimum yield stress of the parent metal in welded condition $R'_{P0,2}$, in N/mm²

S_F : Safety factor:
- structural items in the vessel central part
  $S_F = 1,10$ for steel
  $S_F = 1,20$ for constructions in aluminium alloys
- structural items elsewhere
  $S_F = 1$ for steel
  $S_F = 1,10$ for constructions in aluminium alloys

t : Net plate thickness, in mm

y : Y co-ordinate, in m, of the calculation point

z : Z co-ordinate, in m, of the calculation point of a structural element

α : Aspect ratio of single plate field: $\alpha = a / b$

γ_{WB} : Factor taken as:

- $\gamma_{WB} = 1$ for **IN**

- $\gamma_{WB} = 1,6$ for **IN(x ≤ 2)**

λ : Reference degree of slenderness

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

σ_E : Reference stress, in N/mm²

- for plating:

$$\sigma_E = 0,9E\left(\frac{t}{b}\right)^2$$

- for pillars

$$\sigma_E = \pi^2 E \frac{I}{A(f\ell)^2}10^{-4}$$

σ_X : Membrane stress in x-direction, in N/mm²

σ_y : Membrane stress in y-direction, in N/mm²

ψ : Edge stress ratio taken equal to: $\psi = \sigma_2 / \sigma_1$

where:

σ_1 : Maximum compressive stress

σ_2 : Minimum compressive stress or tensile stress

τ : Shear stress in the x-y plane, in N/mm².

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the buckling check of metallic structural members and plating.

1.1.2 Buckling and ultimate strength assessment application guide is given in [7].

1.1.3 Other buckling rules can be accepted if agreed with the Society.

2 Proof of single plate fields

2.1 Verification of a single plate field in a transverse section analysis

2.1.1 Load cases

The buckling load cases to be applied to the buckling panel under evaluation are defined in Tab 1 and Tab 2, depending on the stress distribution and the panel geometry.

2.1.2 Checking criteria

Proof is to be provided that the following conditions are complied with for the single plate field a x b:

- load case 1 and load case 3:

$$\frac{|\sigma_x|S_F}{\kappa_x R_{eH}} \le 1$$

- load case 2 and load case 4:

$$\frac{|\sigma_y|S_F}{\kappa_y R_{eH}} \le 1$$

where

κ_x, κ_y : Reduction factors as given in Tab 1 and/or Tab 2, with:

- $\kappa_x = 1,0$ when $\sigma_x \le 0$ (tension stress)

- $\kappa_y = 1,0$ when $\sigma_y \le 0$ (tension stress).

2.2 Verification of a single plate field within FEM analysis

2.2.1 General

The FEM analysis is to be carried out according Ch 2, App 1. The determination of the buckling and reduction factors is made for each relevant case of Tab 1 according to the stresses calculated in [2.2.2] loading the considered single plate field.

2.2.2 Stresses

The buckling stresses are to be determined according to Tab 1 and Tab 2 including their stress ratio ψ for the required loading conditions and according to Ch 2, App 1, [6].

2.2.3 Boundary conditions

Buckling load cases 1, 2, 5 or 6 of Tab 1 are to be applied to the buckling panel under evaluation, depending on the stress distribution and geometry of openings.

If the actual boundary conditions are significantly different from simple support condition, another case in Tab 1 can be applied.

2.2.4 Safety factor

The safety factor S_F for the buckling and ultimate strength assessment of the single plate field is to be taken equal to:.

- $S_F = 1$ for steel

- $S_F = 1,1$ for aluminium alloys

2.2.5 Checking criteria

Proof is to be provided that the following condition, in which each term is not to exceed 1,0, is complied with for the single plate field a · b:

$$\left(\frac{|\sigma_x|S_F}{\kappa_x R_{eH}}\right)^{e1} + \left(\frac{|\sigma_y|S_F}{\kappa_y R_{eH}}\right)^{e2} - B\left(\frac{\sigma_x\sigma_y S_F^2}{R_{eH}^2}\right) + \left(\frac{|\tau|S_F\sqrt{3}}{\kappa_\tau R_{eH}}\right)^{e3} \le 1,0$$

where:

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):

$B = 1,00$

$e_1 = 1 + \kappa_x^4$

$e_2 = 1 + \kappa_y^4$

$e_3 = 1 + \kappa_x \kappa_y \kappa_\tau^2$

$\kappa_x, \kappa_y, \kappa_\tau$: Reduction factors as given in Tab 1 and/or Tab 2 with:

- $\kappa_x = 1,0$ when $\sigma_x \le 0$ (tension stress)

- $\kappa_y = 1,0$ when $\sigma_y \le 0$ (tension stress).

3 Effective width of plating

3.1 General

3.1.1 The effective width of plating may be determined by the following formulae (see Fig 1):

- for longitudinal stiffeners: $b_m = \kappa_X \, b$

- for transverse stiffeners: $a_m = \kappa_Y \, a$

The effective width of plating is not to be taken greater than the value obtained from Ch 2, Sec 4, [4.3] or Ch 2, Sec 4, [5.3].

Figure 1 : Structural elements
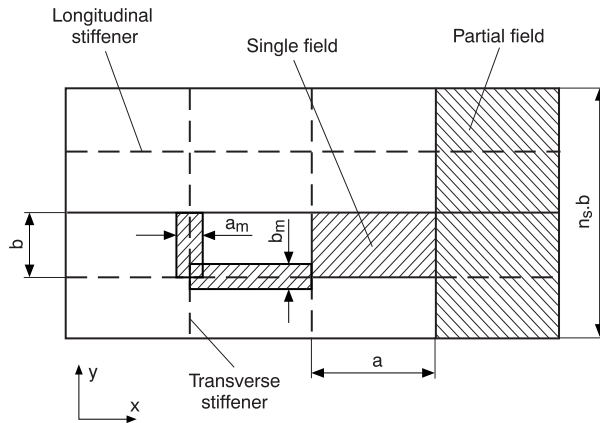
4 Webs and flanges

4.1 General

4.1.1 For non-stiffened webs and flanges of sections and girders, proof of sufficient buckling strength as for single plate fields is to be provided according to [2.1].

Within 0,5 L amidships, the following guidance values are recommended for the ratio web depth to web thickness and/or flange breadth to flange thickness:

- flat bars:

  $h_W \, / \, t_W \leq 19{,}5 \, (k_0 k)^{0,5}$

- angles, tees and bulb sections:

  - for web: $\quad h_W \, / \, t_W \leq 60 \, (k_0 k)^{0,5}$

  - for flange: $b_i \, / \, t_f \leq 19{,}5 \, (k_0 k)^{0,5}$

  where:

  b_i : Parameter defined in Fig 2 and equal to:

         $b_i = MAX \, (b_1 \, ; \, b_2)$

Figure 2 : Section dimensions
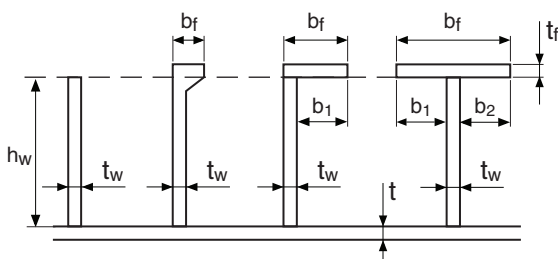
5 Proof of partial and total fields

5.1 Longitudinal and transverse stiffeners

5.1.1 Proof is to be provided that the continuous longitudinal and transverse stiffeners of partial (see Fig 1) and total plate fields comply with the condition set out in [5.2] and [5.3].

5.2 Lateral buckling

5.2.1 The following relation is to be complied with:

$$\frac{\sigma_a + \sigma_b}{R_{eH}} S_F \leq 1$$

where:

σ_a : Uniformly distributed compressive stress, in N/mm², in the direction of the stiffener axis:

      $\sigma_a = \sigma_X$ for longitudinal stiffeners

      $\sigma_a = \sigma_Y$ for transverse stiffeners.

σ_b : Bending stress, in N/mm², in the stiffeners:

$$\sigma_b = \frac{M_0 + M_1}{w_{St} 10^3}$$

with:

M_0 : Bending moment due to deformation w_d of stiffener, in N.mm:

$$M_0 = F_{Ki} \frac{p_z w_d}{c_f - p_Z}$$

      with $(c_f - p_Z) > 0$

F_{Ki} : Ideal buckling force of the stiffener, in N:

- for longitudinal stiffeners:

$$F_{KiX} = \frac{\pi^2}{a^2} EI_X \cdot 10^4$$

- for transverse stiffeners:

$$F_{KiY} = \frac{\pi^2}{(n_s \cdot b)^2} EI_Y \cdot 10^4$$
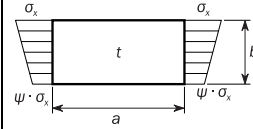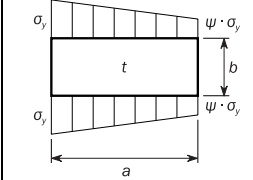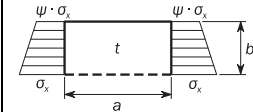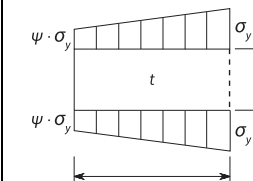
I_X : Moment of inertia, in cm⁴, of the longitudinal stiffener including effective width of plating according to [3.1]:

$$I_X \geq \frac{bt^3}{12 \cdot 10^4}$$

I_Y : Moment of inertia, in cm⁴, of the transverse stiffener including effective width of plating according to [3.1]:

$$I_Y \geq \frac{at^3}{12 \cdot 10^4}$$

Table 1 : Buckling and reduction factors for plane elementary plate panels

Load case	Edge stress ratio ψ	Aspect ratio $\alpha = a/b$	Buckling factor K	Reduction factor κ
Case 1	$1 \geq \psi \geq 0$	$\alpha > 1$	$K = \dfrac{8,4}{\psi + 1,1}$	$\kappa_X = 1$ for $\lambda \leq \lambda_C$ $\kappa_X = c\left(\dfrac{1}{\lambda} - \dfrac{0,22}{\lambda^2}\right)$ for $\lambda > \lambda_C$ $c = (1,25 - 0,12\ \psi) \leq 1,25$
	$0 > \psi > -1$		$K = 7,63 - \psi\ (6,26 - 10\ \psi)$	
	$\psi \leq -1$		$K = 5,975\ (1 - \psi)^2$	$\lambda_C = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0,88}{c}}\right)$
Case 2	$1 \geq \psi \geq 0$	$\alpha \geq 1$	$K = F_1\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2,1}{\psi + 1,1}$	$\kappa_Y = c\left[\dfrac{1}{\lambda} - \dfrac{R + F^2(H - R)}{\lambda^2}\right]$ $c = (1,25 - 0,12\ \psi) \leq 1,25$ $R = \lambda\left(1 - \dfrac{\lambda}{c}\right)$ for $\lambda < \lambda_C$ $R = 0,22$ for $\lambda \geq \lambda_C$ $\lambda_C = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0,88}{c}}\right)$ $F = \left(1 - \dfrac{\frac{K}{0,91} - 1}{\lambda_P^2}\right)c_1 \geq 0$ $\lambda_P^2 = \lambda^2 - 0,5$ with $1 \leq \lambda_P^2 \leq 3$ c_1 is equal to: • for σ_Y due to direct loads: $c_1 = 1$ • for σ_Y due to bending (in general): $c_1 = (1 - F_1 / \alpha) \geq 0$ • for σ_Y due to bending in extreme load cases (e.g. watertight bulkheads): $c_1 = 0$ $H = \lambda - \dfrac{2\lambda}{c(\Gamma + \sqrt{\Gamma^2 - 4})} \geq R$ $\Gamma = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$
	$0 > \psi > -1$	$1,0 \leq \alpha \leq 1,5$	$K = F_1\left[\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2,1(\psi + 1)}{1,1} - \dfrac{\psi}{\alpha^2}(13,9 - 10\psi)\right]$	
		$\alpha > 1,5$	$K = F_1\left[\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2,1(\psi + 1)}{1,1} - \dfrac{\psi}{\alpha^2}\left(5,87 + 1,87\alpha^2 + \dfrac{8,6}{\alpha^2} - 10\psi\right)\right]$	
	$\psi \leq -1$	$1 \leq \alpha \leq \dfrac{3(1 - \psi)}{4}$	$K = 5,975\ F_1\left(\dfrac{1 - \psi}{\alpha}\right)^2$	
		$\alpha > \dfrac{3(1 - \psi)}{4}$	$K = F_1\left[3,9675\left(\dfrac{1 - \psi}{\alpha}\right)^2 + 0,5375\left(\dfrac{1 - \psi}{\alpha}\right)^4 + 1,87\right]$	
Case 3	$1 \geq \psi \geq -1$	$\alpha > 0$	$K = \left(0,425 + \dfrac{1}{\alpha^2}\right)\dfrac{(3 - \psi)}{2}$	$\kappa_X = 1$ for $\lambda \leq 0,7$ $\kappa_X = \dfrac{1}{\lambda^2 + 0,51}$ for $\lambda > 0,7$
Case 4	$1 \geq \psi \geq -1$	$\alpha > 0$	$K = (0,425 + \alpha^2)\dfrac{(3 - \psi)}{2\alpha^2}$	$\kappa_Y = 1$ for $\lambda \leq 0,7$ $\kappa_Y = \dfrac{1}{\lambda^2 + 0,51}$ for $\lambda > 0,7$
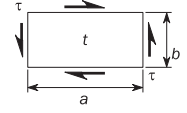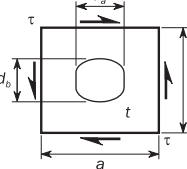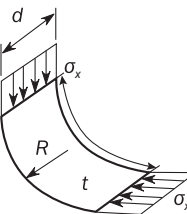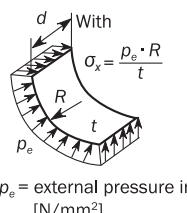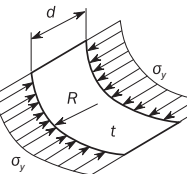
Load case	Edge stress ratio ψ	Aspect ratio $\alpha = a/b$	Buckling factor K	Reduction factor κ
Case 5			$K = K_\tau \sqrt{3}$	$\kappa_\tau = 1$ for $\lambda \le 0,84$
		$\alpha \ge 1$	$K_\tau = 5,34 + \dfrac{4}{\alpha^2}$	
		$0 < \alpha < 1$	$K_\tau = 4 + \dfrac{5,34}{\alpha^2}$	$\kappa_\tau = \dfrac{0,84}{\lambda}$ for $\lambda > 0,84$
Case 6			$K = K'r$ $K' = K$ according to load case 5 $r =$ Opening reduction factor $r = \left(1 - \dfrac{d_a}{a}\right)\left(1 - \dfrac{d_b}{b}\right)$ with $\dfrac{d_a}{a} \le 0,7$ and $\dfrac{d_b}{b} \le 0,7$	

Table 2 : Buckling and reduction factors for curved plate panel with R/t $\le$ 2500

Load case	Aspect ratio b/R	Buckling factor K	Reduction factor κ
Case 1a	$\dfrac{b}{R} \le 1,63 \sqrt{\dfrac{R}{t}}$	$K = \dfrac{b}{\sqrt{Rt}} + 3\,\dfrac{(Rt)^{0,175}}{b^{0,35}}$	• for general application: $\kappa_x = 1,00$ for $\lambda \le 0,4$ $\kappa_x = 1,274 - 0,686\,\lambda$ for $0,4 < \lambda \le 1,2$ $\kappa_x = \dfrac{0,65}{\lambda^2}$ for $\lambda > 1,2$
Case 1b With $\sigma_x = \dfrac{p_e \cdot R}{t}$ $p_e =$ external pressure in [N/mm^2]	$\dfrac{b}{R} > 1,63 \sqrt{\dfrac{R}{t}}$	$K = 0,3\,\dfrac{b^2}{R^2} + 2,25\left(\dfrac{R^2}{b\,t}\right)^2$	• for curved single fields, e.g. bilge strakes, which are bounded by plane panels: $\kappa_x = \dfrac{0,8}{\lambda^2} \le 1,0$
Case 2	$\dfrac{b}{R} \le 0,5 \sqrt{\dfrac{R}{t}}$	$K = 1 + \dfrac{2}{3}\,\dfrac{b^2}{Rt}$	• for general application: $\kappa_x = 1,00$ for $\lambda \le 0,25$ $\kappa_x = 1,233 - 0,933\,\lambda$ for $0,25 < \lambda \le 1,0$ $\kappa_y = \dfrac{0,30}{\lambda^3}$ for $1,0 < \lambda \le 1,5$ $\kappa_y = \dfrac{0,20}{\lambda^2}$ for $\lambda > 1,5$
	$\dfrac{b}{R} > 0,5 \sqrt{\dfrac{R}{t}}$	$K = 0,267\,\dfrac{b^2}{Rt}\left[3 - \dfrac{b}{R}\sqrt{\dfrac{t}{R}}\right] \ge 0,4\,\dfrac{b^2}{Rt}$	• for curved single fields, e.g. bilge strakes, which are bounded by plane panels: $\kappa_y = \dfrac{0,65}{\lambda^2} \le 1,0$
Edge boundary conditions: - - - - - - - - Plate edge free. ———— Plate edge simply supported ▬▬▬ Plate edge clamped.			

p_Z : Nominal lateral load of the stiffener due to σ_X and σ_Y, in N/mm²:

- for longitudinal stiffeners:

$$p_{ZX} = \frac{t}{b}\left[\sigma_{X1}\left(\frac{\pi b}{a}\right)^2 + 2 c_Y \sigma_Y\right]$$

- for transverse stiffeners:

$$p_{ZY} = \frac{t}{a}\left[2 c_X \sigma_{X1} + \sigma_Y\left(\frac{\pi a}{n_s b}\right)^2\left(1 + \frac{A_Y}{a t}\right)\right]$$

with:

$$\sigma_{X1} = \sigma_X\left(1 + \frac{A_X}{b t}\right)$$

A_X, A_Y : Sectional area, in mm², of the longitudinal or transverse stiffener respectively, without attached plating

c_X, c_Y : Factors taking into account the stresses vertical to the stiffener's axis and distributed variable along the stiffener's length:

c_X, c_Y = 0,5 (1 + ψ)   for $0 \leq \psi \leq 1$

c_X, c_Y = 0,5 / (1 − ψ)   for $\psi < 0$

w_d : Value calculated as follows:

$w_d = w_{d0} + w_{d1}$

with:

w_{d0} : Assumed imperfection, in mm, taken equal to:

- for longitudinal stiffeners:

$$w_{d0} = MIN\left(\frac{a}{250} \; ; \; \frac{b}{250} \; ; \; 10\right)$$

- for transverse stiffeners:

$$w_{d0} = MIN\left(\frac{a}{250} \; ; \; \frac{n_s b}{250} \; ; \; 10\right)$$

For stiffeners sniped at both ends w_{d0} 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

w_{d1} : Deformation of stiffener due to lateral load p (in kN/m²) at midpoint of stiffener span, in mm.

In case of uniformly distributed load, the following values for w_{d1} may be used:

- for longitudinal stiffeners:

$$w_{d1} = \frac{p b a^4}{384 \cdot 10^7 E I_X}$$

- for transverse stiffeners:

$$w_{d1} = \frac{5 a p (n_s b)^4}{384 \cdot 10^7 E I_Y c_S^2}$$

c_f : Elastic support provided by the stiffener, in N/mm²:

- for longitudinal stiffeners:

$$c_{fX} = F_{KiX}\frac{\pi^2}{a^2}(1 + c_{PX})$$

with:

$$c_{PX} = \cfrac{1}{1 + \cfrac{0,91\left(\cfrac{12 \cdot 10^4 I_X}{t^3 b} - 1\right)}{c_{X\alpha}}}$$

$$c_{X\alpha} = \left(\frac{a}{2 b} + \frac{2 b}{a}\right)^2 \qquad for \quad a \geq 2 b$$

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

- for transverse stiffeners:

$$c_{fY} = c_S F_{KiY}\frac{\pi^2}{(n_s b)^2}(1 + c_{PY})$$

with:

c_S : As defined hereafter for M_1

$$c_{PY} = \cfrac{1}{1 + \cfrac{0,91\left(\cfrac{12 \cdot 10^4 I_Y}{t^3 a} - 1\right)}{c_{Y\alpha}}}$$

$$c_{Y\alpha} = \left(\frac{n_s b}{2 a} + \frac{2 a}{n_s b}\right)^2 \qquad for \quad n_s b \geq 2 a$$

$$c_{Y\alpha} = \left[1 + \left(\frac{n_s b}{2 a}\right)^2\right]^2 \qquad for \quad n_s b < 2 a$$

w_{St} : Net section modulus of stiffener (longitudinal or transverse), in cm³, including effective width of plating according to [3.1], taken equal to:

- if a lateral pressure is applied on the stiffener:

w_{St} is the net section modulus calculated at flange if the lateral pressure is applied on the same side as the stiffener

w_{St} is the net section modulus calculated at attached plate if the lateral pressure is applied on the side opposite to the stiffener

- if no lateral pressure is applied on the stiffener:

w_{St} is the minimum net section modulus among those calculated at flange and attached plate

M_1 : Bending moment due to the lateral load p, in N.mm:

- for continuous longitudinal stiffeners:

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

- for transverse stiffeners:

$$M_1 = \frac{p a (n_s b)^2}{c_S \cdot 8 \cdot 10^3}$$

c_S : Factor accounting for the boundary conditions of the transverse stiffener:

- for simply supported stiffeners: c_S = 1,0
- for partially constraint stiffeners: c_S = 2,0

p : Lateral load, in kN/m², defined in [7.2.3], determined at the calculation point as defined in Ch 2, Sec 4, [6.1].

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 bi-axial stress field at the plating side).

5.3 Stiffeners not subjected to lateral load

5.3.1 Longitudinal and transverse stiffeners not subjected to lateral load p have sufficient scantlings if their moments of inertia I_X and I_Y, in cm⁴, are not less than obtained by the following formulae:

$$I_X = \frac{p_{zX}a^2}{\pi^2 10^4}\left(\frac{w_{d0X}h_W}{\frac{R_{eH}}{\Sigma} - \sigma_X} + \frac{a^2}{\pi^2 E}\right)$$

$$I_Y = \frac{p_{zY}(n_sb)^2}{\pi^2 10^4}\left[\frac{w_{d0Y}h_W}{\frac{R_{eH}}{\Sigma} - \sigma_Y} + \frac{(n_sb)^2}{\pi^2 E}\right]$$

6 Buckling check of pillars

6.1 Compression axial load

6.1.1 Where pillars are in line, the compression axial load in a pillar is obtained, in kN, from the following formula:

$$F_A = A_D(p_S + \gamma_{W2}p_W) + \sum_{i=1}^{N} r_i(Q_{i,S} + \gamma_{W2}Q_{i,W})$$

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 ith 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 ith pillar of the line above the pillar considered

p_S : Still water pressure, in kN/m², on the deck supported by the pillar, see Ch 3, Sec 4

p_W : Wave pressure, in kN/m², on the deck supported by the pillar, see Ch 3, Sec 4

γ_{W2} : Partial safety factor covering uncertainties regarding wave loads:

- $\gamma_{W2} = 1,0$ for **IN**

- $\gamma_{W2} = 1,2$ for **IN(x ≤ 2)**

6.2 Critical column buckling of pillars

6.2.1 Steel pillars

The critical column buckling stress of pillars is to be obtained, in N/mm2, from the following formulae:

$$\sigma_{cB} = \sigma_{E1} \qquad \text{for} \quad \sigma_{E1} \le \frac{R_{eH}}{2}$$

$$\sigma_{cB} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eH}}{2}$$

where:

σ_{E1} : Euler column buckling stress, to be obtained, in N/mm²: $\sigma_{E1} = \sigma_E$
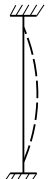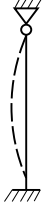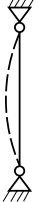
I : Minimum net moment of inertia, in cm⁴, of the pillar

A : Net cross-sectional area, in cm², of the pillar

ℓ : Span, in m, of the pillar

f : Coefficient, to be obtained from Tab 3.

Table 3 : Coefficient f

Boundary conditions of the pillar	Both ends fixed	One end fixed, one end pinned	Both ends pinned
f	0,5	$\frac{\sqrt{2}}{2}$	1

6.2.2 Aluminium alloy pillars

The critical column buckling stress σ_{CB} of pillars made of aluminium alloy is to be obtained, in N/mm², from the following formula:

$$\sigma_{CB} = 2R_{eH} \cdot C$$

where:

C : Coefficient to be taken equal to one of the following formulae or deduced from Fig 3:

- for alloys series5000:

$$\frac{1}{1 + \lambda_1 + \sqrt{(1+\lambda_1)^2 - 0,68 \cdot \lambda_1}}$$

- for alloys series 6000:

$$\frac{1}{1 + \lambda_1 + \sqrt{(1+\lambda_1)^2 - 3,2 \cdot \lambda_1}}$$

where:

$$\lambda_1 = \frac{R_{eH}}{\sigma_E}$$

6.3 Critical local buckling stress of built-up pillars

6.3.1 Steel pillars

The critical local buckling stress of built-up pillars is to be obtained, in N/mm², from the following formulae:

$$\sigma_{cL} = \sigma_{E3} \qquad \text{for} \quad \sigma_{E3} \leq \frac{R_{eH}}{2}$$

$$\sigma_{cL} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E3}}\right) \quad \text{for} \quad \sigma_{E3} > \frac{R_{eH}}{2}$$

where:

σ_{E3} : Euler local buckling stress, to be taken equal to the lesser of the values obtained, in N/mm², from the following formulae:

$$\bullet \quad \sigma_{E3} = 78\left(\frac{t_W}{h_W}\right)^2 10^4$$

$$\bullet \quad \sigma_{E3} = 32\left(\frac{t_F}{b_F}\right)^2 10^4$$

h_W : Web height 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.

6.3.2 Aluminium alloy pillars

The critical local buckling stress σ_{CL} of pillars made of aluminium alloy is to be obtained, in N/mm², from the following formula:

$$\sigma_{CL} = 2\,R_{eH}\,C$$

where:

C : Coefficient as defined in [6.2.2], with:

$$\lambda = \frac{R_{eH}}{\sigma_{Ei}}$$

σ_{Ei} : Euler local buckling stress, in N/mm², to be taken equal to:

for built up pillars, the lesser of:

$$\sigma_{Ei} = 78\left(\frac{E}{206000}\right)\left(\frac{t_W}{h_W}\right)^2 10^4$$

$$\sigma_{Ei} = 32\left(\frac{E}{206000}\right)\left(\frac{t_F}{b_F}\right)^2 10^4$$

where, t_W, t_F, h_W and b_F are defined in [6.3.1].

6.4 Critical local buckling stress of pillars having hollow rectangular section

6.4.1 Steel pillars

The critical local buckling stress of pillars having hollow rectangular section is to be obtained, in N/mm², from the following formulae:

$$\sigma_{cL} = \sigma_{E4} \quad \text{for} \quad \sigma_{E4} \leq \frac{R_{eH}}{2}$$

$$\sigma_{cL} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E4}}\right) \quad \text{for} \quad \sigma_{E4} > \frac{R_{eH}}{2}$$

where:

σ_{E4} : Euler local buckling stress, to be taken equal to the lesser of the values obtained, in N/mm², from the following formulae:

$$\bullet \quad \sigma_{E4} = 78\left(\frac{t_2}{b}\right)^2 10^4$$

$$\bullet \quad \sigma_{E4} = 78\left(\frac{t_1}{h}\right)^2 10^4$$

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.

6.4.2 Aluminium alloy pillars

The critical local buckling stress σ_{CL} of pillars having hollow rectangular section made of aluminium alloy is to be obtained, in N/mm², from the following formula:

$$\sigma_{CL} = 2\,R_{eH}\,C$$

where:

C : Coefficient as defined in [6.2.2], with:

$$\lambda_1 = \frac{R_{eH}}{\sigma_{Ei}}$$

σ_{Ei} : Euler local buckling stress, in N/mm², to be taken equal to:

for built up pillars, the lesser of:

$$\sigma_{Ei} = 78\left(\frac{E}{206000}\right)\left(\frac{t_2}{h}\right)^2 10^4$$

$$\sigma_{Ei} = 78\left(\frac{E}{206000}\right)\left(\frac{t_1}{b}\right)^2 10^4$$

where, t_W, t_F, h_W and b_F are defined in [6.4.1].

6.5 Checking criteria

6.5.1 The net scantlings of the pillar loaded by the compression axial stress F_A defined in [6.1.1] are to comply with the formulae in Tab 4.

Figure 3 : Coefficient C
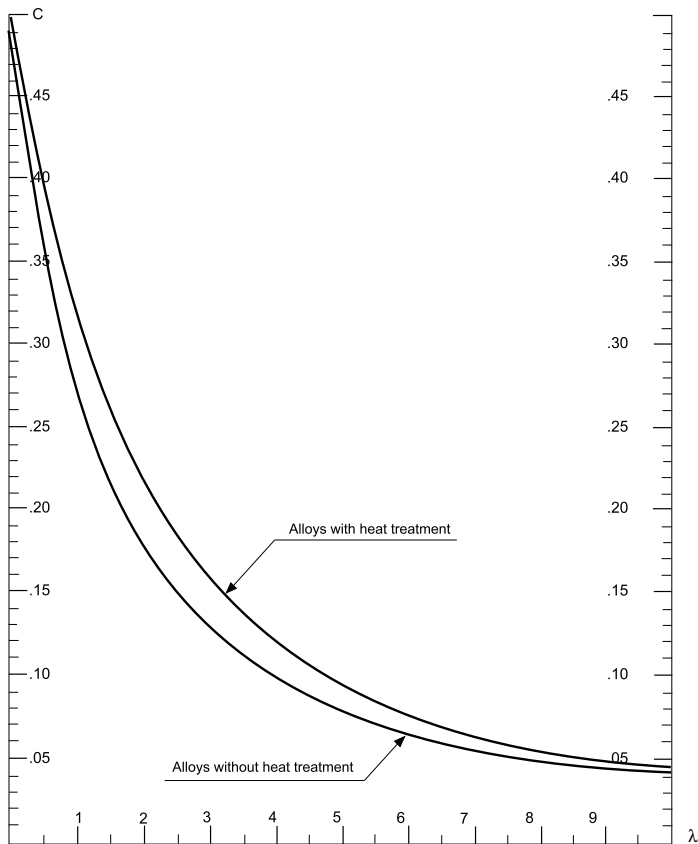
7 Buckling and ultimate strength assessment - application guide

7.1 General application

7.1.1 Change of thickness within an elementary plate panel

If the plate thickness of an elementary plate panel varies over the width b, the buckling check may be performed for an equivalent elementary plate panel $a \times b_{eq}$ having a thickness equal to the smaller plate thickness t_1. The width of this equivalent elementary plate panel is defined by the following formula:

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

where:

ℓ_1 : Width of the part of the plate panel with the smaller net plate thickness t_1, in mm, as defined in Fig 4

ℓ_2 : Width of the part of the plate panel with the greater net plate thickness t_2, in mm, as defined in Fig 4.

7.1.2 Assessment of floors, transverses or other high girders with holes

The following procedure may be used to assess high girders with holes:

a) Divide the plate field in sub-elementary plate panels according to Fig 5

b) Assess the elementary plate panel and all sub-elementary plate panels separately with the following boundary conditions:

- For sub-panels 1 to 4: all edges are simply supported (load cases 1 and 2 in Tab 1)

- For sub-panels 5 to 6: simply supported, one side free (load case 3 in Tab 1).

7.2 Application to hull transverse section analysis

7.2.1 Membrane stresses

The membrane stresses to be considered for the buckling strength check of plating and ordinary stiffeners are obtained, in N/mm², from the following formula:

$$\sigma_{X1} = \sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH})$$

where:

$\sigma_{S1}, \sigma_{WV1}, \sigma_{WH}$: Hull girder normal stresses, in N/mm², defined in Tab 7

C_{FV}, C_{FH} : Combination factors defined in Tab 5.

Table 4 : Buckling check of pillars subject to compression axial load
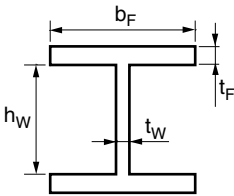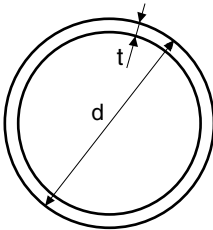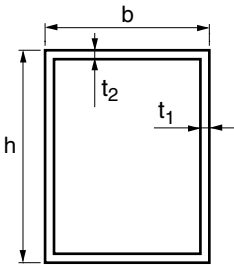
Pillar cross-section		Column buckling check	Local buckling check	Geometric condition
Built-up		$\dfrac{\sigma_{cB}}{\gamma_m \gamma_R} \geq 10 \dfrac{F_A}{A}$	$\dfrac{\sigma_{cL}}{\gamma_m \gamma_R} \geq 10 \dfrac{F_A}{A}$	• $\dfrac{b_F}{t_F} \leq 40$
Hollow tubular		$\dfrac{\sigma_{cB}}{\gamma_m \gamma_R} \geq 10 \dfrac{F_A}{A}$	Not required	• $\dfrac{d}{t} \leq 55$ • $t \geq 5,5$ mm
Hollow rectangular		$\dfrac{\sigma_{cB}}{\gamma_m \gamma_R} \geq 10 \dfrac{F_A}{A}$	$\dfrac{\sigma_{cL}}{\gamma_m \gamma_R} \geq 10 \dfrac{F_A}{A}$	• $\dfrac{b}{t_2} \leq 55$ • $\dfrac{h}{t_1} \leq 55$ • $t_1 \geq 5,5$ mm • $t_2 \geq 5,5$ mm

Note 1:

σ_{cB} : Critical column buckling stress, in N/mm^2, defined in [6.2.1]

σ_{cL} : Critical local buckling stress, in N/mm^2, defined in [6.3.1] for built-up section or in [6.4.1] for hollow rectangular section

γ_R : Partial safety factor covering uncertainties regarding resistance
- $\gamma_R = 1,15$ for column buckling
- $\gamma_R = 1,05$ for local buckling

γ_m : Partial safety factor covering uncertainties regarding material
  $\gamma_m = 1,02$

F_A : Compression axial load in the pillar, in kN, defined in [6.1.1]

A : Net sectional area, in cm^2, of the pillar.

Figure 4 : Plate thickness change over the width b
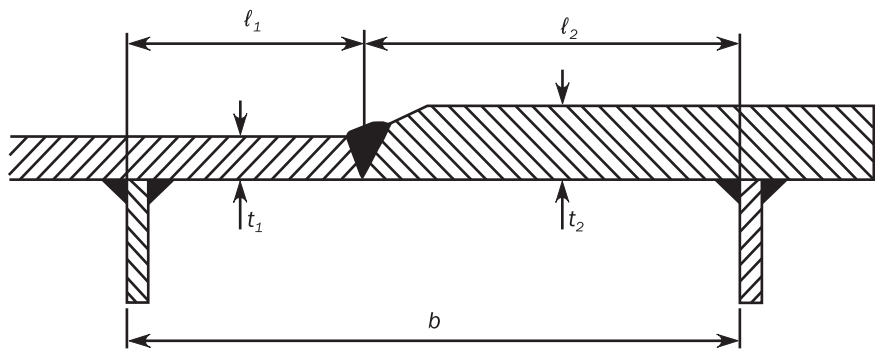
Figure 5 : Elementary plate panels of high girder with hole
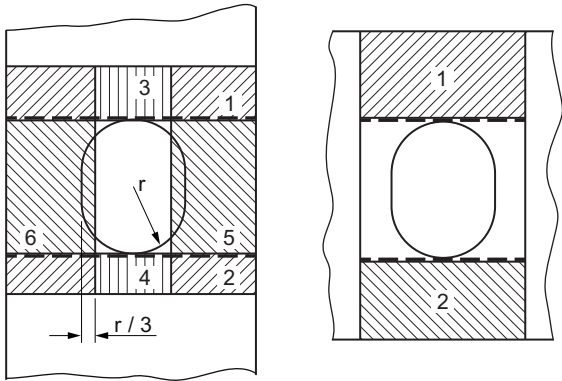
Table 5 : Combination factors C_{FV} and C_{FH}

Load case	Application	C_{FV}	C_{FH}
"a"	-	0	0
"b"	-	1,0	0
"c"	in general	0	0
	IN(1,2 < x ≤ 2)	0,4	1,0
"d"	in general	0	0
	IN(1,2 < x ≤ 2)	0,4	1,0
Flooding	-	0,6	0

7.2.2 Design lateral pressure

The design lateral pressure, p, to be used for hull scantling is defined in Tab 6.

7.2.3 Idealisation of elementary plate panel

The structural members at a considered hull transverse section are to be checked for buckling criteria under the stresses defined in [7.2.1], according to [2.1].

The determination of the buckling and reduction factors is made according to Tab 1 for the plane plate panel and Tab 2 for the curved plate panel.

For the determination of the buckling and reduction factors in Tab 1, the following cases are to be used according to the framing system:

• Buckling load case 1 for longitudinally framed plating, the membrane stress in x-direction σ_x being the hull girder normal stress σ_{x1} defined in [7.2.1]

• Buckling load case 2 for transversely framed plating, the membrane stress in y-direction σ_y being the hull girder normal stress σ_{x1} defined in [7.2.1], and the values of a and b exchanged to obtain α value greater than 1 as it is considered in load case 2.

7.2.4 Ordinary stiffeners

The buckling check of the longitudinal and transverse ordinary stiffeners of partial or total plate panels is to be performed under the loads in defined in [7.2.1] with:

• $\sigma_x = \sigma_{x1}$

• $\sigma_y = 0$

The effective width of the attached plating of the stiffeners is to be determined in accordance with [3]. A constant stress is to be assumed corresponding to the greater of the following values:

• stress at half length of the stiffener

• 0,5 of the maximum compressive stress of the adjacent elementary plate panels.

7.3 Additional application to FEM analysis

7.3.1 Non uniform compressive stresses along the length of the buckling panel

If compressive stresses are not uniform along the length of the unloaded plate edge (e.g. in case of girders subjected to bending), the compressive stress value is to be taken at a distance of b/2 from the transverse plate edge having the largest compressive stress (see Fig 6). This value is not to be less than the average value of the compressive stress along the longitudinal edge.

Table 6 : Design lateral pressure, p, in kN/m²

Structure	In service conditions	In testing conditions	In flooding conditions
Shell structure	p_E $p_C - p_{Em}$ $p_B - p_{Em}$	p_{ST} $p_{ST} - p_{SE}$ **(1)**	–
Deck structure	p_E **(2)** p_C p_B p_D	p_{ST}	–
Hatch coaming	$2 + p_{WD}$	–	–
Internal structure	p_C p_B	p_{ST}	p_{FL}
(1) Testing afloat			
(2) External deck pressure defined in Ch 3, Sec 4, [2.2.1]			

7.3.2 Buckling stress calculation of non rectangular elementary plate panels

a) Quadrilateral panels

According to Fig 7, rectangles that completely surround the irregular buckling panel are searched. Among several possibilities the rectangle with the smallest area is taken. This rectangle is shrunk to the area of the original panel, where the aspect ratio and the centre are maintained.This leads to the final rectangular panel with the dimensions a, b.

b) Trapezoidal elementary plate panel

A rectangle is derived with a being the mean value of the bases and b being the height of the original panel. See Fig 8.

c) Right triangle

The legs of the right triangle are reduced by $0,5^{1/2}$ to obtain a rectangle of same area and aspect ratio. See Fig 9.

d) General triangle

General triangle is treated according to a) above.

Table 7 : In-plane hull girder normal stresses

	Condition	σ_{S1}, in N/mm²	σ_{WV1}, in N/mm²	σ_{WH}, in N/mm²
Compressive stresses	$z \geq N$	$\left\|\dfrac{M_S}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{M_{WV}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{M_{WH}}{I_Z}y\right\|10^{-3}$
	$z < N$	$\left\|\dfrac{M_H}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{M_{WV}}{I_Y}(z-N)\right\|10^{-3}$	
Tensile stresses	$z \geq N$	$\left\|\dfrac{M_H}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{M_{WV}}{I_Y}(z-N)\right\|10^{-3}$	
	$z < N$	$\left\|\dfrac{M_S}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{M_{WV}}{I_Y}(z-N)\right\|10^{-3}$	

Figure 6 : Non uniform compressive stress along longitudinal edge a

Figure 7 : Approximation of non rectangular elementary plate panels

Original irregular panel ———
Intermediate rectangles ———
Rectangle with smallest area — — —
Final rectangle ·········

Figure 8 : Approximation of trapezoidal elementary plate panel

Figure 9 : Approximation of right triangle
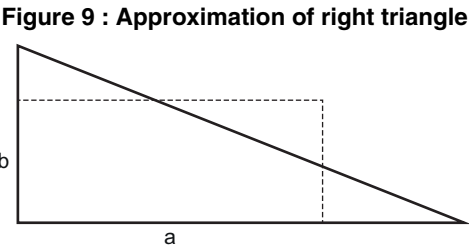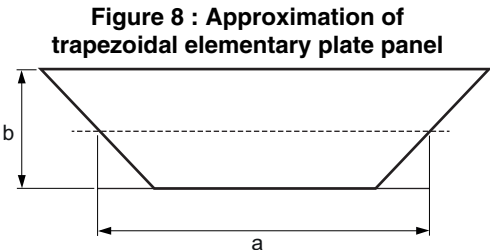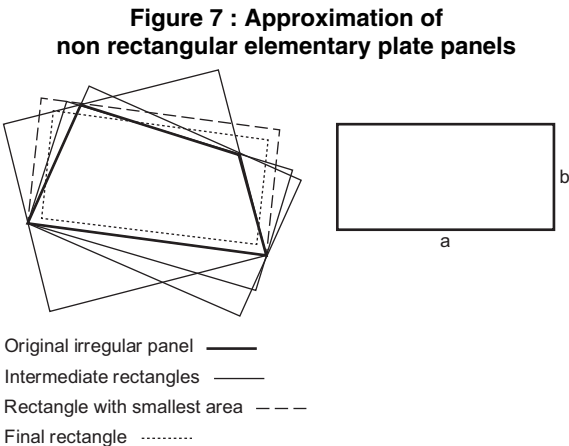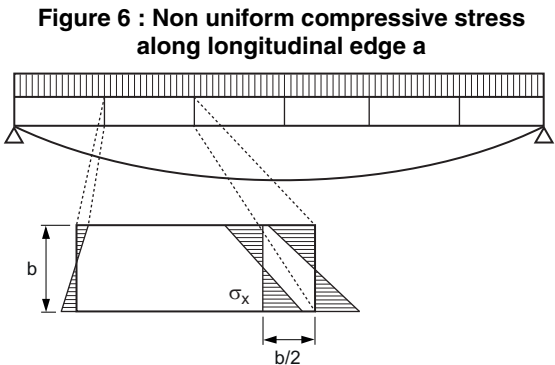
7.3.3 Buckling assessment of side shell plates

In order to assess the buckling criteria for vertically stiffened side shell plating, the following cases have to be considered.

In case vertical and shear stresses are approximately constant along the height of the elementary plate panel:

- Buckling load cases 1, 2 and 5, according to Tab 1

- $\psi = f(\sigma_1, \sigma_2)$ for horizontal stresses

- $\psi = 1$ for vertical stresses

- $t = t_{min}$ (elementary plate panel)

In case of distributed horizontal, vertical and shear stresses along the height of the elementary plate panel, the following stress situations are to be considered separately:

a) Pure vertical stress

- The size of buckling field to be considered is b times b ($\alpha = 1$)

- $\psi = 1$

- The maximum vertical stress in the elementary plate panel is to be considered in applying the criteria.

b) Shear stress associated to vertical stress

- The size of buckling field to be considered is 2b times b ($\alpha = 2$)

- $\psi = 1$

- The following stress combinations are to be considered:

  - The maximum vertical stress in the elementary plate panel plus the shear stress and longitudinal stress at the location where maximum vertical stress occurs

  - The maximum shear stress in the elementary plate panel plus the vertical stress and longitudinal stress at the location where maximum shear stress occurs

- The plate thickness t to be considered is the one at the location where the maximum vertical/shear stress occurs

c) Distributed longitudinal stress associated with vertical and shear stress

- The actual size of the elementary plate panel is to be used ($\alpha = f(a, b)$)

- The actual edge factor ψ for longitudinal stress is to be used

- The average values for vertical stress and shear stress are to be used

- $t = t_{min}$(elementary plate panel)

7.3.4 Buckling assessment of corrugated bulkheads

The transverse elementary plate panel (face plate) is to be assessed using the normal stress parallel to the corrugation. The slanted elementary plate panel (web plate) is to be assessed using the combination of normal and shear stresses.

The plate panel breadth b is to be measured according to Fig 10.

a) Face plate assessment

- The buckling load case 1, according to Tab 1

- The size of buckling field to be considered is b times b ($\alpha = 1$)

- $\psi = 1$

- The maximum vertical stress in the elementary plate panel is to be considered in applying the criteria.

- The plate thickness t to be considered is the one at the location where the maximum vertical stress occurs

b) Web plate assessment

- The buckling load case 1 and 5, according to Tab 1

- The size of buckling field to be considered is 2b times b ($\alpha = 2$)

- $\psi = 1$

- The following two stress combinations are to be considered:

  - The maximum vertical stress in the elementary plate panel plus the shear stress and longitudinal stress at the location where maximum vertical stress occurs

  - The maximum shear stress in the elementary plate panel plus the vertical stress and longitudinal stress at the location where maximum shear stress occurs

- The plate thickness t to be considered is the one at the location where the maximum vertical/shear stress occurs

Figure 10 : Measuring b of corrugated bulkheads
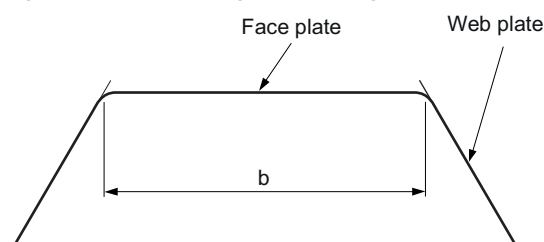
SECTION 8   DIRECT CALCULATION

Symbols

k   :   Material factor defined in Ch 2, Sec 3, [2.3], for steel and Ch 2, Sec 3, [3.5], for aluminium alloys

R_y :   Minimum yield stress, in N/mm², of the material to be taken equal to:

- R_y = 235/k N/mm² for steel

- R_y = 100/k N/mm² for aluminium alloys

unless otherwise specified

1 General

1.1 Application

1.1.1 The requirements of this Section give direct calculation guidance related to:

- yielding and buckling checks of structural members

- calculation of fillet welds.

Direct calculation may be adopted instead of Rule scantling formulae or for the analysis of structural items not covered by the Rules.

2 Strength check of structural members

2.1 General

2.1.1 Net scantlings

All scantlings referred to in this Article are net, i.e, they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 2, Sec 5, [2].

2.1.2 Partial safety factors

The partial safety factors covering uncertainties regarding wave hull girder loads (γ_{W1}), wave local loads (γ_{W2}), material (γ_m) and resistance (γ_R) to be considered for checking structural members are specified in:

- Tab 1 for analyses based on isolated beam models

- Tab 2 for analyses based on three dimensional models.

2.1.3 Yielding check

The yielding check is to be carried out according to:

- [2.3] for structural members analysed through isolated beam models

- [2.4] for structural members analysed through three dimensional beam or finite element models.

2.1.4 Buckling check

The buckling check is to be carried out according to Ch 2, Sec 7, on the basis of the stresses in primary supporting members calculated according to [2.3] or [2.4], depending on the structural model adopted.

2.2 Analysis documentation

2.2.1 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 test, 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

- identification of the critical areas, where the results of the checkings exceed 97,5% of the permissible rule criteria in [2.4.4] and Ch 2, Sec 7.

2.2.2 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.

Table 1 : Primary supporting members analysed through isolated beam models - Partial safety factors

Limit state	Condition	γ_{W1} **(3)**	γ_{W2} **(3)**	γ_R	γ_m
Yielding check	General	1,15	1,20	1,02 **(1)**	1,02
	Bottom and side girders **(4)**	1,15	1,20	1,15	1,02
	Flooding	1,15	1,20	1,02 **(2)**	1,02
	Testing	NA	NA	1,02	1,02
Buckling check	Pillars column buckling	1,15	1,20	1,15	1,02
	Pillars local buckling	1,15	1,20	1,05	1,02
(1) For primary supporting members of the fore peak and aft peak structures, γ_R =1,60.					
(2) For primary supporting members of the collision bulkhead, γ_R =1,25.					
(3) For range of navigation **IN**, $\gamma_{W1} = \gamma_{W2} = 1,00$					
(4) Includes bottom girders, bottom transverses, reinforced floors, side stringers, side transverses and web frames.					
Note 1: NA = not applicable.					

Table 2 : Primary supporting members analysed through three dimensional models - Partial safety factors

Limit state	Condition	γ_{W1} **(2)**	γ_{W2} **(2)**	γ_R	γ_m
Yielding check	General	1,05	1,10	See Tab 3	1,02
	Flooding **(1)**	1,05	1,10		1,02
	Testing	NA	NA	1,02	1,02
Buckling check	Pillars: column buckling	1,05	1,10	1,15	1,02
	Pillars: local buckling	1,05	1,10	1,05	1,02
(1) Applies only to primary supporting members to be checked in flooding conditions.					
(2) For range of navigation **IN**, $\gamma_{W1} = \gamma_{W2} = 1,00$					

Table 3 : Primary supporting members analysed through three dimensional model Resistance partial safety factor γ_R

Calculation model	Yielding check	
	General	Flooding condition
Beam	1,20	1,02
Coarse mesh finite element	1,20	1,02
Fine mesh and standard finite element	1,05	1,02

2.3 Yielding check of structural members analysed through an isolated beam structural model

2.3.1 General

The requirements of this Sub-article apply to the yielding check of structural 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.

The yielding check is also to be carried out for structural members subjected to specific loads, such as concentrated loads.

2.3.2 Load point

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the structural member considered.

For longitudinal structural 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 structural member with attached plating.

2.3.3 Load model

The structural members are to be checked under the combination of loads defined in Part B, Chapter 3.

The external pressure and the pressures induced by the various types of cargoes and ballast are to be considered, depending on the location of the structural member under consideration and the type of compartments adjacent to it, in accordance with Ch 3, Sec 4.

The pressure load in service conditions is to be determined according to Ch 3, Sec 4, [2] and Ch 3, Sec 4, [3].

For structural members subjected to wheeled loads, the yielding check may be carried out according to [2.3.4] considering uniform pressures equivalent to the distribution of vertical concentrated forces, when such forces are closely located, taking into account the most unfavourable case.

2.3.4 Checking criteria

It is to be checked that the normal stress, the shear stress and the Von Mises equivalent stress are in compliance with the following conditions:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0,5 \frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

where:

σ : Normal stress, in N/mm², in the direction of the structural member axis

τ : Shear stress, in N/mm², in the direction of the local loads applied to the structural member.

σ_{VM} : Von Mises equivalent stress, in N/mm²

$$\sigma_{VM} = \sqrt{\sigma^2 + 3\tau^2}$$

2.4 Yielding check of structural members analysed through a three dimensional structural model

2.4.1 General

The requirements of this Sub-article apply to the yielding check of structural 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.

The yielding check is also to be carried out for structural members subjected to specific loads, such as concentrated loads.

2.4.2 Analysis criteria

The analysis of structural members based on three dimensional models is to be carried out according to the requirements in:

- Ch 2, App 1 for structural members subjected to lateral pressure
- Ch 2, App 2 for structural members subjected to wheeled loads.

These requirements apply for:

- the structural modelling
- the load modelling
- the stress calculation.

2.4.3 Checking criteria for beam model analyses

For beam model analyses, according to Ch 2, App 1, [3.5], it is to be checked that the equivalent stress σ_{VM}, in N/mm², calculated according to Ch 2, App 1, [5.2] is in compliance with the following formula:

$$\sigma_{VM} \leq \frac{R_y}{\gamma_R \gamma_m}$$

where the partial safety factors are to be taken as given in **Ch 2, Sec 5, [2.4].**

2.4.4 Checking criteria for finite element model analyses

a) Master allowable stress

The master allowable stress, σ_{MASTER}, in N/mm², is to be obtained from the following formula:

$$\sigma_{MASTER} = \frac{R_y}{\gamma_R \gamma_m}$$

b) General

For all types of analysis (see Ch 2, App 1, [3.4]), it is to be checked that the equivalent Von Mises stress σ_{VM}, calculated according to Ch 2, App 1, [5] is in compliance with the following formula:

$$\sigma_{VM} \leq \sigma_{MASTER}$$

c) Structural detail analysis based on very fine mesh finite elements models

In a fine mesh model as defined in Ch 2, App 1, [3.4.4], high stress areas for which σ_{VM} exceeds $0,95\ \sigma_{MASTER}$ are to be investigated through a very fine mesh structural detail analysis according to Ch 2, App 1, [3.4.4], and the both following criteria are to be checked:

- the average Von Mises equivalent stress σ_{VM-av} as defined in item d) here below is to comply with the following formula:

$$\sigma_{VM-av} \leq \sigma_{MASTER}$$

- the equivalent stress σ_{VM} of each element is to comply with the following formulae:

  - for elements not adjacent to the weld:

    $$\sigma_{VM} \leq 1,53\,\sigma_{MASTER}$$

  - for elements adjacent to the weld:

    $$\sigma_{VM} \leq 1,34\,\sigma_{MASTER}$$

In the 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 item d).

d) Stress averaging on very fine mesh

The average Von Mises equivalent stress σ_{VM-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:

σ_{VM-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 very 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 relevant spacing of ordinary stiffeners (see Fig 1 and Fig 2)

• the area considered for stress averaging is to include an entire number of elements

• 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.

e) Particular requirements

For very 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 the second bullet point of item d).

Other structural details having shapes not allowing the stress averaging as required in item d) are to be specially considered by the Society, on a case by case basis.

Figure 1 : Example of stress averaging area at opening rounded edge
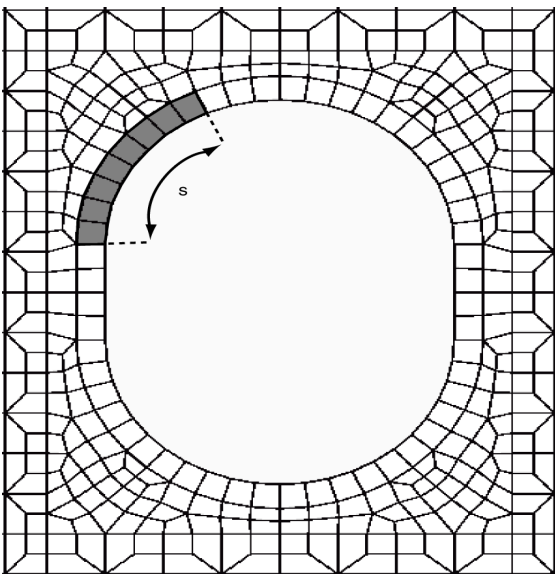
Figure 2 : Example of stress averaging area at rounded bracket edge
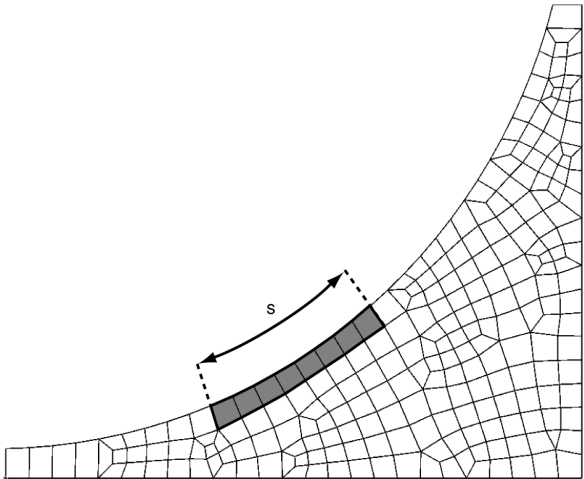
3 Calculation of fillet welds

3.1 General

3.1.1 As an alternative to the determination of the necessary fillet weld throat thicknesses in accordance with Ch 8, Sec 2, [2.3], a mathematical calculation may be performed, e.g. in order to optimize the weld thicknesses in relation to the loads. This Article describes general stress analysis for mainly static loads. For welded joints subjected to loads dynamic in character, e.g. those at the shell connection of single-strut shaft brackets, proof of fatigue strength in compliance with the Society's Rules is to be submitted where necessary.

3.1.2 Definition

For the purposes of calculation, the following stresses in a fillet weld are defined (see also Fig 3):

$\sigma_\perp$: Normal stress perpendicular to direction of seam

$\tau_\perp$: Shear stress perpendicular to direction of seam

$\tau_{\parallel}$: Shear stress parallel to direction of seam.

Normal stresses parallel to the seam are disregarded in the calculation.

The calculated weld seam area is $(a \cdot \ell)$.

For reasons of equilibrium, for the flank of the weld lying vertically to the shaded calculated weld seam area:

$\tau_\perp = \sigma_\perp$

For a composite stress the equivalent stress is to be calculated by the following formula:

$$\sigma_V = \sqrt{\sigma^2_\perp + \tau^2_\perp + \tau^2_{\parallel}}$$

Fillet welds are to be so dimensioned that the stresses determined by the formulae do not exceed the permissible stresses stated in Tab 4.

Figure 3 : Definition
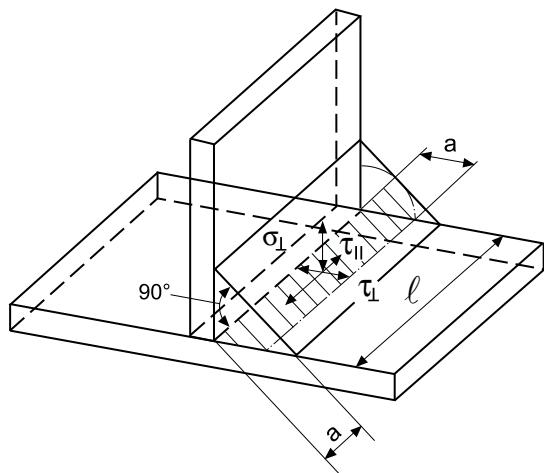
3.2 Fillet welds stressed by normal and shear forces

3.2.1 Flank and frontal welds are regarded as being equal for the purposes of stress analysis. In view of this, normal and shear stresses, in N/mm², are calculated as follows:

$$\sigma = \tau = \frac{P}{\Sigma a \ell}$$

where:

a, ℓ : Thickness and length, in mm, of the fillet weld

P : Force acting on the weld joint, in N.

- for a joint as shown in Fig 4, this produces:

Stresses in frontal fillet welds, in N/mm²:

$$\tau_\perp = \frac{P_1}{2 a (\ell_1 + \ell_2)}$$

$$\tau_{II} = \frac{P_2}{2 a (\ell_1 + \ell_2)} \pm \frac{P_2 e}{2 a F_t}$$

Stresses in flank fillet welds:

$$\tau_\perp = \frac{P_2}{2 a (\ell_1 + \ell_2)}$$

$$\tau_{II} = \frac{P_1}{2 a (\ell_1 + \ell_2)} \pm \frac{P_2 e}{2 a F_t}$$

Equivalent stresses for frontal and flank fillet welds:

$$\sigma_V = \sqrt{\sigma^2_\perp + \tau^2_{II}} \le \sigma_{Vzul}$$

where:

F_t : Parameter, in mm², equal to:

$$F_t = (\ell_2 + a)(\ell_1 + a).$$

P_1 , P_2 : Forces, in N

a_1 , ℓ_1 , ℓ_2 : Weld joint dimensions, in mm.

Figure 4 : Fillet welds stressed by normal and shear forces
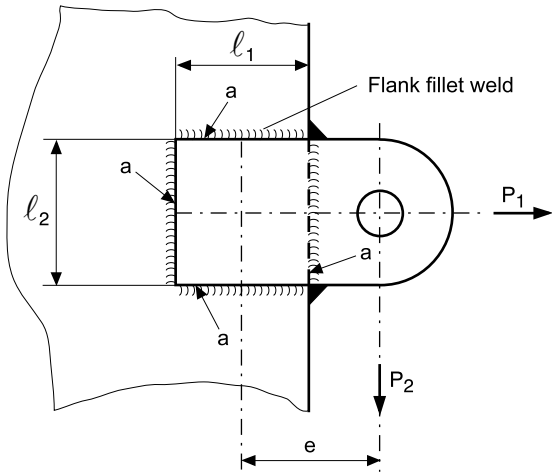
- for a joint as shown in Fig 5, this produces:

$$\tau_\perp = \frac{P_2}{2 a \ell} + \frac{3 P_1 e}{a \ell^2}$$

$$\tau_{II} = \frac{P_1}{2 a \ell}$$

Equivalent stress:

$$\sigma_V = \sqrt{\sigma^2_\perp + \tau^2_{II}} \le \sigma_{Vzul}$$

where σ_{Vzul} is given in Tab 4.

Figure 5 : Fillet welds stressed by normal and shear forces
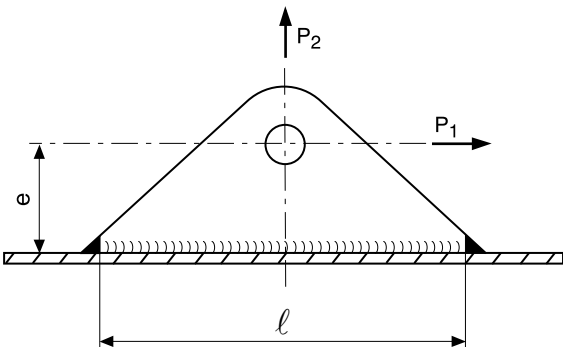
3.3 Fillet welds stressed by bending moments and shear forces

3.3.1 The stresses at the fixing point of a girder (a cantilever beam is given as an example in Fig 6) are calculated as follows:

a) Normal stress due to bending, in N/mm²:

$$\sigma_\perp(z) = \frac{M}{J_s} z$$

$$\sigma_{\perp max} = \frac{M}{J_S}e_u \text{ for } e_u > e_0$$

$$\sigma_{\perp max} = \frac{M}{J_S}e_0 \text{ for } e_u < e_0$$

b) Shear stress due to shear force, in N/mm²:

$$\tau_{II}(z) = \frac{QS_{S(z)}}{10J_S\sum a}$$

$$\tau_{II}(z) = \frac{QS_{S(z)}}{10J_S \cdot 2a}$$

c) Equivalent stress:

It has to be proved that neither $\tau_{\perp max}$ in the region of the flange nor $\tau_{II max}$ in the region of the neutral axis nor the equivalent stress σ_V exceed the permitted limits given in Tab 4 at any given point. The equivalent stress σ_V should always be calculated at the web-flange connection.

$$\sigma_V = \sqrt{\sigma^2_{\perp} + \tau^2_{II}}$$

where:

M   :   Bending moment in way of the welded joint, in N·m

Q   :   Shear force at the point of the welded joint, in N

J_S :   Moment of inertia of the welded joint relative to the x-axis, in cm⁴

$S_{S(z)}$:   First moment of the connected weld section at the point under consideration, in cm³

z   :   Distance from the neutral axis, in cm.

Figure 6 : Fillet welds stressed by bending moments and shear forces
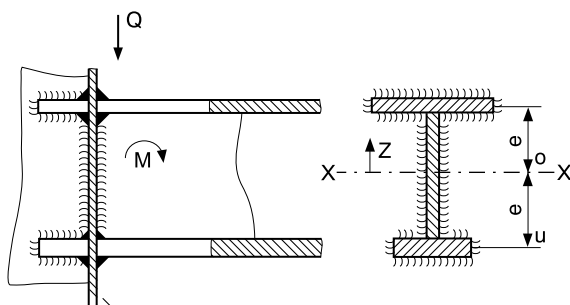
3.4   Fillet welds stressed by bending and torsional moments and shear forces

3.4.1 For the normal and shear stresses, in N/mm², resulting from bending, see [3.3]. Torsional stresses resulting from the torsional moment M_T are to be calculated as follows:

$$\tau_T = \frac{M_T \cdot 10^3}{2a_m A_m}$$

where:

M_T :   Torsional moment, in N.m

a_m :   Mean fillet weld throat thickness, in mm

A_m :   Mean area enclosed by weld seam, in mm².

The equivalent stress composed of all three components (bending, shear and torsion) is calculated by the following formulae:

* where τ_{II} and $\tau_{\perp}$ do not have the same direction:

$$\sigma_V = \sqrt{\sigma^2_{\perp} + \tau^2_{\perp} + \tau^2_{II}}$$

* where τ_{II} and $\tau_{\perp}$ have the same direction:

$$\sigma_V = \sqrt{\sigma^2_{\perp} + (\tau_{\perp} + \tau_{II})^2}$$

3.5   Continuous fillet welded joints between web and flange of bending girders

3.5.1 The stress analysis has to be performed in the area of maximum shear forces.

In the case of continuous double fillet weld connections, the shear stress, in N/mm², is to be calculated as follows:

$$\tau_{II} = \frac{QS}{10J \cdot 2a}$$

where:

Q   :   Shear force at the point considered, in N

S   :   First moment of the cross sectional area of the flange connected by the weld to the web in relation to the neutral beam axis, in cm³

J   :   Moment of inertia of the girder section, in cm⁴

a   :   Thickness of the fillet weld, in mm.

The fillet weld thickness required, in mm, is:

$$a_{erf} = \frac{QS}{10J \cdot 2\tau_{zul}}$$

3.6   Intermittent fillet welded joints between web and flange of bending girders

3.6.1 The shear stress, in N/mm², is to be calculated as follows (see Fig 7):

$$\tau_{II} = \frac{QS\alpha}{10J \cdot 2a} \cdot \frac{b}{\ell}$$

where:

ℓ :   Length of the fillet weld

b   :   Interval

α :   Stress concentration factor which takes into account increases in shear stress at the ends of the lengths of fillet weld seam ℓ: $\alpha = 1,1$

The fillet weld thickness required, in mm, is:

$$a_{erf} = \frac{1,1QS}{10J \cdot 2\tau_{zul}} \cdot \frac{b}{\ell}$$

Figure 7 : Intermittent fillet welded joints between web and flange of bending girders
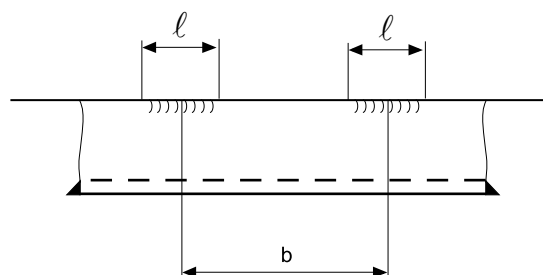
3.7 Fillet weld connections on overlapped profile joints

3.7.1 Profiles joined by means of two flank fillet welds (see Fig 8):

$$\tau_\perp = \frac{Q}{2ad}$$

$$\tau_{II} = \frac{M \cdot 10^3}{2acd}$$

The equivalent stress is:

$$\sigma_V = \sqrt{\tau_\perp^2 + \tau_{II}^2}$$

where:

Q : Shear force to be transmitted, in N

M : Bending moment to be transmitted, in N.m

c, d, ℓ_1, ℓ_2, r: Dimensions, in mm, defined in Fig 8

$$c = r + \frac{(3\ell_1 - \ell_2)}{4}$$

As the influence of the shear force can generally be neglected, the required fillet weld thickness, in mm, is:

$$a_{erf} = \frac{M \cdot 10^3}{2cd\tau_{zul}}$$

or

$$a_{erf} = \frac{w \cdot 10^3}{1,5cd}$$

where:

w : Section modulus of the joined profile, in cm³.

Figure 8 : Fillet weld connections on overlapped profile joints: case a
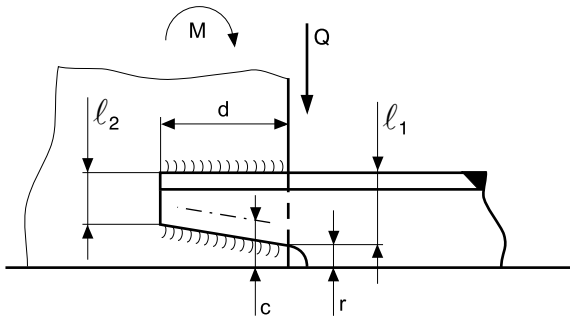
3.7.2 Profiles joined by means of two flank and two front fillet welds (all-round welding as shown in Fig 9):

$$\tau_\perp = \frac{Q}{a(2d + \ell_1 + \ell_2)}$$

$$\tau_{II} = \frac{M \cdot 10^3}{ac(2d + \ell_1 + \ell_2)}$$

The equivalent stress is:

- where τ_{II} and $\tau_\perp$ do not have the same direction:

$$\sigma_V = \sqrt{\tau_\perp^2 + \tau_{II}^2}$$

- where τ_{II} and $\tau_\perp$ have the same direction:

$$\sigma_V = \tau_\perp + \tau_{II}$$

As the influence of the shear force can generally be neglected, the required fillet weld thickness, in mm, is:

$$a_{erf} = \frac{M10^3}{2cd\left(1 + \frac{\ell_1 + \ell_2}{2d}\right)\tau_{zul}}$$

or

$$a_{erf} = \frac{W10^3}{1,5cd\left(1 + \frac{\ell_1 + \ell_2}{2d}\right)}$$

where:

c, d, ℓ_1, ℓ_2, r: Dimensions, in mm, defined in Fig 9.

Figure 9 : Fillet weld connections on overlapped profile joints: case b
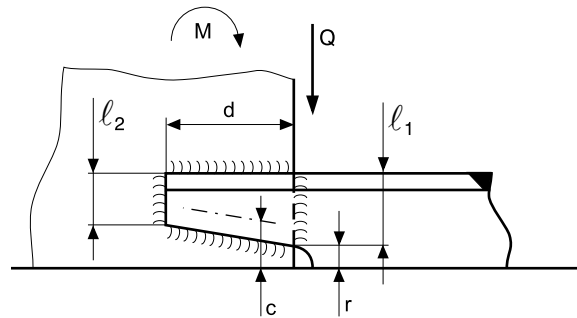
3.8 Bracket joints

3.8.1 Where profiles are joined to brackets as shown in Fig 10, the average shear stress, in N/mm², is:

$$\tau = \frac{3M \cdot 10^3}{4ad^2} + \frac{Q}{4ad}$$

where:

M : Moment of constraint, in N.m

Q : Shear force, in N

d : Length of overlap, in mm.

The required fillet weld thickness, in mm, is to be calculated from the section modulus of the profile, w, as follows:

$$a_{erf} = \frac{w \cdot 10^3}{d^2}$$

Figure 10 : Bracket joint with idealized stress distribution resulting from moment M and shear Q
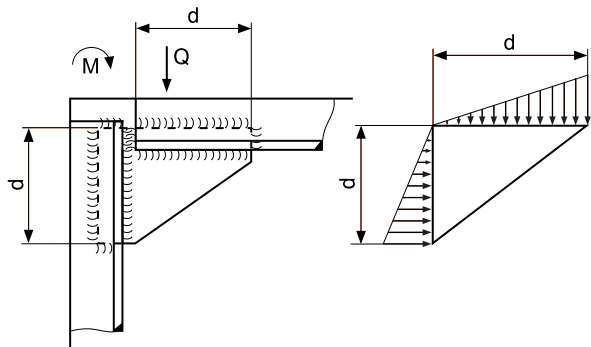
3.9 Admissible stresses

3.9.1 Both, the individual and the reference stresses calculated in accordance with the formulae in [3.1.2] and [3.2] to [3.8], must not exceed the admissible stresses as indicated in Tab 4 for various materials mainly exposed to static loading. The values stated for high tensile steels, stainless austenitic steels and aluminium alloys are applicable only if the strength properties of the weld material employed are at least equal to those of the base material. Where this is not the case, the "a"-values calculated are to be increased accordingly.

Table 4 : Permissible stresses in fillet welded joint

Material		R_{eH} or $R_{p0,2}$ (N/mm²)	Equivalent stress, shear stress $\sigma_{V\,zul}$, τ_{zul} (N/mm²)
Normal hull structural steel	A, B, D **(1)**	235	115
Higher tensile hull structural steel	AH 32 / DH 32 AH 36 / DH 36 **(2)**	315 355	145 160
High tensile steel	St E 460 St E 690	460 685	200 290
Austenitic stainless steels	1.4306/304L 1.4404/316L 1.4435/316L 1.4438/317L 1.4541/321 1.4571/316 Ti	180 190 190 195 205 215	110
Aluminium alloys	Al Mg 3 Al Mg 4,5 Al Mg Si 0,5 Al Mg Si 1	80 **(3)** 125 **(3)** 65 **(4)** 11 **(4)**	35 **(5)** 56 **(6)** 30 **(7)** 45 **(8)**
(1) Also applies to structural steel S 235 JR according to EN 10025-2, rimming steel not permitted **(2)** Also applies to structural steel S 355 J2 according to EN 10025-2 **(3)** Plates, soft condition **(4)** Profiles, cold hardened **(5)** Welding consumables: S-Al Mg 3, S-Al Mg 5 or S-Al Mg 4,5 Mn **(6)** Welding consumables: S-Al Mg 4,5 Mn **(7)** Welding consumables: S-Al Mg 3, S-Al Mg 5, S-Al Mg 4,5 Mn or SAl Si 5 **(8)** Welding consumables: S-Al Mg 5 or S-Al Mg 5, S-Al Mg 4,5 Mn.			

APPENDIX 1   ANALYSES BASED ON THREE DIMENSIONAL MODELS

1 General

1.1 Application

1.1.1 The requirements of this Appendix apply to the analysis criteria, structural modeling, load modeling and stress calculation of primary supporting members which are to be analysed through three dimensional structural models, according to Ch 2, Sec 8, [2.3].

1.1.2 This Appendix deals with that part of the structural analysis which aims at calculating the stresses in the primary supporting members in the midship area and, when necessary, in other areas, which are to be used in the yielding and buckling check.

1.1.3 The strength checks of primary supporting members are to be carried out according to:
- Ch 2, Sec 8, [2.4], for yielding
- Ch 2, Sec 7, for buckling, using the procedure defined in [6] for panel stresses calculation.

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 fine mesh models, as defined in [3.4.4].

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 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 vessel's structural arrangement.

3 Primary supporting members structural modeling

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 modeled with their net scantlings according to Ch 2, Sec 5, [2]. Therefore, also the hull girder stiffness and inertia to be reproduced by the model are those obtained 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 modeling of the boundary conditions.

3.2.2 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 1).

However, larger models may need to be adopted when deemed necessary by the Society on the basis of the vessel's structural arrangement.

Figure 1 : Model longitudinal extension
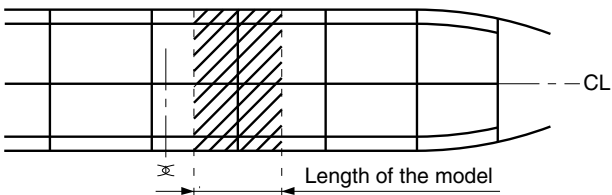
3.2.3 In the case of structural symmetry with respect to the vessel's centreline longitudinal plane, the hull structures may be modeled over half the vessel's breadth.

3.3 Finite element modeling criteria

3.3.1 Modelling of primary supporting members

The analysis of primary supporting members based on fine mesh models, as defined in [3.4.4], is to be carried out by applying one of the following procedures (see Fig 2), depending on the computer resources:

- an analysis of the whole three dimensional model based on a fine 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.

3.3.2 Modeling of the most highly stressed areas

The areas which appear from the analyses based on fine 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 modeling 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.

Figure 2 : Finite element modeling criteria
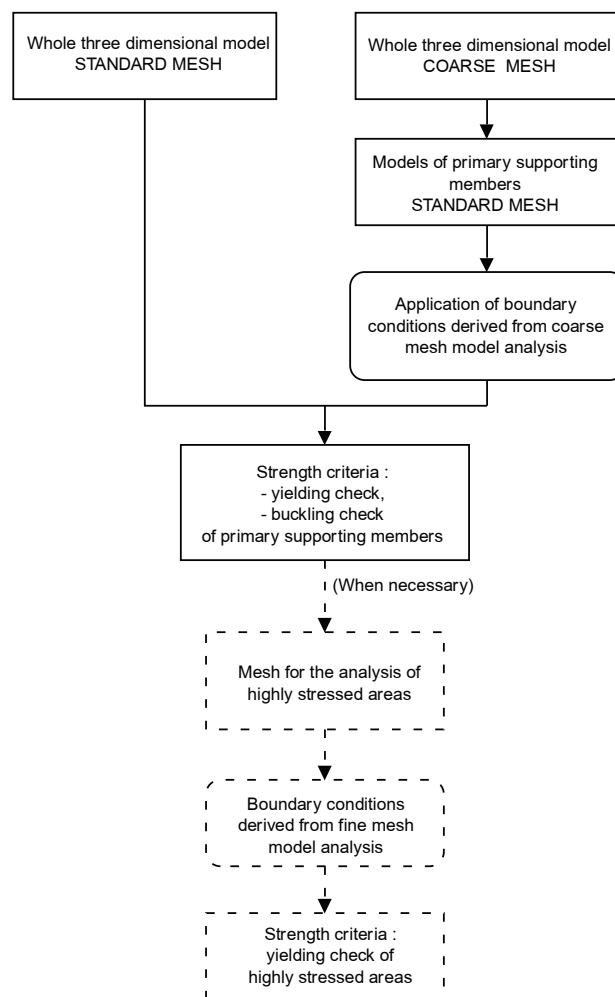
To this end, the structural model is to be built on the basis of the following criteria:

- ordinary stiffeners contributing to the hull girder longitudinal strength and which are not individually represented in the model are to be modeled by rod elements and grouped at regular intervals

- webs of primary supporting members may be modeled 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 modeled 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.

3.4.3 Standard mesh

The vessel's structure may be considered as finely meshed when each longitudinal ordinary stiffener is modeled; 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 modeled with at least three elements on their height

- the plating between two primary supporting members is to be modeled 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 modeled by beam elements with shear strain, positioned on their neutral axes.

3.5.2 Variable cross-section primary supporting members

In the case of variable cross-section primary supporting members, the inertia characteristics of the modeling beams may be assumed as a constant and equal to their average value along the length of the elements themselves.

3.5.3 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.

3.5.4 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 modeling the hull girder bending strength

- on deck, side shell, longitudinal bulkheads, if any, and bottom for modeling 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 modeled over half the vessel's breadth (see [3.2.3]), in way of the vessel'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 vessel'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, [3.1].			

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.

When the hull structure is modeled over half the vessel's breadth (see [3.2.3]), in way of the vessel'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.

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, [3.1].					

4 Primary supporting members load model

4.1 General

4.1.1 Loading conditions

The loads are to be calculated for loading conditions defined in Part D for specific vessel notation.

4.1.2 Partial safety factors

The partial safety factors to be applied for hull made totally of steel or hull made of steel with parts (superstructure or deckhouse) made of aluminium, are defined in Ch 2, Sec 5, [2].

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 vessel's breadth

When the vessel is symmetrical with respect to its centreline longitudinal plane and the hull structure is modeled over half the vessel'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 vessel's centreline longitudinal plane (see [3.6]).

4.2 Local loads

4.2.1 General

Still water loads include:

- the still water external pressure, defined in Ch 3, Sec 4, [2]
- the still water internal loads, defined in Ch 3, Sec 4, [3] for the various types of cargoes and for ballast.

Wave loads include:

- the wave pressure, defined in Ch 3, Sec 4, [2.1.2]
- the inertial loads, defined in Ch 3, Sec 4, [3] for the various types of cargoes and for ballast.

4.2.2 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 modeled or are modeled with rod elements (see [3.4]), the distributed loads are to be applied to the primary supporting members actually supporting the ordinary stiffeners.

4.2.3 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.

4.2.4 Cargo in sacks, bales and similar packages

The vertical loads are comparable to distributed loads. The loads on vertical walls may be disregarded.

4.2.5 Other cargoes

The modeling of cargoes other than those mentioned under [4.2.2] to [4.2.4] will be considered by the Society on a case by case basis.

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 wave horizontal 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

- maximal shear forces in way of the aft transverse bulkhead of the central tank/hold.

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

- maximal shear force for a given studied region along the length of foremost/aftmost cargo tank/hold.

4.3.2 Structural model extended over one cargo tank/hold length

The normal and shear stresses induced by the hull girder loads are to be added to the stresses induced in the primary supporting members by local loads.

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 3, to compensate the portion of distributed loads which, due to the positioning of beams on their neutral axes, are not modeled.

In Fig 3, F_Y and F_Z represent concentrated loads equivalent to the dashed portion of the distributed loads which is not directly modeled.

Figure 3 : Concentrated loads equivalent to non-modelled distributed loads
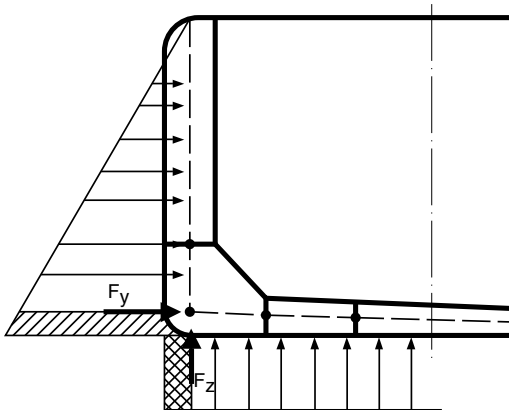
5 Stress calculation

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 4. 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, [3.1].

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 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:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

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.

Figure 4 : Reference and element co-ordinate systems
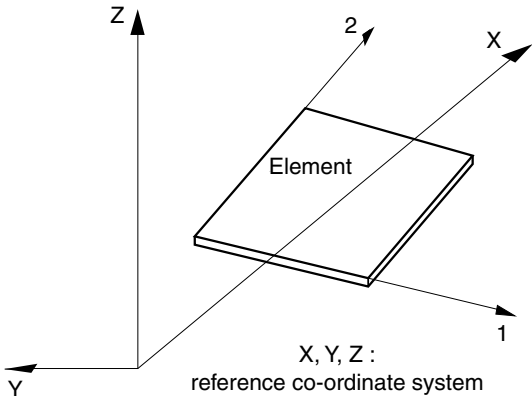
5.2 Analyses based on beam models

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 [3.2.2]), 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 and ultimate strength assessment

6.1 General

6.1.1 Buckling and ultimate strength assessment is to be performed for the panels according to Ch 2, Sec 7, [2.2].

6.2 Stresses of panel

6.2.1 The stresses in each single plate field are to be obtained according to the following procedure:

a) When the mesh model differs from the single plate field geometry, the stresses acting on the single plate field are to be evaluated by extrapolation and/or interpolation of surrounding meshes using the elements stresses or using a displacement based method.

b) If the 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 σx^* and σy^* are to be compressive stresses, in order to apply the stress reduction according to the following formulae:

$\sigma x = (\sigma x^* - \nu\, \sigma y^*) / 0{,}91$

$\sigma y = (\sigma y^* - \nu\, \sigma x^*) / 0{,}91$

with:

$\sigma x^*, \sigma y^*$: Stresses containing the Poisson-effect.

ν : Poisson's ratio:
- $\nu = 0{,}30$ for steel
- $\nu = 0{,}33$ for aluminium alloy

where the compressive stress fulfills the condition:

- $\sigma y^* < \nu\, \sigma x^*$, then: $\sigma y = 0$ and $\sigma x = \sigma x^*$
- $\sigma x^* < \nu\, \sigma y^*$, then: $\sigma x = 0$ and $\sigma y = \sigma y^*$

c) Determine stress distributions along edges of the considered buckling panel by introducing proper linear approximation as shown in Fig 5.

d) Calculate edge stress ratio.

Figure 5 : Stresses of panel for buckling assessment
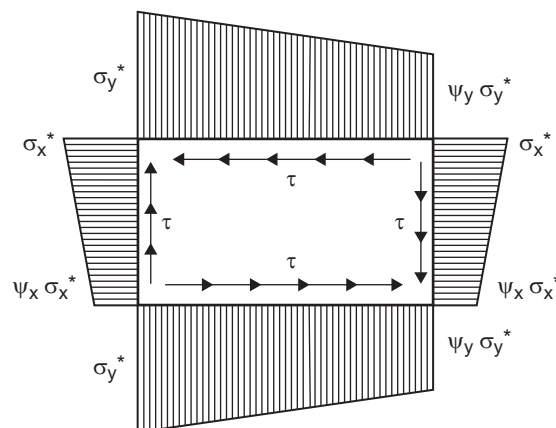
APPENDIX 2   ANALYSES OF PRIMARY SUPPORTING MEMBERS SUBJECTED TO WHEELED LOADS

Symbols

E :   Young's modulus, in N/mm^2:

- $E = 2,06 \cdot 10^5$ for steel, in general

- $E = 1,95 \cdot 10^5$ for stainless steel

- $E = 7,00 \cdot 10^4$ for aluminium alloys.

1 General

1.1 Scope

1.1.1 The requirements of this Appendix apply to the analysis criteria, structural modeling, load modeling and stress calculation of primary supporting members subjected to wheeled loads which are to be analysed through three dimensional structural models, according to Ch 2, Sec 8, [2].

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 2, Sec 8, [2.4.4].

1.2 Application

1.2.1 The requirements of this Appendix apply to vessels 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 vessel ends; their effect on the vessel 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 vessel's structural arrangement and loading conditions.

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 Finite element models may need to be adopted when deemed necessary by the Society on the basis of the vessel's structural arrangement.

2.2   Beam model analyses

2.2.1 Beam models, built according to Ch 2, App 1, [3.5], may be adopted in lieu of the finite element models, 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.

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 modeled with their net scantlings according to Ch 2, Sec 5, [2].

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-modeled 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 modeling 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, [3.1].					

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 vessel conditions 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 vessels 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 modeled, has a stiffness obtained, in kN/m, from the following formula:

$$R_D = \frac{24 E J_D s_a 10^3}{2x^4 - 4 L_D x^3 + L_D^2 \left(x^2 + 15,6 \frac{J_D}{A_D} \right) + L_D^3 x}$$

where:

J_D :   Net moment of inertia, in m^4, of the average cross-section of the deck, with the attached side shell plating

A_D :   Net area, in m^2, 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 vessel's length. Special cases in which such value may be reduced will be considered by the Society on a case by case basis.

Figure 1 : Springs at the fore and aft ends of models subjected to transverse loads
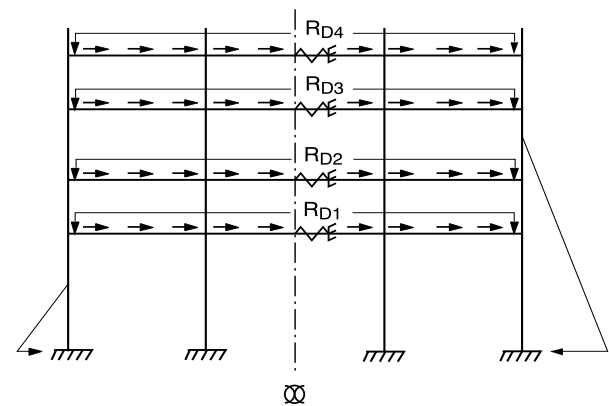
4 Load model

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 loads are to be calculated for the most severe loading conditions, 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 vessel structures.

4.1.3 Loading conditions and load cases: dry uniform cargoes

When the vessel'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.

4.2 Local loads

4.2.1 General

Still water loads include:

- the still water external pressure, defined in Ch 3, Sec 4, [2]

- the still water forces induced by wheeled cargoes, defined in Ch 3, Sec 4, [3.5].

Wave loads include:

- the wave pressure, defined in Ch 3, Sec 4, [2.1.2]

- the inertial forces induced by wheeled cargoes, defined in Ch 3, Sec 4, [3.5].

The partial safety factors to be applied for hull made totally of steel or hull made of steel with parts (superstructure or deckhouse) made of aluminium, are defined in Ch 2, Sec 5, [2].

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 are to be added to the stresses induced in the primary supporting members by local loads.

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, [3.1].

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 2 : Reference and element co-ordinate systems
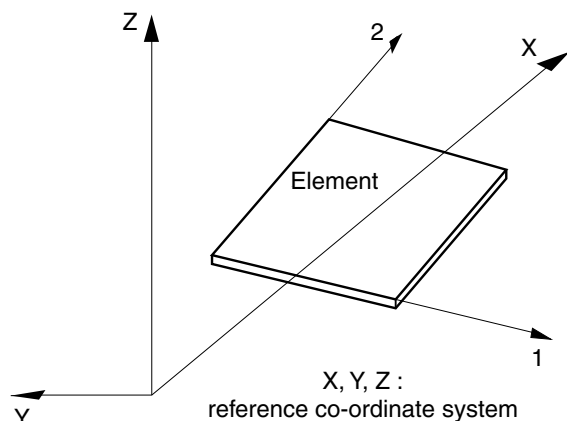
5.2.2 Stress calculation points

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_{11} 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-modeled 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 : Heights, 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 cm⁴, 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].

6.5 Stress calculation

6.5.1 Stress components are to be calculated according to [5.1] and [5.3].

Figure 3 : Heights of tween-decks for grillage analysis of deck primary supporting members
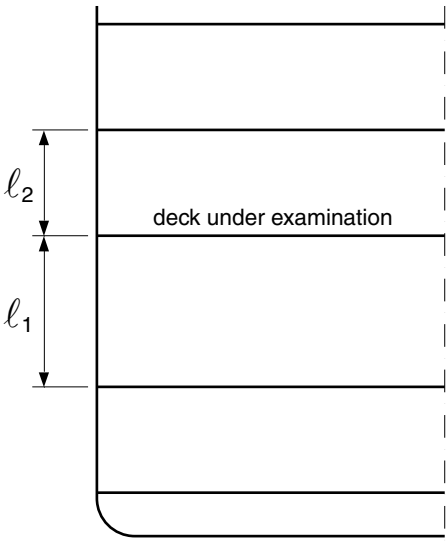
APPENDIX 3   TORSION OF CATAMARANS

Symbols

Refer to Fig 1.

G   :   Centre of the stiffnesses r_i, of the m deck beams

O   :   Origin of abscissae, arbitrarily chosen

m   :   Number of deck transverses

x_i :   Abscissa, in m, of deck beam i with respect to origin O

S_i :   Span of deck beam i, in m, between the inner faces of the hulls

I_i :   Bending inertia of deck beam i, in m^4

E_i :   Young's modulus of deck beam i, in N/mm^2, to be taken equal to

- for steels in general:

  $E_i = 2,06 \cdot 10^5$ N/mm^2

- for stainless steels:

  $E_i = 1,95 \cdot 10^5$ N/mm^2

- for aluminium alloys:

  $E_i = 7,00 \cdot 10^4$ N/mm^2

r_i :   Stiffness of deck beam i, in N/m, equal to:

$$r_i = \frac{12 \cdot E_i \cdot I_i}{S^3_i} \cdot 10^6$$

a   :   Abscissa, in m, of the centre G with respect to the origin O

$$a = \frac{\sum r_i \cdot x_i}{\sum r_i}$$

n   :   Navigation coefficient defined in Ch 3, Sec 1, [5.2]

If F_i, in N, is the force taken over by the deck beam i, the deflection y_i, in m, of the hull in way of the beam i, is:

$$y_i = \frac{F_i S^3_i \cdot 10^{-6}}{12 E_i I_i} = \frac{F_i}{r_i} = d_i \omega$$

where:

d_i :   Abscissa, in m, of the deck beam i with respect to the origin G:

$d_i = x_i - a$

ω :   Rotation angle, in rad, of one hull in relation to the other around a transverse axis passing through G.

1 General

1.1

1.1.1 In the special case of catamaran, when the structure connecting both hulls is formed by a deck with single plating stiffened by m reinforced beams, the normal and shear stresses in the beams can be calculated as indicated in [2].

Figure 1 : Transverse strength of catamaran

2 Transverse strength in special case of catamaran

2.1 General

2.1.1 Deck beams are assumed to be fixed into each hull. Consequently, deck beams are to be extended throughout the breadth of each hull, with the same scantlings all over their span, inside and outside the hulls.

2.2 Transverse torsional connecting moment

2.2.1 The catamaran transverse torsional connecting moment, in kN.m, about a transverse axis is given by:

$$M_{tt} = 1,23 \, \Delta \, L \, a_{CG}$$

where:

Δ : Vessel displacement, in tons

a_{CG} : Design vertical acceleration at LCG, in m/s², to be taken not less than:

$$a_{CG} = 0,36 \, Soc \, \frac{v}{\sqrt{L}}$$

v : Vessel speed, in km/h

Soc : Coefficient depending on the navigation coefficient n, defined as:

$$Soc = 0,1 \, (5,15n + 1,1)$$

Moreover, the transverse torsional moment may be expressed as:

$$M_{tt} = \sum F_i \cdot d_i \cdot 10^{-3}$$

2.3 Calculation of rotation angle

2.3.1 The rotation angle may be derived from [2.2] and is given by the formula:

$$\omega = \frac{M_{tt}}{\sum r_i \cdot d_i^2} \cdot 10^3$$

2.4 Determination of stresses in deck beams

2.4.1 As M_{tt}, r_i and d_i are known, ω is thus deduced. Then F_i, in N, the bending moment M_i, in N.m, and the corresponding normal and shear stresses can be evaluated in each beam:

$$F_i = \omega \, r_i \, d_i$$

$$M_i = F_i \, S_i \, / \, 2$$

2.5 Checking criteria

2.5.1 It is to be checked that the normal stress σ and the shear stress 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:

R_y : Minimum yield stress, in N/mm², of the material to be taken equal to:
- $R_y = 235/k$ N/mm² for steel
- $R_y = 100/k$ N/mm² for aluminium alloys

unless otherwise specified

γ_R : Partial safety factor covering uncertainties regarding resistance, defined in Ch 5, Sec 2, [1.3]

γ_m : Partial safety factor covering uncertainties regarding material, defined in Ch 5, Sec 2, [1.3]

k : Material factor defined in Ch 2, Sec 3, [2.3], for steel and Ch 2, Sec 3, [3.5], for aluminium alloys.

Part B
Hull Design and Construction

Chapter 3
DESIGN LOADS

SECTION 1 GENERAL

Symbols

D : Depth, in m, defined in Ch 1, Sec 2, [2.3]

H_S : Significant wave height, in m, defined in Pt A, Ch 1, Sec 1, [1.2.10]

h_2 : Reference value of the relative motion, in m, defined in Ch 3, Sec 3, [2.2.1]

h_1 : Reference value of the relative motion, in m, defined in Ch 3, Sec 3, [2.2.1]

M_{WV} : Vertical wave bending moment, in kN.m

M_{WH} : Horizontal wave bending moment, in kN.m

Q_W : Vertical wave shear force, in kN.m

T : Scantling draught, in m, defined in Ch 1, Sec 2, [2.4].

1 Definitions

1.1 Still water loads

1.1.1 Still water loads are those acting on the vessel at rest in calm water.

1.2 Wave loads

1.2.1 Wave loads are those due to wave pressures and vessel 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 river pressures and the static pressures and forces induced by the weights carried in the vessel spaces.

- wave local loads are constituted by the external river pressures due to waves and the inertial pressures and forces induced by the vessel accelerations applied to the weights carried in the vessel spaces.

1.5 Hull girder loads

1.5.1 Hull girder loads are still water and wave forces and moments which result as effects of local loads acting on the vessel 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 vessel spaces arranged for their storage.

1.7 Load case

1.7.1 A load case is a state of the vessel structures subjected to a combination of hull girder and local loads.

1.8 Service conditions

1.8.1 Service conditions correspond to intact vessel in operating conditions.

2 Application criteria

2.1 Application

2.1.1 Requirements applicable to all types of vessels
The still water and wave induced loads defined in this Chapter are to be used for the determination of the hull girder strength and structural scantlings in any hull tranverse section.

2.1.2 Requirements applicable to specific vessel types
The design loads applicable to specific vessel types are to be determined in accordance with the requirements in Part D.

2.1.3 Load direct calculation
As an alternative to the formulae given in Ch 3, Sec 2, [3] and Ch 3, Sec 3, the Society may accept the values of wave induced loads derived from direct calculations, when justified on the basis of the vessel's characteristics and intended service. The calculations are to be submitted to the Society for review.

2.2 Hull girder loads

2.2.1 The hull girder loads to be used for the determination of:

- the hull girder strength, according to the requirements of Ch 4, Sec 2

- 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 3, Sec 4, according to the requirements in Part B, Chapter 5 and Part B, Chapter 6,

are specified in Ch 3, 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 [4].

2.3.2 Vessel motions and accelerations

The wave local loads are to be calculated on the basis of the reference values of vessel motions and accelerations specified in Ch 3, 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 vessel motions and accelerations,

are specified in Ch 3, Sec 4, [2] for river pressures and in Ch 3, Sec 4, [3] for internal pressures and forces.

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

* ordinary stiffeners

* primary supporting members for which a three dimensional structural model is not required, according to Ch 2, Sec 8, [2.3].

2.4.2 Cargo and ballast distribution

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 external pressures considered as acting alone without any counteraction from the vessel interior

* the differential pressures (internal pressure minus external pressure) considering the compartment adjacent to the outer shell as being loaded.

2.4.3 Draught T_1 associated with each cargo and ballast distribution

Local loads are to be calculated on the basis of the vessel draught T_1 corresponding to the cargo or lightship distribution considered according to the criteria [2.4.2]. The vessel draught is to be taken as the distance measured vertically on the hull transverse section at the middle of the length L from the base line to the waterline in:

a) full load condition, when:

* one or more cargo compartments are considered as being loaded and the ballast tanks are considered as being empty

* the external pressures are considered as acting alone without any counteraction from the vessel's interior.

b) lightship condition, when one or more ballast tanks are considered as being loaded and the cargo compartments are considered as being empty.

Where the value of T_1 is not provided, it may be taken as follows:

* for cargo carriers which include:

  - cargo vessels, see Pt A, Ch 1, Sec 3, [2]

  - tankers, see Pt A, Ch 1, Sec 3, [3]

  - vessels for dredging activities, see Pt A, Ch 1, Sec 3, [5]

  T_1 as defined in Tab 1.

* for non-cargo carriers

  T_1 as defined in Tab 2.

Table 1 : T_1 for cargo carriers

	Loading condition	External counter pressure	External design pressure
Harbour	**1R** and **Nonhomload**	0,20D	T
	2R	0,575T	0,575T
Navigation	Full load	T	T
	Lightship	0,20D	0,20D

Table 2 : T_1 for non-cargo carriers

Loading condition		External counter pressure	External design pressure
Full load condition (Navigation)		T	T
Lightship condition (Navigation)	Pontoon	0,20D	0,20D
	Tug/Pusher	0,28D	0,28D
	Others **(1)**	0,41D	0,41D
(1) Passenger vessel / Launch / Pleasure vessel			

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 to 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 2, Sec 8, [2.4].

2.5.2 Loading conditions

For all vessel types for which analyses based on three dimensional models are required according to Ch 2, Sec 8, [2.4], 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 for the vessel operation.

Further criteria applicable to specific vessel types are specified in Part D.

2.5.3 Draught associated with each loading condition

Local loads are to be calculated on the basis of the vessel's draught T_1 corresponding to the loading condition considered according to the criteria in [2.5.2].

3 Standard loading conditions

3.1 Cargo vessels and tank vessels

3.1.1 Lightship

For non-propelled cargo vessels (see Pt A, Ch 1, Sec 3, [2]) and tank vessels (see Pt A, Ch 1, Sec 3, [3]), the vessel is assumed empty, without supplies nor ballast.

For self-propelled cargo vessels and tank vessels, the light standard loading conditions are:

- supplies: 100%
- ballast: 50%.

3.1.2 Full load condition

For non-propelled cargo vessels (see Pt A, Ch 1, Sec 3, [2]) and tank vessels (see Pt A, Ch 1, Sec 3, [3]), the vessel is considered to be homogeneously loaded at its maximum draught, without supplies nor ballast.

For self-propelled cargo vessels and tank vessels, the vessel is considered to be homogeneously loaded at its maximum draught with 10% of supplies (without ballast).

3.1.3 Transitory conditions

Transitory standard conditions are defined in [3.1.4] to [3.1.6].

For non-propelled cargo vessels (see Pt A, Ch 1, Sec 3, [2]) and tank vessels (see Pt A, Ch 1, Sec 3, [3]), the vessel is assumed without supplies nor ballast.

For self-propelled cargo vessels and tank vessels, the vessel without ballast, is assumed to carry following amount of supplies:

- in hogging condition: 100% of supplies
- in sagging condition: 10% of supplies.

3.1.4 Loading / unloading in two runs (2R)

Loading and unloading are performed uniformly in two runs of almost equal masses, starting from one end of the cargo space, progressing towards the opposite end.

3.1.5 Loading / unloading in one run (1R)

Loading and unloading are performed uniformly in one run, starting from one end of the cargo space, progressing towards the opposite end.

3.1.6 Loading / unloading for liquid cargoes

Loading and unloading for liquid cargoes are assumed to be performed in two runs (see [3.1.4]), unless otherwise specified.

3.2 Vessels for dredging activities

3.2.1 Application

The requirements under [3.2.2] to [3.2.4] apply to the following vessels for dredging activities:

- **Hopper dredger**
- **Hopper barge**
- **Split hopper barge**
- **Split hopper dredger**.

3.2.2 Lightship

For hopper barges, the vessel is assumed empty, without supplies nor ballast.

For hopper dredgers, the light standard loading conditions are:

- supplies: 100%
- ballast: 50%.

3.2.3 Full load condition

For hopper barges, the vessel is considered to be homogeneously loaded at its maximum draught, without supplies nor ballast.

For hopper dredgers, the vessel is considered to be homogeneously loaded at its maximum draught with:

- supplies: 10%
- ballast: empty.

3.2.4 Working condition

The standard loading conditions are defined in a) and b) below.

For hopper barges, the vessel is assumed without supplies nor ballast.

For hopper dredgers, the vessel without ballast, is assumed to carry the following amount of supplies:

- in hogging condition: 100% of supplies
- in sagging condition: 10% of supplies.

a) Loading / unloading in two runs (**2R**)

   Loading and unloading are performed uniformly in two runs of almost equal masses, starting from one end of the hopper space, progressing towards the opposite end.

b) Loading / unloading in one run (**1R**)

   Loading and unloading are performed uniformly in one run, starting from one end of the hopper space, progressing towards the opposite end.

3.3 Tugs and pushers

3.3.1
The vessel is considered to be homogeneously loaded as follows:

- at minimum draught with 10% supplies
- at maximum draught with 100% supplies.

3.4 Other vessels

3.4.1 The standard loading conditions to be considered for passenger vessels, launches and pleasure vessels are defined in [3.4.2] and [3.4.3].

3.4.2 Lightship

The light standard loading conditions are:

* supplies: 100%

* ballast: 50%.

3.4.3 Full load condition

The vessel is considered to be homogeneously loaded at its maximum draught with:

* all passengers and crew onboard

* supplies: 100%

* ballast: empty.

4 Load cases

4.1 General

4.1.1 The mutually exclusive load cases described in [4.2] to [4.5] are those to be used for the structural element analyses of:

* plating

* ordinary stiffeners

* primary supporting members analysed through isolated beam structural models or three dimensional structural models.

4.2 Upright vessel condition during loading/ unloading in harbour (load case "a")

4.2.1 Vessel condition

The vessel is considered in upright condition at rest in still water.

4.2.2 Local loads

The external pressure is the hydrostatic river pressure.

The internal loads are the still water loads induced by the weights carried, including those carried on decks.

4.2.3 Hull girder loads

The hull girder loads are the vertical still water bending moment and shear force.

4.3 Upright vessel condition during navigation (load case "b")

4.3.1 Vessel condition

The vessel is considered to encounter a wave which produces a relative motion of the water stretch (both positive and negative) symmetric on the vessel sides and induces wave vertical bending moment and shear force in the hull girder. The wave is also considered to induce heave and pitch motions.

4.3.2 Local loads

The external pressure is obtained by adding to or subtracting from the hydrostatic river pressure a wave pressure corresponding to the relative motion.

The internal loads are obtained by adding the still water loads induced by the weights carried, including those carried on decks, to the loads induced by the accelerations.

4.3.3 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.

4.4 Upright vessel condition during working (load case "b")

4.4.1 This load case applies to vessels for dredging activities. Refer to [4.3] for vessel condition and encountered loads.

4.5 Inclined vessel condition during navigation (load cases "c" and "d")

4.5.1 Application

The inclined vessel condition is to be taken into account for **IN(1,2 < x ≤ 2)**.

Regardless of the range of navigation, the inclined vessel condition is also to be taken into account for racking analysis and strength check of vessel specific components such as:

* container supports

* movable decks and ramps

* movable wheelhouses.

4.5.2 Vessel condition

The vessel is considered to encounter a condition which produces:

* sway, roll and yaw motions

* a relative motion of the waterline anti-symmetric on the vessel sides

and induces:

* vertical wave bending moment and shear force in the hull girder

* horizontal wave bending moment in the hull girder.

4.5.3 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 vessel 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.

4.5.4 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.

Table 3 : Wave local loads in each load case

Vessel 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	0,0	a_{X1}; 0; a_{Z1}	0,0
	"b" **(1)**	h_1	1,0	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 vessel 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 vessel 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 on-board equipment foundations and supports.

Table 4 : Wave hull girder loads in each load case

Vessel condition	Load case	Vertical bending moment		Horizontal bending moment	
		Reference value	Combination factor	Reference value	Combination factor
Upright	"a"	M_{WV}	0,0	M_{WH}	0,0
	"b"	M_{WV}	1,0	M_{WH}	0,0
Inclined	"c"	M_{WV}	0,4	M_{WH}	1,0
	"d"	M_{WV}	0,4	M_{WH}	1,0

4.6 Inclined vessel condition during working (load cases "c" and "d")

4.6.1 This load case applies to vessels for dredging activities. Refer to [4.5] for vessel condition and encountered loads.

4.7 Summary of load cases

4.7.1 The wave local and hull girder loads to be considered in each load case are summarized in Tab 3 and Tab 4, respectively.

5 Range of navigation

5.1 General

5.1.1 The ranges of navigation considered in these Rules are defined in Pt A, Ch 2, Sec 3, [10].

5.2 Navigation coefficient n

5.2.1 The navigation coefficient to be used for the determination of vessel scantlings is to be obtain according to the following formula:

$n = 0,165\ H_S$

SECTION 2   Hull Girder Loads

Symbols

C : Wave parameter, taken equal to:

$$C = n(10,7 - 0,023\,L)$$

d_{AV} : Distance of foremost cargo area bulkhead from fore end (FE), in m

d_{AR} : Distance of aftmost cargo area bulkhead from aft end (AE), in m

F : Loading factor equal to: $F = P / P_T$

$0,8 \le F \le 1,0$

k_i : Coefficients defined in Tab 1

L_{AR} : Distance of cargo from aft end, in m, taken equal to:

$$L_{AR} = d_{AR} + X_{AR}$$

L_{AV} : Distance of cargo from fore end, in m, taken equal to:

$$L_{AV} = d_{AV} + X_{AV}$$

L_i : Coefficients taken equal to:

$$L_1 = 0,5\,L - \ell_1 - L_{AV}$$

$$L_2 = 0,5\,L - \ell_2 - L_{AR}$$

$$L_3 = 0,5\,L - 0,5\,L_1 - L_{AV}$$

ℓ_i : Coefficients taken equal to:

$$\ell_1 = \frac{-k_3}{k_2}\,L$$

$$\ell_2 = \frac{-k_3}{k_4}\,L$$

M_H : Design still water bending moment in hogging condition, in kN.m

M_L : Bending moment, in kN·m, taken equal to:

$$M_L = P_L\,(k_2\,L_3 + k_3\,L)$$

M_S : Design still water bending moment in sagging condition, in kN.m

M_{WH} : Horizontal wave bending moment, in kN.m, defined in [3]

M_{WV} : Vertical wave bending moment, in kN.m, defined in [3]

n : Navigation coefficient defined in Ch 3, Sec 1, [5.2]

P : Actual cargo weight, in t

P_L : Coefficient taken equal to:

$$P_L = \frac{0,77\,L_1}{L - L_{AR} - L_{AV}}\,F\,L\,B\,T\,C_B$$

P_T : Cargo weight, in t, corresponding to the vessel scantling draught T

R : Coefficient taken equal to:

$$R = \frac{L - L_{AV} - L_{AR}}{L}$$

R_{ij} : Coefficients taken equal to:

$$R_{11} = \frac{0,5\,L - L_{AV} - L_1}{L - L_{AV} - L_{AR}}$$

$$R_{12} = \frac{L_1}{0,5\,L - L_{AV} - L_1}$$

$$R_{21} = \frac{0,5\,L - L_{AR} - L_2}{L - L_{AV} - L_{AR}}$$

$$R_{22} = \frac{L_2}{0,5\,L - L_{AR} - L_2}$$

T : Scantling draught, in m, defined in Ch 1, Sec 2, [2.4]

X_{AV} : Distance of foremost cargo edge to foremost cargo area bulkhead

X_{AR} : Distance of aftmost cargo edge to aftmost cargo area bulkhead.

1 General

1.1 Design still water bending moments

1.1.1 The design still water bending moments, M_H and M_S, are to be provided by the designer, for all loading conditions considered.

All calculation documents are to be submitted to the Society.

1.1.2 If the design still water bending moments are not provided by the designer, their absolute values are not to be taken less than those derived from [2].

Table 1 : Coefficients k_i

Vessels	Conditions	k_2	k_3	k_4
Non-propelled	-	4,90	− 1,213	4,80
Self-propelled	Hogging	3,45	− 0,70	-
	Sagging	4,40	− 0,865	3,55

2 Estimated still water bending moments

2.1 General

2.1.1 The absolute values of the estimated still water bending moments are given by type of vessels in [2.2] to [2.6].

2.2 Non-propelled cargo carriers

2.2.1 The requirements of this Subarticle apply to non-propelled cargo carriers of characteristics listed hereafter:
- $0,80 \leq R \leq 0,92$
- $C_B \geq 0,92$
- $L \geq 35$ m

2.2.2 The hogging and sagging bending moments (amidships) in still water conditions are to be obtained, in kN.m, from formulae given in Tab 2.

2.3 Self-propelled cargo carriers

2.3.1 The requirements of this Subarticle apply to self-propelled cargo carriers with machinery aft, of characteristics listed hereafter:
- $0,60 \leq R \leq 0,82$
- $0,79 \leq C_B < 0,95$
- $L \geq 35$ m

2.3.2 The hogging and sagging bending moments (amidships) in still water conditions are to be obtained, in kN.m, from formulae given in Tab 3.

2.4 Hopper barges, split hopper barges, hopper dredgers and split hopper dredgers

2.4.1 The still water bending moments are to be as required in:
- [2.2.2] for hopper barges
- [2.3.2] for hopper dredgers,

considering the load case "Working" instead of "Harbour" (see Ch 3, Sec 1, [4]).

2.5 Tugs and pushers

2.5.1 This requirement applies to tugs and pushers whose engines are located amidships and whose bunkers are inside the engine room or adjoin it.

The still water bending moments (amidships), in kN.m, are to be determined using the following formulae:

- still water hogging bending moment:

  $M_H = 1,96 \ L^{1,5} \ B \ D \ (1 - 0,9 \ C_B)$

- still water sagging bending moment:

  $M_S = 0,01 \ L^2 \ B \ T \ (\varphi_1 + \varphi_2)$

  where:

  $\varphi_1 = 5,5 \left(0,6(1 + C_B) - \dfrac{X}{L} \right)$

  $\varphi_2 = \dfrac{10\Phi}{L^2 B}$

  X : Length, in m, of the machinery space increased by the length of adjacent bunkers

  Φ : Total brake power of the propelling installation, in kW.

2.6 Other vessels

2.6.1 The still water bending moments (amidships), in kN.m, for passenger vessels, launches and pleasure vessels with machinery aft are to be determined using the following formulae:

- still water hogging bending moment

  $M_H = 0,2 \ L^2 \ B^{1,48} \ D^{0,172} \ (1,265 - C_B)$

- still water sagging bending moment

  $M_S = 0$

Table 2 : Estimated still water bending moments of non-propelled cargo carriers

		Hogging	Sagging
Navigation		$M_H = 1,4 \ L^{1,98} \ B^{0,8} \ D^{0,2} \ (1,01 - C_B)$	$M_S = F \ (M_{H0} + M_{0S}) - M_{H0}$
Harbour	**2R**	$M_H = M_{H0} + (M_S - M_{S0})$	$M_S = 0,65 \ L \ B \ T^2 \ C_B \ [R_{11} \ (0,52 \ L - 1,84 \ \ell_1) \ (1 - R_{12}) + F \ R_{21} \ (0,5 \ L - 1,23 \ \ell_2)]$
	1R	$M_H = M_{H0} + (M_S - M_{S0})$	$M_S = 0,65 \ L \ B \ T^2 \ C_B \ [R_{11} \ (0,52 \ L - 1,84 \ \ell_1) \ (1 - R_{12}) + 1,15 \ F \ R_{21} \ (0,5 \ L - 1,23 \ \ell_2)]$
Note 1:			

$M_{0S} = 1,4 \ L \ B \ T^2 \ C_B \ [R_{11} \ (0,52 \ L - 1,84 \ \ell_1) \ (1 - R_{12}) + R_{21} \ (0,5 \ L - 1,23 \ \ell_2) \ (1 - R_{22})]$

M_{H0} : Still water bending moment in hogging condition during navigation

M_{S0} : Still water bending moment in sagging condition during navigation

Table 3 : Estimated still water bending moments of self-propelled cargo carriers

		Hogging	Sagging
Navigation		$M_H = 0,2\ L^2\ B^{1,48}\ D^{0,172}\ (1,265 - C_B)$	$M_S = M_{S0}$
Harbour	**2R**	$M_H = M_{HH} + 0,5\ M_L$	$M_S = 0,9\ M_{S0} + 0,5\ M_L$
	1R	$M_H = M_{HH} + M_L$	$M_S = 0,9\ M_{S0} + M_L$
Note 1: $M_{HH} = 0,4\ L^2\ B^{1,2}\ D^{0,2}\ (1,198 - C_B)$ $M_{HS} = 0,4\ L^{1,9}\ B^{1,46}\ (0,712 - 0,622\ C_B)$ $M_{S0} = F\ M_{CS} - M_{HS}$ $M_{CS} = 0,4\ L^{1,86}\ B^{0,8}\ T^{0,48}\ (C_B - 0,47)\ [3,1 + R_{11}\ (10,68\ L - 53,22\ \ell_1)\ (1 - R_{12}) + R_{21}\ (0,17\ L - 0,15\ \ell_2)\ (1 - R_{22})]$			

2.7 Distribution factor

2.7.1 Where estimated values of still water bending moments are used, their distribution factor F_{MT} along the hull girder is to be taken as defined in Tab 4 (see also Fig 1).

Table 4 : Distribution factor F_{MT}

Hull transverse section location	Distribution factor F_{MT}
$0 \leq x < 0,25\ L$	$4\dfrac{x}{L}$
$0,25\ L \leq x \leq 0,75\ L$	1
$0,75\ L < x \leq L$	$4\left(1 - \dfrac{x}{L}\right)$

Figure 1 : Distribution factor F_{MT}
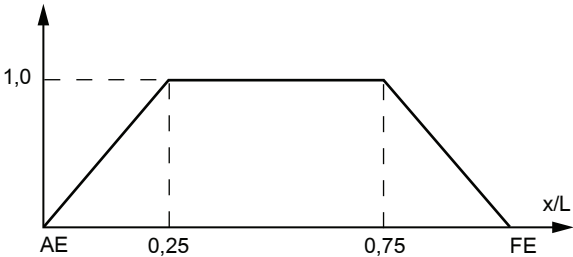
3 Wave bending moments

3.1 General

3.1.1 As an alternative to the requirements in [3.2] and [3.3], the Society may accept the wave bending moment values obtained by direct calculations, when justified on the basis of the vessel's characteristics and intended service. The calculations are to be submitted to the Society for approval.

3.2 Vertical wave bending moment

3.2.1 An additional bending moment/wave bending moment taking into account the stream and water conditions in the navigation zone is to be considered.

- for range of navigation **IN**, the absolute value of the additional bending moment amidships is to be obtained, in kN.m, from the following formula:

$$M_{WV} = 0,045\ L^2\ B\ C_B$$

- for range of navigation **IN(x ≤ 2)**, the absolute value of the vertical wave-induced bending moment amidships is to be obtained, in kN.m, from the following formula:

$$M_{WV} = 0,11\ C\ L^2\ B\ (C_B + 0,7)$$

3.3 Horizontal wave bending moment

3.3.1 The horizontal wave bending moment at any hull transverse section is obtained, in kN.m, from the following formula.

$$M_{WH} = C_{WH} F_{MT} \frac{n}{0,33} L^2 T C_B$$

where

C_{WH} : Horizontal wave coefficient
$\qquad C_{WH} = 0,895$

F_{MT} : Distribution factor defined in [3.4.1].

3.4 Distribution factor

3.4.1 The distribution factor F_{MT} of the wave bending moments along the hull girder is to be taken as defined in Tab 4 (see also Fig 1).

4 Vertical shear forces

4.1 General

4.1.1 The vertical still water and wave shear forces are to be provided by the designer.

4.2 Estimated value of the vertical shear force

4.2.1 If the values of the vertical shear forces are not provided by the designer, they are not to be taken less than, in kN:

$$T_s = \frac{\pi M}{L}$$

where:

M : Maximum vertical bending moment calculated according to:
- [2], for still water shear force
- [3.2], for wave shear force.

SECTION 3   VESSEL MOTIONS AND ACCELERATIONS

Symbols

A_P :   Pitch amplitude, in rad, defined in [2.1.5]

A_R :   Roll amplitude, in rad, defined in [2.1.4]

a_H :   Heave acceleration, in m/s^2, defined in [2.1.3]

a_{SU} :   Surge acceleration, in m/s^2, defined in [2.1.1]

a_{SW} :   Sway acceleration, in m/s^2, defined in [2.1.2]

D   :   Depth, in m, defined in Ch 1, Sec 2, [2.3]

H_W :   Wave parameter:

$$H_W = \frac{n}{0,33}\left(\frac{L}{L_{ref}}\right)^{-3}$$

L_{ref} :   Reference length, in m

$$L_{ref} = 33,7$$

n   :   Navigation coefficient defined in Ch 3, Sec 1, [5.2]

T_P :   Pitch period, in s, defined in [2.1.5]

T_{SW} :   Sway period, in s, defined in [2.1.2]

T_R :   Roll period, in s, defined in [2.1.4]

T_1 :   Draught associated with each cargo and ballast distribution, in m, defined in Ch 3, Sec 1, [2.4.3]

V   :   Maximum ahead service speed, in km/h

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 Ch 1, Sec 2, [3.1]

α_P :   Pitch acceleration, in rad/s^2, defined in [2.1.5]

α_Y :   Yaw acceleration, in rad/s^2, defined in [2.1.6]

α_R :   Roll acceleration, in rad/s^2, defined in [2.1.4]

Δ :   Vessel's displacement, in ton.

1 General

1.1 General considerations

1.1.1 Vessel motions and accelerations are defined, with their signs, according to the reference co-ordinate system in Ch 1, Sec 2, [3.1].

1.1.2 Vessel 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 vessel motions and accelerations derived from direct calculations or obtained from model tests, when justified on the basis of the vessel's characteristics and intended service. In general, the values of

vessel 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 Vessel motions and accelerations

2.1 Vessel absolute motions and accelerations

2.1.1 Surge

The surge acceleration a_{SU} is obtained, in m/s^2, from the formula in Tab 3.

2.1.2 Sway

The sway acceleration a_{SW} is obtained, in m/s^2, from the formula in Tab 3. The sway period T_{SW} is obtained from the following formula:

$$T_{SW} = \frac{0,8\sqrt{L}}{0,1\dfrac{V}{\sqrt{L}}+1}$$

2.1.3 Heave

The heave acceleration a_H is obtained, in m/s^2, from the formula in Tab 3.

2.1.4 Roll

The roll amplitude A_R, period T_R and acceleration α_R are obtained from the formulae in Tab 1.

2.1.5 Pitch

The pitch acceleration α_P is obtained, in rad/s^2, from the formula in Tab 3.

The pitch period T_P is obtained, in s, from the following formula:

$$T_P = 0,575\sqrt{L}$$

The pitch amplitude A_P is obtained, in rad, from the following formula:

$$A_P = \alpha_P\left(\frac{T_P}{2\pi}\right)^2$$

2.1.6 Yaw

The yaw acceleration α_Y is obtained, in rad/s^2, from the formula in Tab 3.

2.2 Vessel relative motions

2.2.1 The reference value of the relative motion in the upright condition h_1, in m, is obtained at any hull transverse section, from the following formulae:

a) **IN**

$h_1 = 0,3$ m

b) **IN(x ≤ 2)**

$h_1 = h_2 - A_R \dfrac{B_W}{2}$

h_2 : Reference value, in m, of the relative motion in the inclined vessel condition, calculated according to Tab 4

B_W : Moulded breadth, in m, measured at the waterline at draught T_1 at the hull transverse section considered

2.2.2 For **IN**, the reference value of the relative motion in the inclined vessel condition at any hull transverse section, is $h_2 = 0,3$ m.

For **IN(x ≤ 2)**, the reference value of the relative motion in the inclined vessel condition is obtained at any hull transverse section, from the formulae in Tab 4.

Table 1 : Roll amplitude, period and acceleration

Amplitude A_R in rad	Period T_R in s	Acceleration α_R in rad/s²
$A_R = \dfrac{n}{0,33}\left(\sqrt{\dfrac{GM}{\delta}} + 0,9\right)\dfrac{T_1}{B}\dfrac{6,3}{\sqrt[3]{\Delta}}$	$2C_a\dfrac{\delta}{\sqrt{GM}}$	$A_R\left(\dfrac{2\pi}{T_R}\right)^2$

C_a : Added mass coefficient

$C_a = 1,066 + 0,066\dfrac{B}{T_1} - 0,123\dfrac{L}{100}$

δ : Roll radius of gyration, in m, for the loading condition considered, when δ is not known, the following value may be assumed:
- full load: $\delta = 0,35B$
- lightship: $\delta = 0,40B$

GM : Distance, in m, from the vessel's centre of gravity to the transverse metacentre, for the loading considered; when GM is not known, the following value may be assumed:

$GM = \dfrac{C_{GM}B^2}{12\,T_1\,C_B} + 0,5\,T_1 - KG$

C_{GM} : GM coefficient to be taken equal to:
- full load: $C_{GM} = 0,95$
- lightship: $C_{GM} = 0,82$

KG : Height, in m, of the vessel's centre of gravity above keel. When KG is unknown, it may be assumed according to Tab 2

T_1 : Draught associated with each cargo and ballast distribution, defined in Ch 3, Sec 1, [2.4.3].

Table 2 : Height of the vessel's centre of gravity above keel KG

Vessel type	KG	
	Full load	Lightship
Tanker	0,64 D	0,57 D
Container vessel	0,71 D	0,54 D
Pontoon	1,20 D	0,59 D
Passenger vessel	1,10 D	1,10 D
Tug/Pusher	0,73 D	0,73 D
Others	0,64 D	0,54 D

Table 3 : Vessel accelerations

$X = \dfrac{1}{\mu}H_w L^{(k-1)}\Gamma$			
X	μ	k	Γ
a_{SU}	1471	3	$1,90\left(\dfrac{1}{B}\right)^{0,30}\left(\dfrac{1}{T_1}\right)^{0,10}$
a_{SW}	911	3	$0,30\left(\dfrac{L}{B}\right)^{0,50}\left(\dfrac{L}{T_1}\right)^{0,15}$
a_H	261	3	$1,50\left(\dfrac{1}{B}\right)^{0,25}T_1^{0,05}$
α_P	64	2	$7\left(\dfrac{1}{B}\right)\left(\dfrac{1}{T_1}\right)^{0,05}$
α_Y	368	2	$0,18\left(\dfrac{L}{B}\right)T_1^{0,25}$

Table 4 : Reference value of the relative motion h_2 in the inclined vessel condition

Location	Reference value of the relative motion h_2 in the inclined vessel condition, in m
$0 \le x \le 0,75L$	$\dfrac{n}{0,33}\left[\left(0,63 - \dfrac{2,5L}{1000}\right) + (BT_1)^{0,14}\right]$
$0,75L < x < L$	$h_{2,FC} + \dfrac{h_{2,FE} - h_{2,FC}}{0,25}\left(\dfrac{x}{L} - 0,75\right)$
$x = L$	$\dfrac{n}{0,33}\dfrac{12}{\sqrt[3]{L}}$

$h_{2,FC}$: Reference value h_2 calculated for x = 0,75 L
$h_{2,FE}$: Reference value h_2 calculated for x = L

2.3 Vessel relative accelerations

2.3.1 Definition

At any point, the accelerations in X, Y and Z direction are the acceleration components which result from the vessel motions defined from [2.1.1] to [2.1.6].

2.3.2 Vessel conditions

Vessel relative motions and accelerations are to be calculated considering the vessel in the following conditions:

- Upright vessel condition

in this condition, the vessel encounters waves which produce vessel motions in the X-Z plane, i.e. surge, heave and pitch

• Inclined vessel condition

in this condition, the vessel encounters waves which produce vessel motions in the X-Y and Y-Z planes, i.e. sway, heave, roll and yaw.

2.3.3   Accelerations

For **IN**, the reference values of the accelerations at any hull transverse section are to be taken equal to:

$$a_X = a_Y = a_Z = 0$$

For **IN(x ≤ 2)**, the reference values of the longitudinal, transverse and vertical accelerations at any point are obtained from the formulae in Tab 5 for upright and inclined vessel conditions.

Table 5 : Reference value of the accelerations a_X, a_Y and a_Z

Direction	Upright vessel condition	Inclined vessel condition
X - Longitudinal a_{x1} and a_{x2} in m/s²	$a_{X1} = \sqrt{a_{SU}^2 + [9,81 A_P + \alpha_P(z - T_1)]^2}$	$a_{X2} = 0$
Y - Transverse a_{y1} and a_{y2} in m/s²	$a_{Y1} = 0$	$a_{Y2} = \sqrt{a_{SW}^2 + [9,81 A_R + \alpha_R(z - T_1)]^2 + \alpha_Y^2 K_X L^2}$
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 : Coefficient defined as: $K_X = 1,2\left(\frac{x}{L}\right)^2 - 1,1\frac{x}{L} + 0,2 \geq 0,018$		
T_1 : Draught, in m, defined in Ch 3, Sec 1, [2.4.3].		

SECTION 4   LOCAL LOADS

Symbols

a_{X1}, a_{Y1}, a_{Z1} : Reference values of the accelerations in the upright vessel condition, defined in Ch 3, Sec 3, [2.3], calculated in way of the centre of gravity:

- of the compartment, in general
- 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 vessel condition, defined in Ch 3, Sec 3, [2.3], calculated in way of the center of gravity:

- of the compartment, in general
- 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"

d_{AP} : Distance from the top of the air pipe to the top of the tank, in m, see Fig 1

g : Gravitational acceleration:

$$g = 9,81 \ m/s^2$$

h_1 : Reference value of the relative motion defined in Ch 3, Sec 3, [2.2.1]

h_2 : Reference value of the relative motion defined in Ch 3, Sec 3, [2.2.1]

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

m_B : Mass of dry bulk cargo, in t, in the hold considered

n : Navigation coefficient defined in Ch 3, Sec 1, [5.2]

p : Design pressure, in kN/m²

p_{pv} : Setting pressure, in kN/m², of safety valves or maximum pressure, in kN/m², in the tank during loading/unloading, whichever is the greater

T_1 : Draught associated with each cargo and ballast distribution, in m, defined in Ch 3, Sec 1, [2.4.3]

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 Ch 1, Sec 2, [3.1]

z_{AP} : Z co-ordinate, in m, of the top of air pipe, (see Fig 1): $z_{AP} = z_{TOP} + d_{AP}$

z_H : Z co-ordinate, in m, of the bottom or inner bottom

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_{TOP} : Z co-ordinate, in m, of the highest point of the tank or compartment, see Fig 1

γ_{WB} : Factor taken as:

- $\gamma_{WB} = 1$, in general
- $\gamma_{WB} = 1,6$ for buckling and ultimate strength check according to Ch 2, Sec 7, when **IN(x ≤ 2)** is assigned

γ_{W2} : Partial safety factor covering uncertainties on wave local loads defined in Ch 5, Sec 1, [1.3]

φ_B : Dry bulk cargo angle of repose

ρ : River/sea water density, in t/m³

ρ_L : Density, in t/m³, of the liquid carried

ρ_B : Dry bulk cargo density, in t/m³.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the definition of local loads to be used for the scantling checks of:

- platings
- ordinary stiffeners
- primary supporting members.

2 External pressure

2.1 Pressure on sides and bottom

2.1.1 External still water pressure

The external still water pressure p_{SE} at any point of the hull, in kN/m², is given by the formula:

$$p_{SE} = \rho g \ (T_1 - z)$$

2.1.2 External wave pressure

The wave pressure p_{WE} at any point of the hull, in kN/m², is to be obtained from the formulae given in:

- Tab 1 (see Fig 3) for the upright vessel condition (load case "b").
- Tab 2 (see Fig 4 and Fig 5) for the inclined vessel condition (load cases "c" and "d").

Figure 1 : Definitions
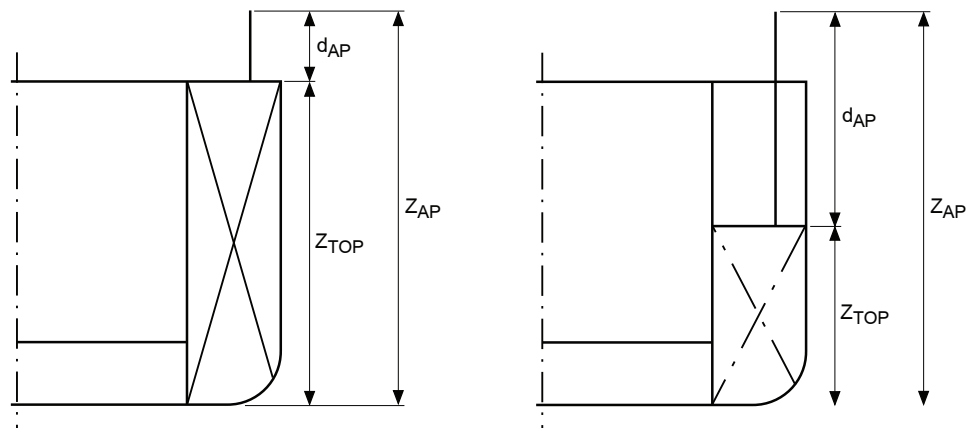
Table 1 : Wave pressure on sides and bottom in upright vessel conditions (load case "b")

Location	Wave pressure p_{WE}, in kN/m²	
	Crest (positive h_1)	Trough (negative h_1)
Bottom and sides below the waterline ($z \leq T_1$)	$\rho g h_1 e^{\frac{-2\pi(T_1-z)}{L}}$	$-\rho g h_1 e^{\frac{-2\pi(T_1-z)}{L}}$ without being taken less than $\rho g (z - T_1)$
Sides above the waterline ($z > T_1$)	$\rho g\left(\frac{(T_1-z)}{\gamma_{WB}} + h_1\right)$ without being taken less than: $(2 + p_{WD})/\gamma_{W2}$	0
Note 1: Wave pressure in way of wave trough is to be used only for the calculation of the external counter pressure p_{Em} P_{WD} : Wind pressure defined in [2.1.3]		

Table 2 : Wave pressure on sides, bottom in inclined vessel conditions (load cases "c" and "d")

Location	Wave pressure p_{WE}, in kN/m² (negative roll angle) **(1)**	
	$y \geq 0$	$y < 0$
Bottom and sides below the waterline ($z \leq T_1$)	$C_{F2}\rho g\frac{2y}{B_W}h_2 e^{\frac{-2\pi(T_1-z)}{L}}$	$C_{F2}\rho g\frac{2y}{B_W}h_2 e^{\frac{-2\pi(T_1-z)}{L}}$ without being taken less than $\rho g (z - T_1)$
Sides above the waterline ($z > T_1$)	$\rho g\left[\frac{(T_1-z)}{\gamma_{WB}} + C_{F2}\frac{2y}{B_W}h_2\right]$ without being taken less than $(2 + p_{WD})/\gamma_{W2}$	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.
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"
P_{WD} : Wind pressure defined in [2.1.3]		

Figure 2 : External still water pressure
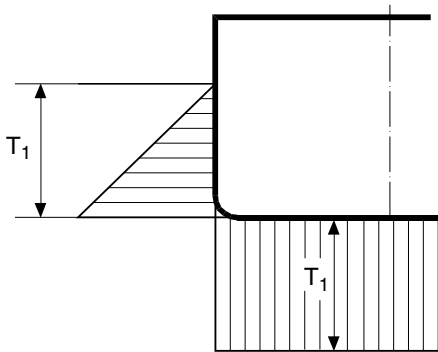
Figure 3 : Wave pressure in load case "b"

Positive h_1
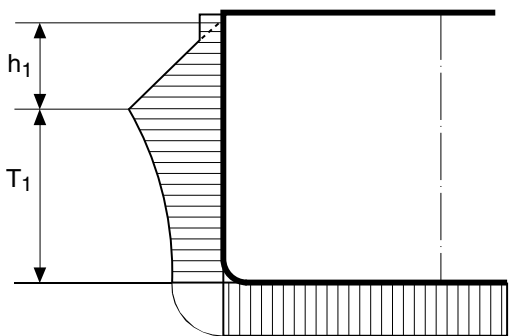
Negative h_1
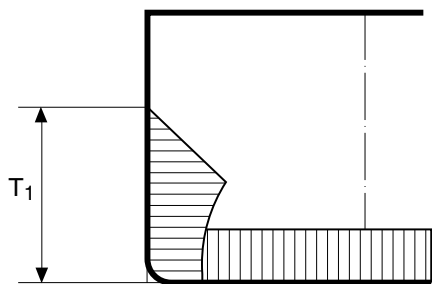
Figure 4 : Wave pressure in load case "c"
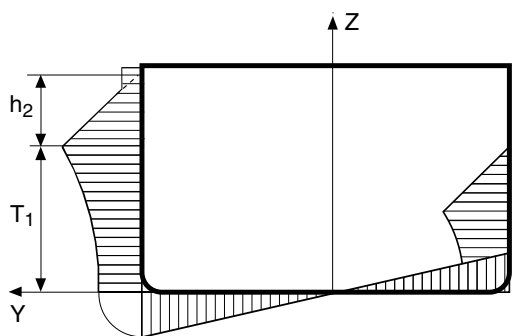
Table 3 : Wind pressure p_{WD}

Range of navigation	p_{WD}, in kN/m²
IN(x ≤ 2)	$0,25(1+n)$
IN	$0,25$

Figure 5 : Wave pressure in load case "d"
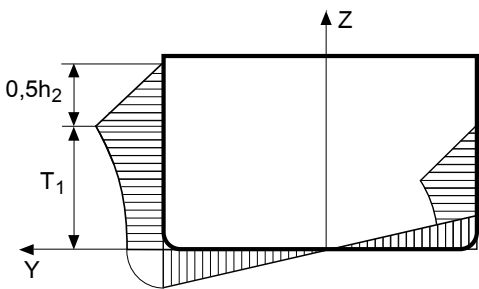
2.1.3 Wind pressure

The wind pressure p_{WD}, in kN/m² is to be determined according to Tab 3.

2.2 Pressure on exposed decks

2.2.1 External pressure on the weather deck

The weather pressure p_E, in kN/m², transmitted to the hull structure is given by the formula:

$p_E = 3,75\ (5,15\ y + 0,8)$

where:

y   :   Coefficient to be taken as:
- Range of navigation **IN**:
  $y = 0,099$
- Range of navigation **IN(x ≤ 2)**:
  $y = n$

2.2.2 Pressure due to load carried

The pressure p_D, in kN/m², transmitted to the hull structure is the combination of the still water pressure p_S and the wave pressure p_W.

The still water pressure p_S is to be provided by the designer. Otherwise, it is not to be taken less than the values defined in Tab 4. The wave pressure p_W is defined in Tab 5.

Table 4 : Still water pressure on exposed decks

Deck location/type	p_S, in kN/m²
Weather deck, trunk	3,0
First tier (non public)	2,0
Upper tiers (non public)	1,5
Public	4,0

Table 5 : Inertial pressure on exposed decks

Vessel condition	Load case	Inertial pressure p_W, in kN/m²
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_W = p_S \dfrac{a_{Z1}}{g}$
Inclined	"c"	Except vessels assigned a range of navigation **IN(1,2 < x ≤ 2)**, the inertial pressure transmitted to the deck structures in inclined condition may generally be disregarded. See also Ch 3, Sec 1, [4.5.1]
	"d"	

3 Internal loads

3.1 Liquids

3.1.1 Still water pressure

The still water pressure p_S is to be obtained, in kN/m², from the following formulae:

- liquid cargo:

  $p_S = \rho_L g (z_L - z)$

  $p_S = \rho_L g (z_{TOP} - z) + 1,15 p_{pv}$

- ballast:

  $p_S = \rho g (z_{TOP} - z + d_{AP})$

3.1.2 Inertial pressure

The inertial pressure p_W is to be obtained, in kN/m², from the formulae in Tab 6.

In addition, p_W should be taken such that $p_S + p_W \geq 0$

Table 6 : Watertight bulkheads of liquid compartments - Inertial pressure

Vessel 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"	$\rho_L \left[a_{TY}(y - y_H) + a_{TZ}(z - z_H) + \dfrac{g}{\gamma_{WB}}(z - z_{TOP}) \right]$
	"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 6)

a_{TY}, a_{TZ} : Y and Z components, in m/s², of the total acceleration vector defined in [3.1.3] 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 [3.1.4] for load case "c" and load case "d".

Figure 6 : Distance ℓ_B
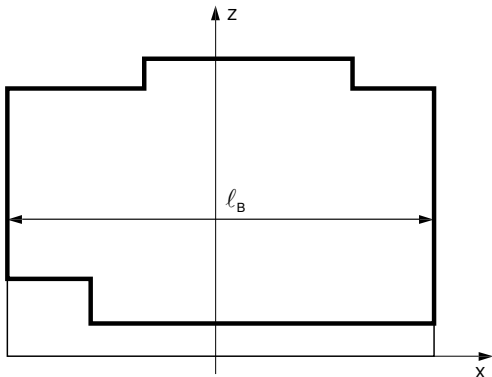
3.1.3 Total acceleration vector

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 3, Sec 3, [2.3.3]

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 7.

**Table 7 : Inclined vessel 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	
$0,7 C_{FA} a_{Y2}$	$- 0,7 C_{FA} a_{Z2} - g$	$\operatorname{atan}\dfrac{a_{TY}}{a_{TZ}}$

**Figure 7 : Inclined vessel conditions
Highest point H of the tank in the direction
of the total acceleration vector**
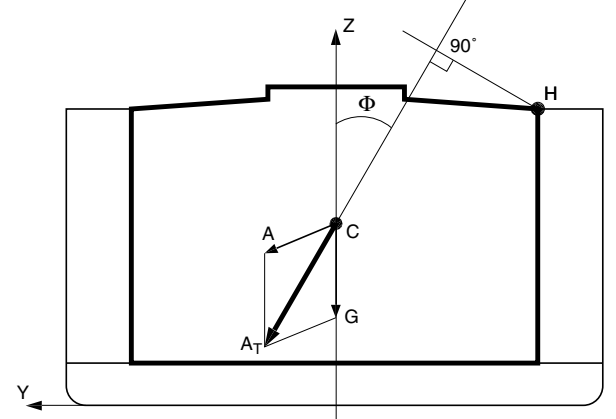
3.1.4 Highest point of the tank in the direction of the total acceleration vector

The highest point of the tank in the direction of the total acceleration vector A_T, defined in [3.1.3], 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 vessel condition, as indicated in Fig 7, where A and G are the vectors defined in [3.1.3] and C is the tank's centre of gravity.

3.2 Dry bulk cargoes

3.2.1 Pressure on side (or inner side) and bulkhead structures

The pressure p_C, in kN/m² transmitted to side (or inner side) and bulkhead structures is to be obtained using the formula:

$$p_C = \left(\frac{D - z}{D - z_H}\right) p_0$$

where:

p_0 : Mean total pressure on bottom or inner bottom, in kN/m²: $p_0 = p_S + p_W \geq 0$

p_S : Mean still water pressure on bottom or inner bottom, in kN/m²:

$$p_S = \frac{g\,m_B}{L_H B_1}$$

p_W : Mean inertial pressure on bottom or inner bottom is obtained, in kN/m², as specified in Tab 8.

**Table 8 : Dry bulk cargoes
Inertial pressure for side and inner side**

Vessel condition	Load case	Inertial pressure p_W, in kN/m²
Upright	"a"	No inertial pressure
	"b"	$p_W = \dfrac{a_{Z1} m_B}{L_H B_1}$
Inclined	"c"	Except vessels assigned a range of navigation **IN(1,2 < x ≤ 2)**, the inertial pressure transmitted to the hull structures in inclined condition may generally be disregarded. See also Ch 3, Sec 1, [4.5.1]
	"d"	

Note 1:
B_1 : Breadth, in m, of the hold

**Table 9 : Dry bulk cargoes
Inertial pressure for bottom and inner bottom**

Vessel condition	Load case	Inertial pressure p_W, in kN/m²
Upright	"a"	No inertial pressure
	"b"	$p_W = a_{Z1}\sqrt{\rho_B \tan\varphi_B \dfrac{m_B}{L_H}}$
Inclined	"c"	Except vessels assigned a range of navigation **IN(1,2 < x ≤ 2)**, the inertial pressure transmitted to the hull structures in inclined condition may generally be disregarded. See also Ch 3, Sec 1, [4.5.1]
	"d"	

3.2.2 Bottom or inner bottom still water design pressure

The bottom or inner bottom still water design pressure p_S is obtained, in kN/m², from the following formula:

$$p_S = g\sqrt{\rho_B \tan\varphi_B \frac{m_B}{L_H}}$$

3.2.3 Bottom or inner bottom inertial design pressure

The bottom or inner bottom inertial design pressure p_W is obtained, in kN/m², as specified in Tab 9:

3.3 Dry uniform cargoes

3.3.1 Design pressure

The design pressure p_C, in kN/m², is the combination of the still water pressure p_S, to be defined by the Designer and the inertial pressure p_W, defined in Tab 10.

3.4 Dry unit cargoes

3.4.1 The force F, in kN, transmitted to the hull structure is the combination of the still water force, F_S and the inertial force, F_W defined in [3.4.2] and [3.4.3], respectively.

Account is to be taken of the elastic characteristics of the lashing arrangement and/or the structure which contains the cargo.

Table 10 : Dry uniform cargoes - Inertial pressure

Vessel condition	Load case	Inertial pressure p_W, in kN/m²	
Upright (positive heave motion)	"a"	No inertial pressure	
	"b"	$p_{W,Z} = p_S \dfrac{a_{Z1}}{g}$	in z direction
Inclined (negative roll angle)	"c"	$p_{W,Y} = p_S \dfrac{C_{FA} a_{Y2}}{g}$	in y direction
	"d"	$p_{W,Z} = p_S \dfrac{C_{FA} a_{Z2}}{g}$	in z direction

Table 11 : Dry unit cargoes Inertial forces

Vessel condition	Load case	Inertial force F_W, in kN	
Upright (positive heave motion)	"a"	No inertial force	
	"b"	$F_{W,X} = m_C\,a_{X1}$ in x direction $F_{W,Z} = m_C\,a_{Z1}$ in z direction	
Inclined (negative roll angle)	"c"	$F_{W,Y} = m_C\,C_{FA}\,a_{Y2}$ in y direction	
	"d"	$F_{W,Z} = m_C\,C_{FA}\,a_{Z2}$ in z direction	

Note 1:
m_C : Mass, in t, as defined in [3.4.2].

3.4.2 Still water force

The still water force F_S transmitted to the hull structure is to be determined on the basis of the force obtained, in kN, from the following formula:

$F_S = g\,m_C$

where m_C is the mass, in t, of the dry unit cargo.

3.4.3 Inertial forces

The inertial forces F_W are to be obtained, in kN, from Tab 11.

3.5 Wheeled cargoes

3.5.1 Tyred vehicles

The forces transmitted through the tyres are considered as 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 axle and the tyre pressures.

With the exception of dimensioning of plating, such forces may be considered as concentrated in the tyre print centre.

3.5.2 Non-tyred vehicles

The requirements of [3.5.4] 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.

3.5.3 The force F, in kN, transmitted to the hull structure is the combination of the still water force, F_S and the inertial force, F_W defined in [3.5.4] and [3.5.5], respectively.

3.5.4 Still water force

The still water force F_S transmitted to the hull structure by one wheel is to be determined on the basis of the force obtained, in kN, from the formula:

$$F_s = g \, m_C$$

where:

$m_C = Q_A / n_w$

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.

3.5.5 Inertial forces

The inertial forces F_W are to be obtained, in kN, from Tab 12.

3.6 Accommodation

3.6.1 The pressure, p_D, in kN/m², is the combination of the still water pressure p_S and the inertial pressure p_W, defined in [3.6.2] and [3.6.3], respectively.

3.6.2 Still water pressure

The still water pressure p_S, in kN/m², transmitted to the deck structure is to be defined by the designer and, in general, is not to be taken less than values given in Tab 13.

3.6.3 Inertial pressure

The deck inertial pressure p_W is to be obtained, in kN/m², from Tab 14.

Table 12 : Wheeled cargoes - Inertial forces F_W

Vessel condition	Load case	Inertial force F_W, in kN	
Upright (positive heave motion)	"a"	No inertial force	
	"b"	$F_{W,X} = m_C \, a_{X1}$	in x direction
		$F_{W,Z} = m_C \, a_{Z1}$	in z direction
Inclined (negative roll angle)	"c"	$F_{W,Y} = m_C \, C_{FA} \, a_{Y2}$	in y direction
	"d"	$F_{W,Z} = m_C \, C_{FA} \, a_{Z2}$	in z direction
Note 1:			
m_C : Mass, in t, as defined in [3.5.4].			

Table 13 : Minimum deck still water pressure p_S in accommodation compartments

Type of accommodation compartment	p_S, in kN/m²
Large spaces (such as: restaurants, halls, cinemas, lounges, kitchen, service spaces, games and hobbies rooms, hospitals)	4,0
Cabins	3,0
Other compartments	2,5

Table 14 : Accommodation - Inertial pressure

Vessel condition	Load case	Inertial pressure p_W, in kN/m²
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_W = p_S \dfrac{a_{Z1}}{g}$
Inclined	"c"	Except vessels assigned a range of navigation **IN(1,2 < x ≤ 2)**, the inertial pressure transmitted to the hull structures in inclined condition may generally be disregarded. See also Ch 3, Sec 1, [4.5.1]
	"d"	

4 Flooding pressure

4.1 Still water pressure

4.1.1 On vessels required to comply with damage stability, the still water pressure p_{FL} to be considered as acting on platings and stiffeners of watertight bulkheads of compartments not intended to carry liquids is obtained, in kN/m², from the following formula:

$$p_{FL} = \rho g \, d_F$$

where:

d_F : Distance, in m, from the calculation point to the deepest waterline to be provided by the designer. Where the location of the deepest waterline is not known, d_F will be taken as:

$$d_F = D - z$$

5 Testing pressures

5.1 Still water pressures

5.1.1 The still water pressures p_{ST} to be considered as acting on plates and stiffeners subject to tank testing are specified in Tab 15.

Table 15 : Testing - Still water pressure p_{ST}

Compartment or structure to be tested	Still water pressure p_{ST}, in kN/m²
Double bottom tanks Double side tanks Fore peaks used as tank After peaks used as tank	$p_{ST} = g \, [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = g \, [(z_{TOP} - z) + 1]$ whichever is the greater
Cargo tank bulkheads Deep tanks Independent cargo tanks Fuel oil tanks	$p_{ST} = g \, [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = g \, [(z_{TOP} - z) + 1]$ $p_{ST} = g \, (z_{TOP} - z) + 1,3 \, p_{pv}$ whichever is the greater
Ballast compartments Cofferdams	$p_{ST} = g \, [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = g \, [(z_{TOP} - z) + 1]$ whichever is the greater
Double bottom Fore peaks not used as tank After peaks not used as tank	$p_{ST} = g \, (z_{AP} - z)$
Other independent tanks	$p_{ST} = g \, [(z_{TOP} - z) + d_{AP}]$

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Part B

Hull Design and Construction

</div>

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Chapter 4

GLOBAL STRENGTH ANALYSIS - METALLIC HULLS

</div>

SECTION 1   LONGITUDINAL HULL GIRDER STRENGTH ANALYSIS

Symbols

k : Material factor defined in Ch 2, Sec 3, [2.3], for steel hulls and Ch 2, Sec 3, [3.5]. for aluminium hulls

M_H : Design still water bending moment in hogging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_S : Design still water vertical bending moment in sagging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_{WV} : Vertical wave bending moment, in kN.m, defined in Ch 3, Sec 2, [3.2]

n : Navigation coefficient defined in Ch 3, Sec 1, [5.2]

Z : Hull girder section modulus, in cm³.

1   General

1.1   Application

1.1.1 This Section specifies:

- the criteria for calculating the hull girder strength characteristics to be used for the checks, in association with the hull girder loads

- the yielding strength check criteria.

1.2   Length-to-depth ratio - Steel hulls

1.2.1 In principle, the length-to-depth ratio is not to exceed the following values:

- for **IN(1,2 ≤ x ≤ 2)**: L / D = 25

- for **IN(x < 1,2)**:   L / D = 38(1-1,7n)

- for **IN**:   L / D = 35.

Vessels having a different ratio will be considered by the Society on a case by case basis.

1.3   Length-to-depth ratio - Aluminium alloy hulls

1.3.1 For vessels with a rule length equal to or greater than 40 m, the length-to-depth ratio will be specially considered by the Society.

2   Characteristics of the hull girder transverse sections

2.1   Hull girder transverse sections

2.1.1   General

The 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 of [2.1.2] to [2.1.8].

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 bulkheads with vertical corrugations

Longitudinal bulkheads with vertical corrugations may not be included in the hull girder transverse sections.

2.1.5   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 $2,06 \cdot 10^5$ 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.

2.1.6 Large openings and scallops

Large openings are:

- in the side shell plating: openings having a diameter greater than or equal to 300 mm

- in the strength deck: openings having a diameter greater than or equal to 350 mm.

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.

2.1.7 Small openings

Individual small openings which do not comply with the arrangement requirements given in Ch 5, Sec 4, [3.4], are to be deducted from the sectional areas included in the hull girder transverse sections.

2.1.8 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals or girders need not be deducted if their height is less than $0,25\ h_W$, without being greater than 75 mm, where h_W is the web height, in mm.

Otherwise, the excess is to be deducted from the sectional area or compensated.

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.

Superstructures and deckhouses are deck erections defined in Ch 1, Sec 2, [2.8] and Ch 1, Sec 2, [2.9].

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:

$$t_{EQ} = 10^3 \left[\ell_P \left(\frac{Gh^2}{12\,EI_J} + \frac{1}{A_J} \right) \right]^{-1}$$

where (see Fig 1):

ℓ_P : Longitudinal distance, in m, between the frames beside the opening

h : Height, in m, of openings

I_J : Moment of inertia, in m^4, of the opening jamb about the transverse axis y-y (jamb stiffeners included)

A_J : Shear area, in m^2, of the opening jamb in the direction of the longitudinal axis x-x (jamb stiffeners not included)

G : Coulomb's modulus, in N/mm^2, of the material used for the opening jamb, to be taken equal to:

- for steels:

$G = 8,0.10^4\ N/mm^2$

- for aluminium alloys:

$G = 2,7.10^4\ N/mm^2$.

Figure 1 : Side openings

Cross section the opening ja
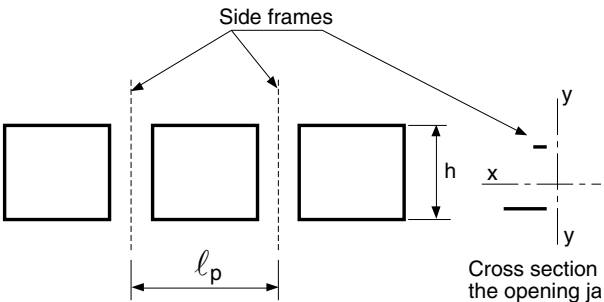
2.3 Hull girder section modulus

2.3.1 The section modulus at any point of a hull transverse section is obtained, in cm^3, from the following formula:

$$Z = \frac{I_Y}{100|z - N|}$$

where:

I_Y : Moment of inertia, in cm^4, of the hull girder transverse section defined in [2.1], about its horizontal neutral axis

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section

z : Z co-ordinate, in m, of the calculation point of a structural element.

2.3.2 The section moduli at bottom and at deck are obtained, in m^3, from the following formulae:

- at bottom:

$$Z = \frac{I_Y}{N}$$

- at deck:

$$Z = \frac{I_Y}{V_D}$$

where:

I_Y, N : Defined in [2.3.1]

V_D : Vertical distance, in m:

- in general:

$V_D = z_D - N$

- if continuous trunks or hatch coamings are taken into account in the calculation of I_Y:

$$V_D = (z_T - N)\left(0,9 + 0,2\frac{y_T}{B}\right) \geq z_D - N$$

- if longitudinal ordinary stiffeners or girders welded above the strength deck are taken into account in the calculation of I_Y, 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, [3].

z_D : Z co-ordinate, in m, of strength deck with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [3]

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, [3]; y_T and z_T are to be measured for the point which maximises the value of V_D

3 Characteristics of the hull girder transverse sections for multihulls

3.1 General

3.1.1 The longitudinal hull girder strength of a multihull having more than two floats will be considered on a case-by-case basis.

3.1.2 The characteristics of the hull girder transverse sections are to be determined as specified in [2].

The moment of inertia I_Y is to be calculated for only one float. A platform extending in length over at least $0,4 \, L_{WL}$ is to be considered for the calculation of the inertia of the float with breadths b_R and b_{WD} as defined in Fig 2, limited to 10% of the platform longitudinal length.

Figure 2 : Hull girder strength areas to be taken into account for continuous structural members
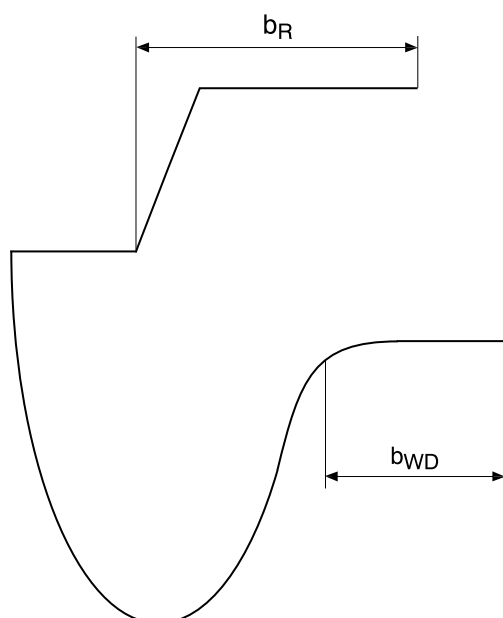
4 Yielding strength check

4.1 Stress calculation

4.1.1 The hull girder normal stresses σ_1 induced by vertical bending moments are obtained, in N/mm^2, from the following formulae:

- in sagging conditions

$$\sigma_1 = \frac{M_S + M_{WV}}{Z} 10^3$$

- in hogging conditions

$$\sigma_1 = \frac{M_H + M_{WV}}{Z} 10^3$$

4.2 Checking criterion

4.2.1 It is to be checked that the hull girder normal stresses, in N/mm^2, at any point of the net hull girder transverse section, calculated according to [2] are in compliance with the following condition:

$\sigma_1 \leq \sigma_{1,All}$

where

$\sigma_{1,All}$: Allowable hull girder normal stress, in N/mm^2

- $\sigma_{1,All} = 190/k$, for steel hulls
- $\sigma_{1,All} = 60/k$, for aluminium alloy hulls.

4.2.2 The requirement [4.2.1] does not apply to vessels with rule length less than 40 m complying with the alternative requirements of Ch 5, Sec 6.

SECTION 2   TRANSVERSE STRENGTH ANALYSIS FOR MULTIHULLS

Symbols

Refer to Fig 1.

G   :   Centre of the stiffnesses r_i, of the m deck beams

O   :   Origin of abscissae, arbitrarily chosen

m   :   Number of deck transverses

x_i :   Abscissa, in m, of deck beam i with respect to origin O

S_i :   Span of deck beam i, in m, between the inner faces of the hulls

I_i :   Bending inertia of deck beam i, in m^4

E_i :   Young's modulus of deck beam i, in N/mm^2, to be taken equal to

- for steels in general:

$$E_i = 2,06 \cdot 10^5 \ N/mm^2$$

- for stainless steels:

$$E_i = 1,95 \cdot 10^5 \ N/mm^2$$

- for aluminium alloys:

$$E_i = 7,00 \cdot 10^4 \ N/mm^2$$

r_i :   Stiffness of deck beam i, in N/m, equal to:

$$r_i = \frac{12 \cdot E_i \cdot I_i}{S^3_i} \cdot 10^6$$

a   :   Abscissa, in m, of the centre G with respect to the origin O

$$a = \frac{\sum r_i \cdot x_i}{\sum r_i}$$

n   :   Navigation coefficient defined in Ch 3, Sec 1, [5.2]

If F_i, in N, is the force taken over by the deck beam i, the deflection y_i, in m, of the hull in way of the beam i, is:

$$y_i = \frac{F_i S^3_i \cdot 10^{-6}}{12 E_i I_i} = \frac{F_i}{r_i} = d_i \omega$$

where:

d_i :   Abscissa, in m, of the deck beam i with respect to the origin G:

$$d_i = x_i - a$$

ω :   Rotation angle, in rad, of one hull in relation to the other around a transverse axis passing through G.

1 General

1.1

1.1.1 The transverse strength of a multihull having more than two floats will be considered on a case-by-case basis.

1.1.2 In the special case of catamaran, when the structure connecting both hulls is formed by a deck with single plating stiffened by m reinforced beams, the normal and shear stresses in the beams can be calculated as indicated in [2].

Figure 1 : Transverse strength of catamaran

2 Transverse strength in special case of catamaran

2.1 General

2.1.1 Deck beams are assumed to be fixed into each hull. Consequently, deck beams are to be extended throughout the breadth of each hull, with the same scantlings all over their span, inside and outside the hulls.

2.2 Transverse torsional connecting moment

2.2.1 The catamaran transverse torsional connecting moment, in kN.m, about a transverse axis is given by:

$$M_{tt} = 1,23 \, \Delta \, L \, a_{CG}$$

where:

Δ : Vessel displacement, in tons

a_{CG} : Design vertical acceleration at LCG, in m/s², to be taken not less than:

$$a_{CG} = 0,36 \, Soc \frac{v}{\sqrt{L}}$$

v : Vessel speed, in km/h

Soc : Coefficient depending on the navigation coefficient n, defined as:

Soc = 0,1 (5,15y + 1,1)

    y : Coefficient to be taken as:
- y = 0.099 for **IN**
- y = n for **IN(x ≤ 2)**

Moreover, the transverse torsional moment may be expressed as:

$$M_{tt} = \sum F_i \cdot d_i \cdot 10^{-3}$$

2.3 Calculation of rotation angle

2.3.1 The rotation angle may be derived from Ch 2, App 3, [2.2] and is given by the formula:

$$\omega = \frac{M_{tt}}{\sum r_i \cdot d_i^2} \cdot 10^3$$

2.4 Determination of stresses in deck beams

2.4.1 As M_{tt}, r_i and d_i are known, ω is thus deduced. Then F_i, in N, the bending moment M_i, in N.m, and the corresponding normal and shear stresses can be evaluated in each beam:

$F_i = \omega \, r_i \, d_i$

$M_i = F_i \, S_i / 2$

2.5 Checking criteria

2.5.1 It is to be checked that the normal stress, the shear stress and the Von Mises equivalent stress are in compliance with the following conditions:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0,5 \frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

where:

σ : Normal stress, in N/mm², in the direction of the deck beam axis

τ : Shear stress, in N/mm², in the direction of the force F_i applied to the deck beam.

σ_{VM} : Von Mises equivalent stress, in N/mm²

$$\sigma_{VM} = \sqrt{\sigma^2 + 3\tau^2}$$

R_y : Minimum yield stress, in N/mm², of the material to be taken equal to:
- R_y = 235/k N/mm² for steel
- R_y = 100/k N/mm² for aluminium alloys

unless otherwise specified

γ_R : Partial safety factor covering uncertainties regarding resistance, defined in Ch 2, Sec 8, [2.1.2]

γ_m : Partial safety factor covering uncertainties regarding material, defined in Ch 2, Sec 8, [2.1.2]

k : Material factor defined in Ch 2, Sec 3, [2.3], for steel and Ch 2, Sec 3, [3.5], for aluminium alloys.

Part B
Hull Design and Construction

Chapter 5
HULL SCANTLINGS

SECTION 1 GENERAL

Symbols

I_Y : Moment of inertia, in cm⁴, of the hull girder transverse section defined in Ch 4, Sec 1, [2.1], about its horizontal neutral axis

M_H : Design still water bending moment in hogging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_S : Design still water vertical bending moment in sagging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_{WV} : Vertical wave bending moment, in kN.m, defined in Ch 3, Sec 2, [3.2]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section

p_B : Ballast design pressure, in kN/m²

$p_B = p_S + \gamma_{W2}\, p_W$

p_C : Cargo design pressure, in kN/m²

$p_C = p_S + \gamma_{W2}\, p_W$

p_D : External design pressure, in kN/m²

$p_D = p_S + \gamma_{W2}\, p_W$

p_E : External design pressure, in kN/m²

$p_E = p_{SE} + \gamma_{W2}\, p_{WE}$

p_S : Still water pressure, in kN/m², defined in Ch 3, Sec 4, [3]

p_{SE} : External still water pressure, in kN/m², defined in Ch 3, Sec 4, [2.1.1]

p_{ST} : Test pressure, in kN/m², defined in Ch 3, Sec 4, [5.1.1]

p_W : Inertial pressure, in kN/m², defined in Ch 3, Sec 4, [3]

p_{WD} : Wind pressure, in kN/m², defined in Ch 3, Sec 4, [2.1.3]

p_{WE} : External wave pressure, in kN/m², defined in Ch 3, Sec 4, [2.1.2]

z : Z co-ordinate, in m, of the calculation point of a structural element.

1 General

1.1 Application

1.1.1 This Chapter contains the requirements for the arrangement and the determination of the hull scantlings applicable to the central part (see Ch 1, Sec 1, [2.1.3]) of all types of vessels covered by these Rules, made of metallic material. For the structures of other parts, see Part B, Chapter 6.

These requirements are to be integrated with those specified under applicable Chapters of Part D, depending on the vessel notations.

1.1.2 The scantling determination is to be carried out independently for all applicable load cases defined in Ch 3, Sec 1, [4].

1.1.3 The scantling determination is to be carried out considering the vessel in service conditions (see Ch 3, Sec 1, [1.8], for definition) and, as applicable, in flooding and testing conditions.

1.2 Net scantlings

1.2.1 All scantlings referred to in this Chapter are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 2, Sec 5, [2].

1.3 Partial safety factors

1.3.1 Plating

The partial safety factors covering uncertainties regarding wave hull girder loads (γ_{W1}), wave local loads (γ_{W2}), material (γ_m) and resistance (γ_R) to be considered for the checking of the plating are specified in Tab 1.

1.3.2 Ordinary stiffeners

The partial safety factors covering uncertainties regarding wave hull girder loads (γ_{W1}), wave local loads (γ_{W2}), material (γm) and resistance (γ_R) to be considered for the checking of ordinary stiffeners are specified in Tab 2.

1.3.3 Primary supporting members

The partial safety factors covering uncertainties regarding wave hull girder loads (γ_{W1}), wave local loads (γ_{W2}), material (γm) and resistance (γ_R) to be considered for checking primary structural members are specified in Tab 3 for analyses based on isolated beam models.

Table 1 : Plating - Partial safety factors

Limit state	Condition	γ_{W1} **(2)**	γ_{W2} **(2)**	γ_R	γ_m
Strength check of plating subjected to lateral pressure	General	1,15	1,20	1,20	1,02
	Flooding	1,15	1,20	1,05 **(1)**	1,02
	Testing	NA	NA	1,05	1,02
(1) For plating of the collision bulkhead, γ_R =1,25.					
(2) For range of navigation **IN**, $\gamma_{W1} = \gamma_{W2} = 1,00$					
Note 1: NA = not applicable.					

Table 2 : Ordinary stiffeners - Partial safety factors

Limit state	Condition	γ_{W1} **(2)**	γ_{W2} **(2)**	γ_R	γ_m
Yielding check	General	1,15	1,20	1,02	1,02
	Flooding	1,15	1,20	1,02 **(1)**	1,02
	Testing	NA	NA	1,02	1,02
(1) For ordinary stiffeners of the collision bulkhead, γ_R =1,25.					
(2) For range of navigation **IN**, $\gamma_{W1} = \gamma_{W2} = 1,00$					
Note 1: NA = not applicable.					

Table 3 : Primary supporting members analysed through isolated beam models - Partial safety factors

Limit state	Condition	γ_{W1} **(2)**	γ_{W2} **(2)**	γ_R	γ_m
Yielding check	General	1,15	1,20	1,02	1,02
	Bottom and side girders **(3)**	1,15	1,20	1,15	1,02
	Flooding	1,15	1,20	1,02 **(1)**	1,02
	Testing	NA	NA	1,02	1,02
(1) For primary supporting members of the collision bulkhead, γ_R =1,25.					
(2) For range of navigation **IN**, $\gamma_{W1} = \gamma_{W2} = 1,00$					
(3) Includes bottom girders, bottom transverses, reinforced floors, side stringers, side transverses and web frames.					
Note 1: NA = not applicable.					

2 Load model

2.1 Design lateral pressure

2.1.1 The design lateral pressure, p, to be used for hull scantling is defined in Tab 4.

Table 4 : Design lateral pressure, p, in kN/m²

Structure	In service conditions	In testing conditions	In flooding conditions
Shell structure	p_E $p_C - p_{Em}$ $p_B - p_{Em}$	p_{ST} $p_{ST} - p_{SE}$ **(1)**	–
Deck structure	p_E **(2)** p_C p_B p_D	p_{ST}	–
Hatch coaming	$2+p_{WD}$	–	–
Internal structure	p_C p_B	p_{ST}	p_{FL}
(1) Testing afloat			
(2) External deck pressure defined in Ch 3, Sec 4, [2.2.1].			

2.2 Forces induced by wheeled and dry unit cargoes

2.2.1 The force transmitted to the hull structure by dry unit cargoes and wheeled cargoes are given by the formula:

$$F = F_S + \gamma_{W2}F_W$$

where:

F_S, F_W : Still water and wave forces defined in Ch 3, Sec 4, [3.3], for dry unit cargoes, and Ch 3, Sec 4, [3.5], for wheeled cargoes.

2.3 Hull girder normal stresses

2.3.1 The requirements in Pt D, Ch 2, Sec 12, [4.2] apply in addition to vessels assigned the range of navigation **IN(1,2 < x ≤ 2)**.

Table 5 : Combination factors C_{FV}

Load case	C_{FV}
"a"	0
"b"	1,0
"c"	Except vessels assigned a range of naviga-tion **IN(1,2 < x ≤ 2)**, the hull girder wave loads in inclined condition may generally be disregarded.
"d"	
Flooding	0,6

Table 6 : Hull girder normal stresses - Plating subjected to lateral loads

Condition	σ_{S1} , in N/mm² **(1)**	σ_{WV1} , in N/mm²
$\dfrac{M_S + \gamma_W \gamma_{W1} C_{FV} M_{WV}}{M_H + \gamma_W \gamma_{W1} C_{FV} M_{WV}} \geq 1$	$\left\| \dfrac{M_S}{I_Y}(z - N) \right\| 10^{-3}$	$\left\| \dfrac{\gamma_W M_{WV}}{I_Y}(z - N) \right\| 10^{-3}$
$\dfrac{M_S + \gamma_W \gamma_{W1} C_{FV} M_{WV}}{M_H + \gamma_W \gamma_{W1} C_{FV} M_{WV}} < 1$	$\left\| \dfrac{M_H}{I_Y}(z - N) \right\| 10^{-3}$	$\left\| \dfrac{\gamma_W M_{WV}}{I_Y}(z - N) \right\| 10^{-3}$

(1) When the vessel in still water is always in hogging condition, M_S is to be taken equal to 0.
Note 1:
• For range of navigation **IN**, $\gamma_W = 1,00$
• For range of navigation **IN(x ≤ 2)**, $\gamma_W = 0,625$

Table 7 : Hull girder normal stresses -
Ordinary stiffeners and primary supporting members subjected to lateral pressure

Condition	σ_{S1} , in N/mm² **(1)**	σ_{WV1} , in N/mm²
Lateral pressure applied on the side opposite to the ordinary stiffener, with respect to the plating: • z ≥ N in general ; z < N for stiffeners simply supported at both ends	$\left\| \dfrac{M_S}{I_Y}(z - N) \right\| 10^{-3}$	$\left\| \dfrac{\gamma_W M_{WV}}{I_Y}(z - N) \right\| 10^{-3}$
• z < N in general ; z ≥ N for stiffeners simply supported at both ends	$\left\| \dfrac{M_H}{I_Y}(z - N) \right\| 10^{-3}$	$\left\| \dfrac{\gamma_W M_{WV}}{I_Y}(z - N) \right\| 10^{-3}$
Lateral pressure applied on the same side as the ordinary stiffener: • z ≥ N in general ; z < N for stiffeners simply supported at both ends	$\left\| \dfrac{M_H}{I_Y}(z - N) \right\| 10^{-3}$	$\left\| \dfrac{\gamma_W M_{WV}}{I_Y}(z - N) \right\| 10^{-3}$
• z < N in general ; z ≥ N for stiffeners simply supported at both ends	$\left\| \dfrac{M_S}{I_Y}(z - N) \right\| 10^{-3}$	$\left\| \dfrac{\gamma_W M_{WV}}{I_Y}(z - N) \right\| 10^{-3}$

(1) When the vessel in still water is always in hogging condition, M_S is to be taken equal to 0.
Note 1:
• For range of navigation **IN**, $\gamma_W = 1,00$
• For range of navigation **IN(x ≤ 2)**, $\gamma_W = 0,625$

Table 8 : Hull girder normal stresses -
Ordinary stiffeners and primary supporting members subjected to wheeled loads

Condition	σ_{S1} , in N/mm² **(1)**	σ_{WV1} , in N/mm²
Hogging	$\left\| \dfrac{M_H}{I_Y}(z - N) \right\| 10^{-3}$	$\left\| \dfrac{\gamma_W M_{WV}}{I_Y}(z - N) \right\| 10^{-3}$
Sagging **(1)**	$\left\| \dfrac{M_S}{I_Y}(z - N) \right\| 10^{-3}$	$\left\| \dfrac{\gamma_W M_{WV}}{I_Y}(z - N) \right\| 10^{-3}$

(1) When the vessel in still water is always in hogging condition, M_S is to be taken equal to 0.
Note 1:
• For range of navigation **IN**, $\gamma_W = 1,00$
• For range of navigation **IN(x ≤ 2)**, $\gamma_W = 0,625$

2.3.2 The hull girder normal stresses to be considered for the strength check of plating, ordinary stiffeners and primary supporting members are obtained, in N/mm2, from the following formulae:

- in general $\sigma_{X1} = \sigma_{S1} + \gamma_{W1} C_{FV} \sigma_{WV1}$

- for structural members not contributing to the hull girder longitudinal strength: $\sigma_{X1} = 0$

where:

$\sigma_{S1}, \sigma_{WV1}$: Hull girder normal stresses, in N/mm^2, defined in:
  - Tab 6, for plating subjected to lateral loads
  - Tab 7, for ordinary stiffeners and primary supporting members subjected to lateral pressure
  - Tab 8, for ordinary stiffeners and primary supporting members subjected to wheeled loads

C_{FV} : Combination factors defined in Tab 5.

3 Direct calculation

3.1 General

3.1.1 Direct calculation may be adopted instead of the Rule scantling requirements in the following cases:

- as an alternative to the Rule scantling formulae

- for the analysis of structural members not covered by the Rules

- for the analysis of structural members with configurations not covered by the Rules.

The direct calculation guidance for the yielding and buckling strength checks of structural members is given in Ch 2, Sec 8, [2].

SECTION 2   BOTTOM SCANTLINGS

Symbols

A_{sh} : Net shear sectional area, in cm^2

B_1 : Breadth, in m, of the hold or tank:
- if no longitudinal bulkhead is fitted:
  $B_1 = B - 2\,B_2$
- if a longitudinal bulkhead is fitted:
  $B_1 = (B - 2\,B_2) / 2$

B_2 : Breadth, in m, of the side tank

C_a : Aspect ratio, equal to:

$$C_a = 1,21\sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell} \leq 1$$

C_r : Coefficient of curvature:

$$C_r = 1 - 0,5\frac{s}{r} \geq 0,5$$

where:

r : Radius of curvature, in m

c : Dry bulk coefficient to be taken equal to:

$$c = \frac{p_C}{9,81\,\rho_B B_1 \tan\varphi_B}$$

with $0,55 \leq c \leq 1$

k : Material factor defined in:
- Ch 2, Sec 3, [2.3] for steel
- Ch 2, Sec 3, [3.5] for aluminium alloys

k_0 : Coefficient to be taken equal to:
- $k_0 = 1$ for steel
- $k_0 = 2,35$ for aluminium alloys

n : Navigation coefficient defined in Ch 3, Sec 1, [5.2]

p : Design lateral pressure, in kN/m^2, defined in Ch 5, Sec 1, [2.1]

p_C : Cargo design pressure, in kN/m^2, defined in Ch 5, Sec 1, [2.1]

R_y : Minimum yield stress, in N/mm^2, of the material to be taken equal to:
- $R_y = 235/k$ N/mm^2 for steel
- $R_y = 100/k$ N/mm^2 for aluminium alloys
unless otherwise specified

S : Spacing, in m, of primary supporting members

s : Spacing, in m, of ordinary stiffeners

t : Net thickness, in mm, of plating

w : Net section modulus, in cm^3, of ordinary stiffeners or primary supporting members

β_b, β_s : Span correction coefficients defined in Ch 2, Sec 4, [5.2]

γ_R : Partial safety factor covering uncertainties regarding resistance, defined in Ch 2, Sec 5, [2]

γ_m : Partial safety factor covering uncertainties regarding material, defined in Ch 2, Sec 5, [2]

η : Coefficient taken equal to:

$\eta = 1 - s / (2\,\ell)$

φ_B : Dry bulk cargo angle of repose, in degree

ℓ : Span, in m, of ordinary stiffeners or primary supporting members defined in Ch 2, Sec 4, [4.2] or Ch 2, Sec 4, [5.2]

ρ_B : Dry bulk cargo density, in t/m^3

σ_{X1} : Hull girder normal stress, in N/mm^2, defined in Ch 5, Sec 1, [2.3]

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the scantling and arrangement of longitudinally or transversely framed single and double bottom structures made of steel or aluminium alloys, fitted in the vessel central part.

The requirements applicable to specific vessel notations are defined in Part D.

1.1.2 Buckling strength check

The buckling strength check of plating, stiffeners and primary supporting members is to be performed according to the applicable requirements of Ch 2, Sec 7.

1.2 General arrangement

1.2.1 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 vessel.

1.2.2 The bottom is to be locally stiffened where concentrated loads are envisaged.

1.2.3 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.

1.2.4 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.

1.2.5 Provision is to be made for the free passage of water from all parts of the bottom to the suctions.

1.2.6 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 Vessels having a rise of floor are to be fitted with a keel plate of about 0,1 B in width, with a thickness equal to 1,15 times the bottom plating thickness.

In the case there is no rise of floor, the keel plate thickness is to be not less than the bottom plating thickness.

1.4 Bilge

1.4.1 Radius

Where the bilge plating is rounded, the radius of curvature is not to be less than 20 times the thickness of the plating.

1.4.2 Extension of rounded bilge

The bilge is to extend at least 100 mm on either side of the rounded part.

1.4.3 On tank vessels for oil and/or chemicals, wear plates in form of doubling plates are not permitted to be attached to the bilge plating within the cargo area, i.e. between the aftmost and the foremost cofferdam bulkhead.

1.5 Drainage and openings for air passage

1.5.1 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.

2 Plating scantling

2.1 Plating net thicknesses

2.1.1 In the central part, the bottom and inner bottom plating net thicknesses, in mm, are not to be less than the values t_1 and t_2 given in Tab 1.

2.2 Bilge plating

2.2.1 Rounded bilge plating

The bilge plating net thickness, in mm, is to be not less than the following values:

- in the case of a bilge radius of curvature practically equal to the floor depth or bottom transverse depth:

  $t = 1,15\ t_0$

- in the case of a bilge radius of curvature less than the floor depth or bottom transverse depth but greater than 20 times the bottom plating thickness:

  $t = 1,15\ t_0 + 1$

where $t_0 = \max(t_1; t_2)$ for adjacent bottom plating.

Figure 1 : Square bilge
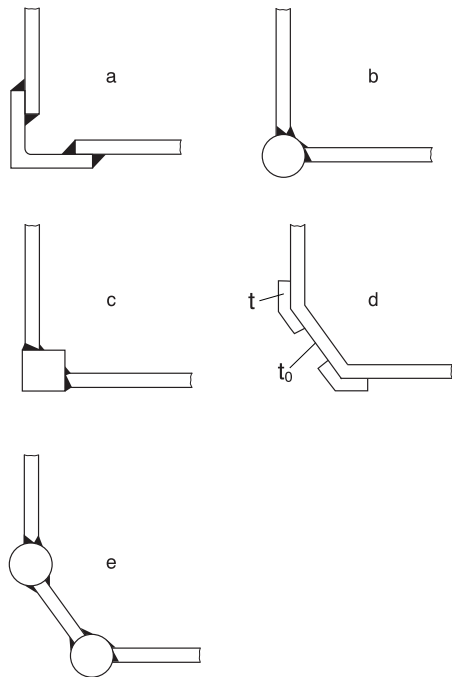
2.2.2 Square bilge plating

In the case of a square bilge with chine bars (sketches a, b, c and e of Fig 1), the net scantling of the chine bar is to be determined as follows:

- angle bars

  The net thickness of the bars plating, in mm, is to be not less than the following formulas, where t_0 is the rule bottom plating net thickness:

  - angle bars inside the hull: $t = t_0 + 2$

  - other cases: $t = t_0 + 3$

- round bars and square bars

  The diameter of the round bars or the side of the square bars is to be not less than 30 mm.

In the case of a double chine without chine bars (sketch d of Fig 1), the thickness of the doublers, in mm, is to be not less than: $t = t_0 + 3$

where t_0 is the adjacent bottom plating thickness, in mm.

3 Structural member scantlings

3.1 Minimum web net thicknesses

3.1.1 Ordinary stiffeners

The net thickness, in mm, of the web of ordinary stiffeners is to be not less than:

- for L < 120 m: $t = 1,63 + 0,004\ L\ (k_0 k)^{0,5} + 4,5\ s$

- for L ≥ 120 m: $t = 3,9\ (k_0 k)^{0,5} + s$

3.1.2 Primary supporting members

The net thickness, in mm, of plating which forms the web of primary supporting members is to be not less than the value obtained from the following formula:

$t = 3,8 + 0,016\ L\ (k_0 k)^{0,5}$

Table 1 : Bottom and inner bottom plating net thicknesses, in mm

Plating	Transverse framing	Longitudinal framing
Bottom	$t_1 = 1,85 + 0,03\, L\, (k_0 k)^{0,5} + 3,6\, s$ $t_2 = 17,2\, C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t_1 = 1,1 + 0,03\, L\, (k_0 k)^{0,5} + 3,6\, s$ $t_2 = 14,9\, C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$
Inner bottom	$t_1 = 1,5 + 0,016\, L\, (k_0 k)^{0,5} + 3,6\, s$ $t_2 = 17,2\, C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t_1 = 1,5 + 0,016\, L\, (k_0 k)^{0,5} + 3,6\, s$ $t_2 = 14,9\, C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$

Note 1:

$$\lambda_L = \sqrt{1 - 0,95\left(\gamma_m \frac{\sigma_{x1}}{R_y}\right)^2} - 0,225\,\gamma_m \frac{\sigma_{x1}}{R_y}$$

$$\lambda_T = 1 - 0,89\,\gamma_m \frac{\sigma_{x1}}{R_y}$$

Note 2: In testing conditions

$$t_2 = 14,9\, C_a C_r s \sqrt{\frac{\gamma_R \gamma_m p}{R_y}}$$

Table 2 : Net scantlings of single bottom structure

Item	w, in cm³	A_{sh}, in cm²
Bottom longitudinals	$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} s\ell^2 10^3$	$A_{sh} = 10\,\gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$
Floors **(1) (2)**	$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m R_y} s\ell^2 10^3$	$A_{sh} = 10\,\gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$
Bottom transverses / reinforced floors **(2)**	$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m R_y} S\ell^2 10^3$	$A_{sh} = 10\,\gamma_R \gamma_m \beta_s \dfrac{p}{R_y} S \ell$
Bottom centre and side girders **(3)**	$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} S\ell^2 10^3$	$A_{sh} = 10\,\gamma_R \gamma_m \beta_s \dfrac{p}{R_y} S \ell$

(1) In way of side ordinary frames: $\beta_b = \beta_s = 1$

(2) Scantlings of floors and bottom transverses are to be at least the same as those of web frames or side transverses connected to them.

(3) The span ℓ is to be taken equal to the web frames / side transverses spacing.

Note 1: The value of σ_{X1} is to be taken in relation with the pressure p considered.

Note 2:

m   : Boundary coefficient, to be taken equal to:
- for bottom longitudinals: m = 12
- for other bottom structural members: m = 8

3.2 Net section modulus and net shear sectional area of structural members

3.2.1 The net scantlings of single and double bottom structural members are not to be less than the values obtained from:
- Tab 2 for single bottom structure
- Tab 3 for double bottom structure,

taking into account the following for double bottom floors and transverses:
- in way of side plate web frames or where the inner side plating extends down to the bottom plating:

  $\ell = B_1$ and $B_3 = 0$
- elsewhere:

if no longitudinal bulkhead is fitted: $\ell = B$ and $B_3 = B_2$

if a longitudinal bulkhead is fitted: $\ell = 0,5B$ and $B_3 = 0,5B_2$

4 Transversely framed single bottom

4.1 Floors

4.1.1 Floors are to be fitted at every frame.

4.1.2 Minimum shear sectional area of floors

The minimum shear sectional area A_{sh} of floors, in cm², is to be not less than the value given in Tab 2, however, the Society may waive this rule subject to direct calculation of the shearing stresses.

Table 3 : Net scantlings of double bottom structure

Item	w, in cm^3	A_{Sh}, in cm^2
Bottom longitudinals Inner bottom longitudinals	$w = \dfrac{\gamma_R\gamma_m\beta_b p}{m(R_y - \gamma_R\gamma_m\sigma_{X1})}s\ell^2 10^3$	$A_{sh} = 10\gamma_R\gamma_m\beta_s\dfrac{p}{R_y}\eta s\ell$
Floors in the way of hold / cargo tank **(1)**	$w = \max(w_1 ; w_2)$ $w_1 = \dfrac{\gamma_R\gamma_m\beta_b p_E}{mR_y}s\ell^2 10^3$ $w_2 = \dfrac{\gamma_R\gamma_m\beta_b(p_{\gamma l} - p_{Em})}{mR_y}s(\ell^2 - 4B_3^2)10^3$	$A_{Sh} = \max(A_1 ; A_2)$ $A_1 = 10\gamma_R\gamma_m\beta_s\dfrac{p_E}{R_y}\eta s\ell$ $A_2 = 10\gamma_R\gamma_m\beta_s\dfrac{(p_{\gamma l} - p_{Em})}{R_y}\eta s(\ell - 2B_3)$
Floors in the way of side tank **(1)**	$w = \max(w_1 ; w_2)$ $w_1 = 4,2\dfrac{\gamma_R\gamma_m\beta_b p_E}{mR_y}sB_2(\ell - B_2)10^3$ $w_2 = 4,2\dfrac{\gamma_R\gamma_m\beta_b(p_{\gamma l} - p_{Em})}{mR_y}sB_2(\ell - 2B_3)10^3$	
Bottom transverses/reinforced floors in the hold / cargo tank	$w = \max(w_1 ; w_2)$ $w_1 = \dfrac{\gamma_R\gamma_m\beta_b p_E}{mR_y}S\ell^2 10^3$ $w_2 = \dfrac{\gamma_R\gamma_m\beta_b(p_{\gamma l} - p_{Em})}{mR_y}S(\ell^2 - 4B_3^2)10^3$	$A_{Sh} = \max(A_1 ; A_2)$ $A_1 = 10\gamma_R\gamma_m\beta_s\dfrac{p_E}{R_y}S\ell$ $A_2 = 10\gamma_R\gamma_m\beta_s\dfrac{(p_{\gamma l} - p_{Em})}{R_y}S(\ell - 2B_3)$
Bottom transverses/reinforced floors in the side tank	$w = \max(w_1 ; w_2)$ $w_1 = 4,2\dfrac{\gamma_R\gamma_m\beta_b p_E}{mR_y}SB_2(\ell - B_2)10^3$ $w_2 = 4,2\dfrac{\gamma_R\gamma_m\beta_b(p_{\gamma l} - p_{Em})}{mR_y}SB_2(\ell - 2B_3)10^3$	
Bottom centre and side girders **(2)**	$w = \dfrac{\gamma_R\gamma_m\beta_b p}{m(R_y - \gamma_R\gamma_m\sigma_{X1})}S\ell^2 10^3$	$A_{sh} = 10\gamma_R\gamma_m\beta_s\dfrac{p}{R_y}S\ell$

(1) In way of side ordinary frames: $\beta_b = \beta_s = 1$

(2) The span ℓ is to be taken equal to the web frames or side transverses spacing.

Note 1: The value of σ_{X1} is to be taken in relation with the pressure p considered.

Note 2:

m : Boundary coefficient, to be taken equal to:
- $m = 12$ for bottom and inner bottom longitudinals
- $m = 8$ for other double bottom structural members.

4.1.3 Floor height

Where the ratio of the floor web height to its net thickness exceeds 100, the floor web is to be provided with stiffeners in compliance with Ch 2, Sec 4, [5.8.1].

In the case of vessels with rise of floor, the floor height may be required to be increased so as to assure a satisfactory connection to the side frames.

4.2 Girders

4.2.1 Centre girder

All single bottom vessels are to have a centre girder. The Society may waive this rule for vessels with B_F less than 6 m, when the floor is a rolled section or when the floor stability is covered otherwise, where B_F is the breadth of the vessel, in m, measured on the top of floor.

The web depth of the centre girder has to extend to the floor plate upper edge. The web thickness is not to be less than that of the floor plates.

Centre girder is to be fitted with a face plate or a flange, the net sectional area of which, in cm^2, is not to be less than:

$A_f = 0,6\,L + 2,7$

4.2.2 Side girders

Depending on the breadth B_F defined in [4.2.1], side girders are to be fitted in compliance with the following:

- $B_F \leq 6$ m: no side girder
- 6 m $< B_F \leq 9$ m: one side girder at each side
- $B_F > 9$ m: two side girders at each side.

Side girders are to be fitted with a face plate or a flange, the net sectional area of which is not to be less than that of the floor plate.

4.2.3 Centre and side girders are to be extended as far aft and forward as practicable.

Intercostal web plates of centre and side girders are to be aligned and welded to floors.

4.2.4 Where two girders are slightly offset, they are to be shifted over a length at least equal to two frame spacings.

4.2.5 Towards the ends, the thickness of the web plate as well as the sectional area of the top plate may be reduced by 10%. Lightening holes are to be avoided.

4.2.6 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.

5 Longitudinally framed single bottom

5.1 Bottom longitudinals

5.1.1 General

Longitudinal ordinary stiffeners are generally to be continuous when crossing primary supporting members.

5.1.2 Strengthening

The section modulus of longitudinals located in way of the web frames of transverse bulkheads is to be increased by 10%.

The Society may call for strengthening of the longitudinal located in the centreline of the vessel.

5.2 Bottom transverses

5.2.1 Spacing

In general, the transverse spacing is to be not greater than 8 frame spacings, nor than 4 m, which is the lesser.

5.2.2 Minimum shear sectional area of bottom transverses

Taking into account the possible cuttings provided for the longitudinals, the minimum shear sectional area A_{sh} of bottom transverses, in cm², is to be not less than the value given in Tab 2, however, the Society may waive this rule subject to direct calculation of the shearing stresses.

5.2.3 Bottom transverse height

Where the ratio of the bottom transverse web height to its net thickness exceeds 100, the bottom transverse web is to be provided with stiffeners in way of longitudinals in compliance with Ch 2, Sec 4, [5.8.1] to Ch 2, Sec 4, [5.8.3], as applicable. The stiffeners are to extend between the longitudinals and the upper faceplate of the transverse, without any connection with that faceplate.

In the case of vessels with rise of floor, the bottom transverse height may be required to be increased so as to assure a satisfactory connection to the side transverses.

5.3 Girders

5.3.1 The requirements in [4.2] apply also to longitudinally framed single bottoms, with transverses instead of floors.

Where the ratio of the girder web height to its net thickness exceeds 100, the girder web is to be provided with stiffeners in compliance with Ch 2, Sec 4, [5.8.1].

6 Transversely framed double bottom

6.1 Double bottom arrangement

6.1.1 Where the height of the double bottom varies in the longitudinal direction, the variation is to be made gradually over an adequate length.

The knuckles of inner bottom plating are to be located in way of plate floors. Where this is impossible, suitable longitudinal structures such as partial girders, longitudinal brackets etc., fitted across the knuckle are to be arranged.

6.1.2 For vessels without a flat bottom, the height of double bottom specified in [6.1.1] may be required to be adequately increased such as to ensure sufficient access to the areas towards the sides.

6.1.3 Strength continuity

Adequate strength continuity of floors is to be ensured in way of the side tank by means of brackets.

6.2 Floors

6.2.1 Spacing

Floors are to be fitted at every frame.

Watertight floors are to be fitted:

- in way of transverse watertight bulkheads
- in way of double bottom steps.

6.2.2 In general, floors are to be continuous.

6.2.3 Minimum shear sectional area of floors

The minimum shear sectional area A_{sh} of floors, in cm², is to be not less than the value given in Tab 3, however, the Society may waive this rule subject to direct calculation of the shearing stresses.

6.2.4 Where the double bottom height does not enable to connect the floors and girders to the inner bottom by fillet welding, slot welding may be used. In that case, the floors and girders are to be fitted with a face plate or a flange.

6.3 Bilge wells

6.3.1 Bilge wells arranged in the double bottom are to be limited in depth and formed by steel plates having a thickness not less than the greater of that required for watertight floors and that required for the inner bottom.

6.3.2 In vessels subject to stability requirements, such bilge wells are to be fitted so that the distance of their bottom from the shell plating is not less than 400 mm.

6.4 Girders

6.4.1 A centre girder is to be fitted on all vessels exceeding 6 m in breadth.

This centre girder is to be formed by a vertical intercostal plate connected to the bottom plating and to double bottom top.

The intercostal centre girder is to extend over the full length of the vessel or over the greatest length consistent with the lines. It is to have the same thickness as the floors. No man-holes are to be provided into the centre girder.

6.4.2 For vessels with a range of navigation **IN(1,2 ≤ x ≤ 2)**, continuous or intercostal girders are to be fitted in the extension of the inner sides. These girders are to have a net thickness equal to that of the inner sides.

For vessels with a range of navigation **IN(x < 1,2)** built in the transverse system and without web frames, partial intercostal girders are to be fitted in way of the transverse bulkheads of the side tanks, in extension of the inner sides. These girders are to be extended at each end by brackets having a length equal to one frame spacing. They are to have a net thickness equal to that of the inner sides.

7 Longitudinally framed double bottom

7.1 General

7.1.1 The requirements in [6.1], [6.3] and [6.4] are applicable to longitudinally framed double bottoms.

7.2 Transverses

7.2.1 The spacing of transverses, in m, is generally to be not greater than 8 frame spacings nor 4 m, whichever is the lesser.

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

Where the ratio of the double bottom transverse web height to its net thickness exceeds 100, the double bottom transverse web is to be provided with stiffeners in way of longitudinals in compliance with Ch 2, Sec 4, [5.8.1] to Ch 2, Sec 4, [5.8.3], as applicable. The stiffeners are to extend between the longitudinals and the upper faceplate of the transverse, without any connection with that faceplate.

7.3 Bottom and inner bottom longitudinal ordinary stiffeners

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

In the case the longitudinals are interrupted in way of a transverse, brackets on both sides of the transverse are to be fitted in perfect alignment.

7.4 Brackets to centreline girder

7.4.1 In general, intermediate brackets are to be fitted connecting the centre girder to the nearest bottom and inner bottom ordinary stiffeners.

7.4.2 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.

SECTION 3   SIDE SCANTLINGS

Symbols

A_{sh} : Net shear sectional area, in cm^2

C_a : Aspect ratio, equal to:

$$C_a = 1,21 \sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell} \le 1$$

C_r : Coefficient of curvature:

$$C_r = 1 - 0,5\frac{s}{r} \ge 0,5$$

where:

     r   :   Radius of curvature, in m

k : Material factor defined in:
- Ch 2, Sec 3, [2.3] for steel
- Ch 2, Sec 3, [3.5] for aluminium alloys

k_0 : Coefficient to be taken equal to:
- $k_0 = 1$ for steel
- $k_0 = 2,35$ for aluminium alloys

n : Navigation coefficient defined in Ch 3, Sec 1, [5.2]

p : Design lateral pressure, in kN/m^2, defined in Ch 5, Sec 1, [2.1]

R_y : Minimum yield stress, in N/mm^2, of the material to be taken equal to:
- $R_y = 235/k$ N/mm^2 for steel
- $R_y = 100/k$ N/mm^2 for aluminium alloys

unless otherwise specified

S : Spacing, in m, of primary supporting members

s : Spacing, in m, of ordinary stiffeners

t : Net thickness, in mm, of plating

w : Net section modulus, in cm^3, of ordinary stiffeners or primary supporting members

z : Z co-ordinate, in m, of the calculation point

β_b, β_s : Span correction coefficients defined in Ch 2, Sec 4, [5.2]

γ_R : Partial safety factor covering uncertainties regarding resistance, defined in Ch 2, Sec 5, [2]

γ_m : Partial safety factor covering uncertainties regarding material, defined in Ch 2, Sec 5, [2]

η : Coefficient taken equal to:

$$\eta = 1 - s / (2 \ell)$$

ℓ : Span, in m, of ordinary stiffeners or primary supporting members, defined in Ch 2, Sec 4, [4.2] or Ch 2, Sec 4, [5.2]

λ_b, λ_s : Coefficients for pressure distribution correction defined in Ch 2, Sec 4, [6.3]

σ_{X1} : Hull girder normal stress, in N/mm^2, defined in Ch 5, Sec 1, [2.3].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the scantling and arrangement of longitudinally or transversely framed single and double side structures made of steel or aluminium alloys, fitted in the vessel central part.

The requirements applicable to specific vessel notations are defined in Part D.

1.1.2 Buckling strength check

The buckling strength check of plating, stiffeners and primary supporting members is to be performed according to the applicable requirements of Ch 2, Sec 7.

1.2 General arrangement

1.2.1 The transversely framed side structures are built with transverse frames possibly supported by struts, side stringers and web frames.

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

2 Plating scantling

2.1 Plating net thicknesses

2.1.1 In the central part, the side and inner side plating net thicknesses, in mm, are not to be less than the values t_1 and t_2 given in Tab 1.

3 Structural member scantlings

3.1 Minimum web net thicknesses

3.1.1 Ordinary stiffeners

The net thickness, in mm, of the web of ordinary stiffeners is to be not less than:
- for $L < 120$ m: $t = 1,63 + 0,004\ L\ (k_0 k)^{0,5} + 4,5\ s$
- for $L \ge 120$ m: $t = 3,9\ (k_0 k)^{0,5} + s$

3.1.2 Primary supporting members

The net thickness, in mm, of plating which forms the web of side and inner side primary supporting members is to be not less than the value obtained from the following formula:

$t = 3,8 + 0,016\ L\ (k_0 k)^{0,5}$

Table 1 : Side and inner side plating net thicknesses, in mm

Plating	Transverse framing	Longitudinal framing
Side	$t_1 = 1{,}68 + 0{,}025\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ $t_2 = 17{,}2\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t_1 = 1{,}25 + 0{,}02\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ $t_2 = 14{,}9\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$
Inner side	$t_1 = 2 + 0{,}003\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ $t_2 = 17{,}2\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t_1 = 2 + 0{,}003\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ $t_2 = 14{,}9\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$

Note 1:

$$\lambda_L = \sqrt{1 - 0{,}95\left(\gamma_m \frac{\sigma_{x1}}{R_y}\right)^2} - 0{,}225\,\gamma_m \frac{\sigma_{x1}}{R_y}$$

$$\lambda_T = 1 - 0{,}89\,\gamma_m \frac{\sigma_{x1}}{R_y}$$

Note 2: In testing conditions

$$t_2 = 14{,}9\,C_a C_r s \sqrt{\frac{\gamma_R \gamma_m p}{R_y}}$$

Table 2 : Net scantlings of single side structure

Item		w, in cm³	A_{sh}, in cm²
Side frames	• if $\ell_0 \le \ell$:	$w = \dfrac{\gamma_R \gamma_m \beta_b s}{m R_y}(6\,\ell\,\ell_0^2 + 1{,}45\,\lambda_W p_F \ell_F^2)10^3$	$A_{sh} = 68\,\gamma_R \gamma_m \beta_s \dfrac{\ell}{R_y}\eta s \ell_0$
	• if $\ell_0 > \ell$:	$w = \dfrac{\gamma_R \gamma_m \beta_b s}{m R_y}(\lambda_b p \ell^2 + 1{,}45\,\lambda_W p_F \ell_F^2)10^3$	$A_{sh} = 10\,\gamma_R \gamma_m \lambda_s \beta_s \dfrac{p}{R_y}\eta s \ell$
Side longitudinals		$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})}s\ell^2 10^3$	$A_{sh} = 10\,\gamma_R \gamma_m \beta_s \dfrac{p}{R_y}\eta s \ell$
Side web frames and side transverses **(1)**	• if $\ell_0 \le \ell$:	$w = k_1 \dfrac{\gamma_R \gamma_m \beta_b \ell}{m R_y}S\ell_0^2 10^3$	$A_{sh} = 68\,\gamma_R \gamma_m \beta_s \dfrac{\ell}{R_y}S\ell_0$
	• if $\ell_0 > \ell$:	$w = k_2 \dfrac{\gamma_R \gamma_m \lambda_b \beta_b p}{m R_y}S\ell^2 10^3$	$A_{sh} = 10\,\gamma_R \gamma_m \lambda_s \beta_s \dfrac{p}{R_y}S\ell$
Side stringers **(2)**		$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})}S\ell^2 10^3$	$A_{sh} = 10\,\gamma_R \gamma_m \beta_s \dfrac{p}{R_y}S\ell$

(1) Scantlings of web frames and side transverses at the lower end are to be the same as those of floors or bottom transverses connected to them.

(2) The span of side stringers is to be taken equal to the side transverses spacing or web frames spacing.

Note 1: The value of σ_{X1} is to be taken in relation with the pressure p considered.

Note 2:

m	:	Boundary coefficient, to be taken, in general, equal to:
		• m = 12 for side ordinary stiffeners
		• m = 8 for side primary supporting members
ℓ_F	:	Floor span, in m
ℓ_0	:	Span parameter, in m, equal to:
		$\ell_0 = p_d / g$
p_d	:	Total pressure, in kN/m², at the lower end of the stiffener
p_F	:	Floor design lateral pressure, in kN/m²
λ_W	:	Coefficient to be taken equal to:
		• in transverse framing: $\lambda_W = 0{,}08$
		• in combination framing: $\lambda_W = 0$
k_1, k_2	:	• For open deck vessels:
		$k_1 = 26$
		$k_2 = 4{,}4$
		• For other vessels:
		$k_1 = 6$
		$k_2 = 1$

Table 3 : Net scantlings of double side hull structure

Item		w, in cm³	A_{sh}, in cm²
Side frames Inner side frames	• if $\ell_0 \le \ell$:	$w = 6\dfrac{\gamma_R \gamma_m \beta_b \ell}{m R_y} s \ell_0^2 10^3$	$A_{sh} = 68 \gamma_R \gamma_m \beta_s \dfrac{\ell}{R_y} \eta s \ell_0$
	• if $\ell_0 > \ell$:	$w = \dfrac{\gamma_R \gamma_m \lambda_b \beta_b p}{m R_y} s \ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \dfrac{p}{R_y} \eta s \ell$
Side and inner side longitudinals		$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} s \ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$
Side and inner side web frames and transverses	• if $\ell_0 \le \ell$:	$w = 6\dfrac{\gamma_R \gamma_m \beta_b \ell}{m R_y} S \ell_0^2 10^3$	$A_{sh} = 68 \gamma_R \gamma_m \beta_s \dfrac{\ell}{R_y} S \ell_0$
	• if $\ell_0 > \ell$:	$w = \dfrac{\gamma_R \gamma_m \lambda_b \beta_b p}{m R_y} S \ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \dfrac{p}{R_y} S \ell$
Plate web frames	• if $\ell_0 \le \ell$:	$w = k_1 \dfrac{\gamma_R \gamma_m \beta_b \ell}{m R_y} S \ell_0^2 10^3$	$A_{sh} = 68 \gamma_R \gamma_m \beta_s \dfrac{\ell}{R_y} S \ell_0$
	• if $\ell_0 > \ell$:	$w = k_2 \dfrac{\gamma_R \gamma_m \lambda_b \beta_b p}{m R_y} S \ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \dfrac{p}{R_y} S \ell$
Side and inner side stringers **(1)**		$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} S \ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} S \ell$

(1) The span of side and inner side stringers is to be taken equal to the side transverses spacing or web frames spacing.

Note 1: The value of σ_{X1} is to be taken in relation with the pressure p considered.

Note 2:

m   :   Boundary coefficient, to be taken, in general, equal to:
- m = 12 for ordinary stiffeners
- m = 8 for primary supporting members

ℓ_0 :   Span parameter, in m

    $\ell_0 = p_d / g$

p_d :   Total pressure, in kN/m², at the lower end of the stiffener

k_1, k_2 :   • For open deck vessels:
    $k_1 = 26$
    $k_2 = 4,4$
- For other vessels:
    $k_1 = 6$
    $k_2 = 1$

Figure 1 : Connection with floors
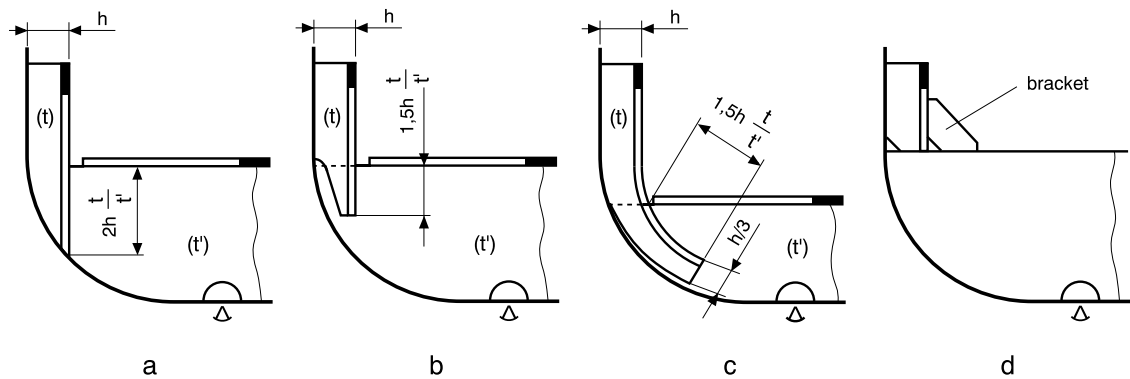
a   b   c   d

3.2 Net section modulus and net shear sectional area of structural members

3.2.1 The net scantlings of single and double side structural members are not to be less than the values obtained from:

- Tab 2 for single side structure
- Tab 3 for double side structure.

4 Transversely framed single side

4.1 Side frames

4.1.1 Transverse frames are to be fitted at every frame.

4.1.2 Continuity
Frames are generally to be continuous when crossing primary supporting members.

Otherwise, the detail of the connection is to be examined by the Society on a case by case basis.

4.1.3 Connection with floors
The frames are to be connected to the floors in accordance with Fig 1, or in an equivalent way.

For overlapping connection as to Fig 1 sketches b and c, a fillet weld run all around has to be provided.

4.1.4 Connection with deck structure
At the upper end of frames, connecting brackets are to be provided in compliance with [8].

On single hull open deck vessels, such brackets are to extend to the hatch coaming.

In the case of longitudinally framed deck, connecting brackets are to extend up to the deck longitudinal most at side and even to:

- the side trunk bulkhead, in the case of a trunk vessel
- the hatch coaming, in other cases.

4.1.5 Reduction on section modulus
When a side stringer is fitted at about mid-span of the frame, the required section modulus of the frame may be reduced by 20%.

4.1.6 Single bottom: connection of frames to bottom longitudinals
In the case of a longitudinally framed single bottom, the side frames are to be connected to the bottom longitudinal most at side, either directly or by means of a bracket, in accordance with Fig 2.

Figure 2 : Connection of frames to bottom longitudinals
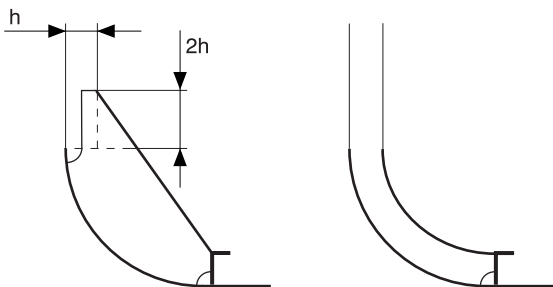
4.2 Side stringers

4.2.1 Arrangement
Side stringers, if fitted, are to be flanged or stiffened by a welded face plate.

The side stringers are to be connected to the frames by welds, either directly or by means of collar plates.

4.3 Web frames

4.3.1 Spacing
Web frames are to be fitted with a spacing, in m, not greater than 5 m.

For a construction on the combination system, side web frames are to be provided in way of bottom transverses.

4.3.2 End connections
Where the web frames are connected to the floors or the strong beams, web frame strength continuity is to be ensured according to Ch 2, Sec 4, [5.6].

4.3.3 End connection in the case of a trunk deck
For vessels fitted with a trunk having a breadth greater than 0,8 B, the web frames determined as laid down before are to extend up to the level of the trunk deck where, as a rule, they are to be connected to strong beams.

5 Longitudinally framed single side

5.1 Side transverses

5.1.1 Spacing
Side transverses are to be fitted:

- in general, with a spacing not greater than 8 frame spacings, nor than 4m
- in way of hatch end beams.

5.1.2 The side transverses are generally directly welded to the shell plating.

In the case of a double bottom, the side transverses are to be bracketed to the bottom transverses.

5.1.3 Minimum shear sectional area
Taking into account the possible cuttings provided for the longitudinals, the minimum shear sectional area of a side transverse, in cm², is to be not less than the value given in Tab 2.

The Society may waive this rule subject to direct calculation of the shearing stresses.

5.2 Side longitudinals

5.2.1 Longitudinal ordinary stiffeners are generally to be continuous when crossing primary supporting members.

In the case the longitudinals are interrupted by a primary supporting member, brackets on both sides of the primary supporting member are to be fitted in perfect alignment.

The section modulus of side longitudinals located in way of the stringers of transverse bulkheads is to be increased by 20%.

6 Transversely framed double side

6.1 General

6.1.1 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.

6.2 Side and inner side frames

6.2.1 Struts

Side frames may be connected to the inner side frames by means of struts having a sectional area not less than those of the connected frames.

Struts are generally to be connected to side and inner side frames by means of vertical brackets or by appropriate weld sections.

Where struts are fitted between side and inner side frames at mid-span, the section modulus of side frames and inner side frames may be reduced by 30%.

6.3 Side and inner side web frames

6.3.1 It is recommended to provide web frames, fitted every 3 m and in general not more than 6 frame spacings apart.

In any case, web frames are to be fitted in way of strong deck beams.

6.3.2 At their upper end, side and inner side web frames are to be connected by means of a bracket. This bracket can be a section or a flanged plate with a section modulus at least equal to that of the web frames.

At mid-span, the web frames are to be connected by means of struts, the cross sectional area of which is not to be less than those of the connected web frames.

At their lower end, the web frames are to be adequately connected to the floors.

7 Longitudinally framed double side

7.1 General

7.1.1 The requirements in [6.1.1] also apply to longitudinally framed double side.

7.2 Side and inner side longitudinal

7.2.1 Struts

Side longitudinal may be connected to the inner side longitudinal by means of struts having a sectional area not less than those of the connected longitudinal.

Struts are generally to be connected to side and inner side longitudinal by means of brackets or by appropriate weld sections.

Where struts are fitted between side and inner side longitudinal at mid-span, the section modulus of side longitudinal and inner side longitudinal may be reduced by 30%.

7.3 Side transverses

7.3.1 The requirements in [6.3] also apply to longitudinally framed double side, with side transverses instead of side web frames.

8 Frame connections

8.1 General

8.1.1 End connections

At their lower end, frames are to be connected to floors, by means of lap weld or by means of brackets.

At the upper end of frames, connecting brackets are to be provided, in compliance with [8.2]. In the case of open deck vessels, such brackets are to extend to the hatch coaming.

Brackets are normally connected to frames by lap welds. The length of overlap is to be not less than the depth of frames.

8.1.2 Brackets

The same minimum value d is required for both arm lengths of straight brackets. Straight brackets may therefore have equal sides.

A curved bracket is to be considered as the largest equal-sided bracket contained in the curved bracket.

8.2 Upper and lower brackets of frames

8.2.1 Arm length

The arm length of upper brackets, connecting frames to deck beams, and the lower brackets, connecting frames to the inner bottom or to the face plate of floors is to be not less than the value obtained, in mm, from the following formula:

$$d = \varphi \sqrt{\frac{w + 30}{t}}$$

where:

t   : Bracket net thickness, in mm, to be taken not less than the stiffener thickness.

w   : Required net section modulus of the stiffener, in cm^3, given in [8.2.2] and depending on the type of connection

φ : Coefficient equal to:
  - for unflanged brackets:
    $\varphi = 50$
  - for flanged brackets:
    $\varphi = 45$

Figure 3 : Connections of perpendicular stiffeners in the same plane
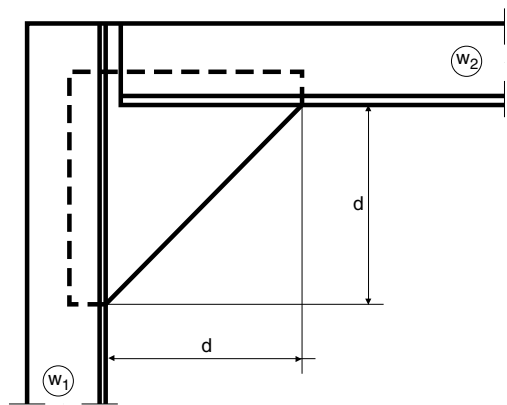
Figure 4 : Connections of stiffeners located in perpendicular planes
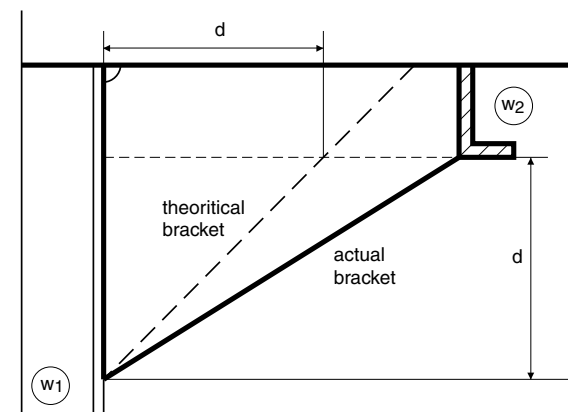
8.2.2 Section modulus of connections

For connections of perpendicular stiffeners located in the same plane (see Fig 3) or connections of stiffeners located in perpendicular planes (see Fig 4), the required 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 3 and Fig 4.

8.2.3 All brackets for which:

$$\frac{\ell_b}{t} > 60$$

where:

t   :   Bracket net thickness, in mm,

ℓ_b :   Length, in mm, of the free edge of the bracket

are to be flanged or stiffened by a welded face plate.

The sectional area, in cm², of the flange or the face plate is to be not less than 0,01 ℓ_b .

The width of the face plate, in mm, is to be not less than 10 t.

9 Side shell openings

9.1 General

9.1.1 Openings in the vessel's 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.

9.2 Local strengthening

9.2.1 Openings are to be compensated if their edge is less than 0,25 D from the bottom or from the deck and if all these openings are located over 0,25L from either end perpendicular.

Compensation is not required for circular openings having a diameter at most equal to 300 mm.

9.2.2 Openings for water intakes are to be well rounded at the corners and, within 0,6L amidships, located outside the bilge strakes. Where arrangements are such that water 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.

9.2.3 Openings in [9.2.1] and [9.2.2] and, when deemed necessary by the Society, other openings of considerable size, are to be compensated by means of insert plates 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.

9.2.4 Circular openings on the sheerstrake need not be compensated where their diameter does not exceed 20% of the sheerstrake minimum width, and where they are located away from openings on deck at the side of hatchways or superstructure ends.

SECTION 4　　　DECK SCANTLINGS

Symbols

A_{sh} : Net shear sectional area, in cm^2

C_a : Aspect ratio, equal to:

$$C_a = 1,21\sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell} \leq 1$$

C_r : Coefficient of curvature:

$$C_r = 1 - 0,5\frac{s}{r} \geq 0,5$$

where:

r : Radius of curvature, in m

D_1 : Unsupported stringer plate length, in m

k : Material factor defined in:

- Ch 2, Sec 3, [2.3] for steel
- Ch 2, Sec 3, [3.5] for aluminium alloys

k_0 : Coefficient to be taken equal to:

- $k_0 = 1$ for steel
- $k_0 = 2,35$ for aluminium alloys

n : Navigation coefficient defined in Ch 3, Sec 1, [5.2]

p : Design lateral pressure, in kN/m^2, defined in Ch 5, Sec 1, [2.1]

R_{eH} : Minimum yield stress, in N/mm^2, of the material, defined in Ch 2, Sec 3, [2]

R_y : Minimum yield stress, in N/mm^2, of the material to be taken equal to:

- $R_y = 235/k$ N/mm^2 for steel
- $R_y = 100/k$ N/mm^2 for aluminium alloys

unless otherwise specified

S : Spacing, in m, of primary supporting members

s : Spacing, in m, of ordinary stiffeners

t : Net thickness, in mm, of plating

w : Net section modulus, in cm^3, of ordinary stiffeners or primary supporting members

z_{hc} : Z co-ordinate, in m, of the top of hatch coaming

β_b , β_s : Span correction coefficients defined in Ch 2, Sec 4, [5.2]

γ_R : Partial safety factor covering uncertainties regarding resistance, defined in Ch 2, Sec 5, [2]

γ_m : Partial safety factor covering uncertainties regarding material, defined in Ch 2, Sec 5, [2]

η : Coefficient taken equal to: $\eta = 1 - s / (2\,\ell)$

λ_b , λ_s : Coefficients for pressure distribution correction defined in Ch 2, Sec 4, [6.3]

ℓ : Span, in m, of ordinary stiffeners or primary supporting members, defined in Ch 2, Sec 4, [4.2] or Ch 2, Sec 4, [5.2]

σ_{X1} : Hull girder normal stress, in N/mm^2, defined in Ch 5, Sec 1, [2.3].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the scantling and arrangement of deck structures made of steel or aluminium alloys, fitted in the vessel central part.

The requirements applicable to specific vessel notations are defined in Part D.

The vessels covered by these Rules may be fitted with:

- open decks, consisting of a stringer plate and a longitudinal hatch coaming (Fig 1)
- flush decks, consisting of a deck continuous over the breadth of the vessel (Fig 2 and Fig 3)
- trunk decks, differing from flush decks solely by the presence of a trunk.

Figure 1 : Open deck
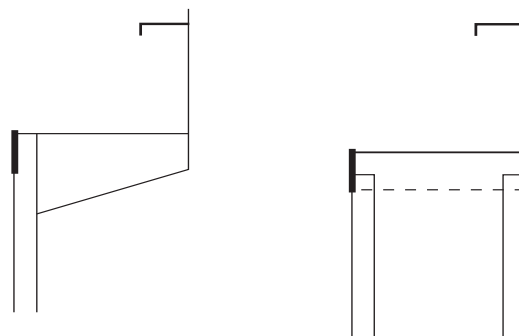
Figure 2 : Transversely framed flush deck
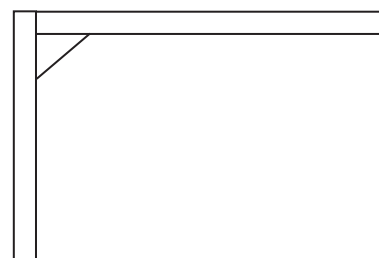
Figure 3 : Longitudinally framed flush deck
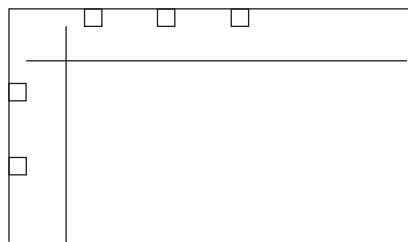
1.1.2 The decks can be longitudinally or transversely framed and may be sustained by pillars, bulkheads or strong beams.

1.1.3 The requirements applicable to specific vessel notations are defined in Part D.

1.1.4 Buckling strength check

The buckling strength check of plating, stiffeners and primary supporting members is to be performed according to the applicable requirements of Ch 2, Sec 7.

1.2 General arrangement

1.2.1 Breaks in the deck of the cargo zone are to be avoided. In any case, the continuity of longitudinal strength is to be ensured at such places.

To ensure continuity in the case of a break, the stringer plate of the lower deck is to:

*   extend beyond the break, over a length at least equal to three times its width

*   stop at a web frame of sufficient scantlings.

Decks which are interrupted are to be tapered on the side by means of horizontal brackets.

1.2.2 Adequate continuity of strength is also to be ensured in way of changes in the framing system.

Details of structural arrangements are to be submitted to the Society for review / approval.

1.2.3 Deck supporting structures under deck machinery, cranes and king posts are to be adequately stiffened.

1.2.4 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 scantlings required by the load carried.

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

1.2.6 Manholes and flush deck plugs

Manholes and flush deck plugs exposed to the weather are to be fitted with steel covers of efficient construction capable of ensuring tightness. These covers are to be fitted with permanent securing device, unless they are secured with closed spaced bolts.

1.2.7 Freeing ports

Arrangements are to be made to ensure rapid evacuation of water on the decks; in particular, where the bulwarks constitute wells on the weather deck, freeing ports of adequate sectional area are to be provided.

1.2.8 Scuppers

Scuppers on the weather deck and terminating outside the hull are to be made of pipes the thickness of which, as a rule, is not to be less than that of the side plating under the sheerstrake but, however needs not exceed 8 mm.

See also Ch 6, Sec 7, [4].

1.2.9 Stringer plate openings

The openings made in the stringer plate other than scupper openings are to be wholly compensated to the satisfaction of the Society.

2 Open deck

2.1 Stringer plate

2.1.1 Width

The stringer plate is to extend between the side shell plating and the hatch coaming. In principle its width, in m, is to be not less than:

* $b = 0,1\ B$ for single hull vessels

* $b = 0,6\ m$ for double hull vessels unless otherwise specified.

The stringer plate width and arrangements are to be so that safe circulation of people is possible.

2.1.2 Stringer plate net thickness

The net thickness of the stringer plate, in mm, is not to be less than the values t_1 and t_2 obtained from Tab 1.

2.1.3 Stringer plate longitudinal stiffeners

The scantling of stringer plate longitudinal stiffeners are to be obtained from Tab 5.

Table 1 : Stringer plate net thickness, in mm

Transverse framing	Longitudinal framing
$t_1 = 2 + 0,02\ L\ (k_0 k)^{0,5} + 3,6\ s$	$t_1 = 2 + 0,02\ L\ (k_0 k)^{0,5} + 3,6\ s$
$t_2 = 17,2 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$

Note 1:

$$\lambda_L = \sqrt{1 - 0,95\left(\gamma_m \frac{\sigma_{x1}}{R_y}\right)^2} - 0,225\gamma_m \frac{\sigma_{x1}}{R_y}$$

$$\lambda_T = 1 - 0,89\gamma_m \frac{\sigma_{x1}}{R_y}$$

Note 2: In testing conditions

$$t_2 = 14,9 C_a C_r s \sqrt{\frac{\gamma_R \gamma_m p}{R_y}}$$

2.1.4 Stringer angle

If a stringer angle is provided, its thickness is to be at least equal to that of the side shell plating plus 1 mm, being not less than that of the stringer plate. This stringer angle is to be continuous on all the hold length.

2.1.5 In vessels having range of navigation **IN(x ≤ 2)**, the Society may require transverse deck plating strips efficiently strengthened and joining the stringer plates of both sides to be fitted.

2.2 Sheerstrake

2.2.1 General

The sheerstrake may be either an inserted side strake welded to the stringer plate or a doubling plate.

2.2.2 Net thickness

The sheerstrake net thickness is not to be less than that of the stringer plate nor than that of the side shell plating.

In addition, this thickness is not to be less than the minimum value, in mm, obtained from following formulae:

$t_1 = 3{,}6 + 0{,}11 \, L \, (k_0 k)^{0,5} + 3{,}6 \, s$

Where a doubling plate is provided instead of an inserted side strake, its thickness, in mm, is not to be less than:

$t_1 = 2{,}6 + 0{,}076 \, L \, (k_0 k)^{0,5} + 3{,}6 \, s$

2.2.3 Width

Where the sheerstrake thickness is greater than that of the adjacent side shell plating, the sheerstrake is to extend over a height b, measured from the deckline, in compliance with the following:

$0{,}08 \, D \le b \le 0{,}15 \, D$

2.3 Hatch coaming

2.3.1 Height

The height of the hatch coaming above the deck, in m, is not to be less than the value obtained from the following formula, where b is the stringer plate width defined in [2.1.1]:

$h_C = 0{,}75 \, b$

Furthermore, the height of the hatch coaming above the deck is to comply with the following:

$z_{hc} \ge T + h_2 + 0{,}15$

2.3.2 Expanded depth

The expanded depth of the underdeck portion of the hatch coaming is to be not less than:

• 0,15 m   for single hull vessels

• 0,25 b for double hull vessels, where b_2 is the stringer plate width, in m.

2.3.3 Stiffening arrangements

The hatch coaming is to be fitted with a longitudinal stiffening member close to the coaming upper edge. Intermediate longitudinals may be required, depending upon the hatch coaming height, to withstand the hull girder loads.

The hatch coaming longitudinal stiffeners are to be protected against tripping and buckling by means of stays fitted above web frames and transverse bulkheads.

The spacing of the stays is not to be greater than that required for web frames or side transverses in accordance with Ch 5, Sec 3, [4.3] or Ch 5, Sec 3, [5.1].

Strength continuity of the stays is to be ensured below the deck, as far as practicable, in way of web frames and bulkheads. Stiffeners are to be provided under the deck where necessary, in way of the intermediate stays and of the transverse boundary stays.

The net moment of inertia (I_{es}) in way of the lower end of the stays with attached plating, in cm⁴, shall be in compliance with the following formula:

$$I_{es} = 13\left(\frac{h_C}{\ell}\right)^3 I_e$$

where:

ℓ : Span of hatch coaming longitudinal stiffener, in m

I_e : Net moment of inertia, in cm⁴, of the upper hatch coaming longitudinal stiffener with attached plating.

2.3.4 Plating scantling

The net thickness of the hatch coaming plating is to be maintained over the length of the hold and is not to be less than t_1 and t_2 given in Tab 2.

When the height of the upper most strake (above the hatch coaming upper most longitudinal stiffener) exceeds 8 times the hatch coaming net thickness, the buckling strength is to be checked in compliance with Ch 2, Sec 7.

Table 2 : Hatch coaming plate net thickness, in mm

Transverse framing	Longitudinal framing
$t_1 = 1{,}6 + 0{,}04 \, L \, (k_0 k)^{0,5} + 3{,}6 \, s$	$t_1 = 1{,}6 + 0{,}04 \, L \, (k_0 k)^{0,5} + 3{,}6 \, s$
$t_2 = 17{,}2 \, C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t_2 = 14{,}9 \, C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$
Note 1:	
$\lambda_L = \sqrt{1 - 0{,}95\left(\gamma_m \dfrac{\sigma_{x1}}{R_y}\right)^2} - 0{,}225 \gamma_m \dfrac{\sigma_{x1}}{R_y}$	
$\lambda_T = 1 - 0{,}89 \gamma_m \dfrac{\sigma_{x1}}{R_y}$	
p : Lateral pressure to be taken equal to 3 kN/m².	

2.4 Transverse strength of topside structure for single hull vessels

2.4.1 General

The topside structure is to be considered as a girder consisting of the stringer plate, the sheerstrake and the hatch coaming, with scantlings according to [2.1], [2.2] and [2.3].

The distributed transverse load, in kN/m, acting on the topside structure is to be taken not less than:

• if $\ell_0 \le \ell$:

$q = 0{,}25 \, (6 \, \ell \, \ell_0 + \lambda_W \, p_F \, \ell_F)$

- if $\ell_0 > \ell$:

  $q = 0,25 \, (\lambda_b \, p \, \ell + \lambda_W \, p_F \, \ell_F)$

where:

ℓ_0 : Span parameter, in m, equal to:

$\ell_0 = p_d \, / \, g$

p_d : Total pressure, in kN/m², at the lower end of the stiffener

ℓ : Side frame span, in m

p : Side frame pressure, in kN/m², defined in Ch 2, Sec 5, [3.1]

p_F : Floor design lateral pressure, in kN/m², defined in Ch 5, Sec 2, Tab 2

ℓ_F : Span of floor connected to the side frame, in m

λ_W : $\lambda_W = 0,08$ in transverse framing system

$\lambda_W = 0$ in combination framing system.

The actual section modulus of the topside structure, in cm³, may be determined by means of the following formula:

$$w = Ab + \frac{tb^2}{60}\left(1 + \frac{A_a - A}{A_a + 0,05\,tb}\right)$$

where:

t : Thickness of stringer plate, in mm

b : Width of stringer plate in, cm

$A = \min(A_1 \, ; \, A_2)$

$A_a = \max(A_1 \, ; \, A_2)$

A_1 : Sheerstrake sectional area, in cm², including a part of the shell plating extending on 0,15 D

A_2 : Hatch coaming sectional area, in cm², including longitudinal stiffeners. The width, in m, of the hatch coaming to be considered is:

$h = h_S + \min(0,75 \, h_C \, ; \, 1)$

h_S : Expanded depth of the underdeck portion of the hatch coaming, in m, defined in [2.3.2]

h_C : Hatch coaming height above deck, in m.

2.4.2 Unsupported stringer plate length

The unsupported stringer plate length D_1, in m, is to be taken as the distance between transverse efficient supports (transverse bulkheads, transverse partial bulkheads, reinforced rings).

2.4.3 Topside structure strength check

The minimum required net section modulus, in cm³, of the topside structure is to be obtained using the formula:

$$Z_{TS} = \frac{q}{mk_1(200/k - \sigma_1)}D_1^2 10^3$$

where:

q : Distributed transverse load, in kN/m, defined in [2.4.1]

D_1 : Length not to be taken greater than 33,3 m

k_1 : Coefficient to be taken equal to:

$$k_1 = 1 + 0,25\left(\frac{D_1}{s} - 1\right)\frac{w}{100D}$$

w : Side frame net section modulus, in cm³

σ_1 : Maximum hull girder normal stress, in N/mm², in the stringer plate.

m : Boundary coefficient, to be taken, in general, equal to:

- $m = 12$ for ordinary stiffeners

- $m = 8$ for primary supporting members

2.4.4 Strong deck box beams

Where the stringer plate is supported by reinforced rings, the net section modulus of the strong deck box beams is to be not less than:

$$w = \frac{\gamma_R \gamma_m p}{m(R_y - \gamma_R \gamma_m \sigma_A)}D_1 \ell^2 10^3$$

where:

p : Deck design load, in kN/m², to be defined by the Designer. In any case, p is not to be taken less than the value derived from formula given under [2.2]

σ_A : Deck box beam axial stress, in N/mm²:

$$\sigma_A = \frac{10qD_1}{A}$$

A : Deck box beam sectional area, in cm²

q : Distributed transverse load, in kN/m, defined in [2.4.1].

m : Boundary coefficient, defined in [2.4.3]

2.5 Cargo hatchways

2.5.1 Position of openings and local strengthening

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 to be cut as far as practicable from hatchway corners.

Stringer plate cut-outs situated in the cargo hold space of open deck vessels are to be strengthened by means of plates having an increased thickness or by means of doubling plates. This is not applicable to scupper openings.

2.5.2 Corners of hatchways

The corners of hatchways are recommended to be rounded.

In any case, continuity is to be ensured by means of brackets and extended girders.

2.5.3 Deck strengthening

The deck plating where the hatchways form corners is to have:

- twice the thickness of the stringer plate over 0,5 L amidships

- the same thickness as the stringer plate over 0,15 L at the ends of the vessel.

As an alternative for small hatch openings, the deck plating may be strengthened by a doubling plate having the same thickness as the stringer plate.

The area of strengthened plating is to extend over twice the actual stringer plate width on either side of the hatch end and, if necessary, beyond the transverse bulkheads of passenger and crew accommodation if the floor of these cabins is not level with the upper deck.

The strengthenings referred to herebefore may be partly or wholly dispensed with if the hatch coamings blend with the longitudinal bulkheads of the accommodation located beyond the hatchway, thus ensuring longitudinal strength continuity in that region.

2.5.4 Hatch coamings arrangement

Where there are cut-outs in the coaming upper part to make way for the hatchway beams, the edges of the cut-outs are to be carefully rounded and a doubling plate or a plate with an increased thickness is to be provided to ensure adequate bearing capability of the hatchway beams.

Longitudinal coamings are to be extended under the deck. In the case of single hull vessels, the longitudinal coaming extension is to be bent under the brackets to which it is connected.

As far as practicable, it is recommended to extend the part of the hatch coaming which is located above the deck and to connect it to the side bulkheads of the accommodation spaces.

At the end of large-size hatchways, strength continuity of the top structure is to be ensured. This is to be arranged by extending the deck girders beyond the hatchways over two frame spacings or over a distance equal to the height of the hatch coaming.

Transverse coamings are to extend below the deck at least to the lower edge of the longitudinal coaming. Transverse coamings not in line with ordinary deck beams below are to extend below the deck up to the next deck girder.

3 Flush deck

3.1 Stringer plate

3.1.1 Net thickness

The stringer plate net thickness, in mm, is to be determined in accordance with Tab 3.

The stringer plate thickness is to be not less than that of the adjacent deck plating.

3.1.2 Width

Where the stringer plate has a thickness greater than that of the deck plating, its width is to be not less than 50 times its thickness.

3.1.3 Stringer angle

Where a stringer angle is fitted, its thickness is not to be less than that of the side shell plating increased by 1 mm nor, as a rule, when the vessel is built on the transverse system, than that of the stringer plate.

3.1.4 If the stringer plate is rounded at side, it is to extend on the side shell plating over a length at least equal to 25 times its thickness, for vessels built on the transverse system.

3.2 Deck plating

3.2.1 Plating net thickness

The deck plating net thickness, in mm, is not to be less than the values t_1 and t_2 given in Tab 3.

Table 3 : Deck plating and stringer plate net thicknesses, in mm

Transverse framing	Longitudinal framing
$t_1 = 0,9 + 0,034\, L\, (k_0 k)^{0,5} + 3,6\, s$	$t_1 = 0,57 + 0,031\, L\, (k_0 k)^{0,5} + 3,6\, s$
$t_2 = 17,2\, C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t_2 = 14,9\, C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$
Note 1: $\lambda_L = \sqrt{1 - 0,95\left(\gamma_m \dfrac{\sigma_{x1}}{R_y}\right)^2} - 0,225\,\gamma_m \dfrac{\sigma_{x1}}{R_y}$ $\qquad \lambda_T = 1 - 0,89\,\gamma_m \dfrac{\sigma_{x1}}{R_y}$ **Note 2:** In testing conditions $t_2 = 14,9\, C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{R_y}}$	

3.3 Sheerstrake

3.3.1 General

The sheerstrake may be either an inserted side strake welded to the stringer plate or a doubling plate.

See also Ch 2, Sec 4, [3.1.2].

3.3.2 Net thickness

The sheerstrake net thickness is not to be less than that of the stringer plate nor than that of the side shell plating.

In addition, this thickness is not to be less than the minimum value, in mm, obtained from following formulae:

$t_1 = 3,6 + 0,11\, L\, (k_0 k)^{0,5} + 3,6\, s$

Where a doubling plate is provided instead of an inserted side strake, its thickness, in mm, is not to be less than:

$t_1 = 2,6 + 0,076\, L\, (k_0 k)^{0,5} + 3,6\, s$

3.3.3 Rounded sheerstrake

In the case of a rounded sheerstrake connecting the side shell to the deck, the radius of curvature of the strake, in mm, is not to be less than 5 times its thickness.

3.3.4 Width

Where the sheerstrake thickness is greater than that of the adjacent side shell plating, the sheerstrake is to extend over a height b, measured from the deckline, in compliance with the following relation:

$0,08\, D \le b \le 0,15\, D$

Where a sheerstrake does not rise above deck, a footguard angle or flat is to be fitted at about 100 mm from the side shell.

The height of the sheerstrake / footguard above the deck is to be at least 50 mm.

3.4 Cargo hatchways

3.4.1 Position of openings and local strengthening

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 to be cut as far as practicable from hatchway corners.

No compensation is required where the openings are:

- circular of less than 350 mm in diameter and at a distance, sufficiently far, from any other opening
- elliptical with the major axis in the longitudinal direction and the ratio of the major to minor axis not less than 2.

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.

3.4.2 Corners of hatchways

Hatchways are to be rounded at their corners. 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.

Strengthening by insert plates in the cargo area are, in general, not required in way of corners where the plating cut-out has an elliptical or parabolic profile and the half axis 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.

3.4.3 Deck strengthening

The deck plating where the hatchways form corners, is to be increased by 60% with respect to the adjacent plates. As an alternative, the deck plating may be strengthened by a doubling plate having the same thickness.

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.

3.4.4 Hatch coamings arrangement

The lower part of longitudinal coamings are to extend to the lower edge of the nearest beams to which they are to be efficiently secured.

In case of girders fitted under deck or under beams in the plane of the coaming longitudinal sides, strength continuity is to be ensured by means of suitable shifting. The same applies in case of strengthened beams in the plane of the coaming transverse boundaries.

Where necessary, the coaming boundaries are to be stiffened with stays.

3.4.5 Very small hatches

The following requirements apply to very small hatchways with a length and width of not more than 1,2 m.

In case of very small hatches, no brackets are required.

Small hatch covers are to have strength equivalent to that required for main hatchways. In any case, weathertightness is to be maintained.

Accesses to cofferdams and ballast tanks are to have manholes fitted with weathertight covers fixed with bolts which are sufficiently closely spaced. Other design configurations may be agreed by the Society case by case basis.

Hatchways of special design are considered by the Society on a case by case basis.

4 Trunk deck

4.1 General

4.1.1 The top structure of a trunk deck vessel is made of:
- sheerstrake
- stringer plate
- trunk, made of longitudinal vertical plating strips and the upper deck (trunk top) to which they are connected.

4.2 Sheerstrake

4.2.1 General

The sheerstrake may be either an inserted side strake welded to the stringer plate or a doubling plate.

See also Ch 2, Sec 4, [3.1.2].

4.2.2 Net thickness

The sheerstrake net thickness is not to be less than that of the stringer plate nor than that of the side shell plating.

Moreover, this thickness is not to be less than the minimum value, in mm, obtained from the following formula:

$$t_1 = 3,6 + 0,11 \, L \, (k_0 k)^{0,5} + 3,6 \, s$$

Where a doubling plate is provided instead of an inserted side strake, its thickness, in mm, is not to be less than:

$$t_1 = 2,6 + 0,076 \, L \, (k_0 k)^{0,5} + 3,6 \, s$$

4.2.3 Rounded sheerstrake

In the case of a rounded sheerstrake connecting the side shell to the deck, the radius of curvature of the strake, in mm, is not to be less than 5 times its thickness.

4.2.4 Width

Where the sheerstrake is thicker than the adjacent side shell plating, the sheerstrake is to extend over a height b_3, measured from the deckline, in compliance with the following relation:

$$0,08 \, D \leq b_3 \leq 0,15 \, D$$

Where a sheerstrake does not rise above deck, a footguard angle or flat is to be fitted at about 100 mm from the side shell.

The height of the sheerstrake/footguard above the deck is to be at least 50 mm.

4.3 Stringer plate

4.3.1 Net thickness

The stringer plate net thickness, in mm, is to be determined in accordance with Tab 4.

4.3.2 Width

The stringer plate is to extend between the side shell and the trunk. Its width and arrangements are to be so that safe circulation of people is possible.

4.3.3 Stringer angle

Where a stringer angle is fitted, its thickness is not to be less than that of the side shell plating increased by 1 mm nor, as a rule, when the vessel is built on the transverse system, than that of the stringer plate.

4.3.4 If the stringer plate is rounded at side, it is to extend on the side shell plating over a length at least equal to 25 times its thickness, for vessels built on the transverse system.

4.4 Trunk

4.4.1 Trunk plating net thickness

The plating net thicknesses of the trunk longitudinal bulkhead and trunk deck are not to be less than t_1 and t_2 given in Tab 4.

Table 4 : Plating net thickness, in mm

Transverse framing	Longitudinal framing
$t_1 = 0,9 + 0,034 L (k_0 k)^{0,5} + 3,6 s$	$t_1 = 0,57 + 0,031 L (k_0 k)^{0,5} + 3,6 s$
$t_2 = 17,2 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$
Note 1: $\lambda_L = \sqrt{1 - 0,95\left(\gamma_m \dfrac{\sigma_{x1}}{R_y}\right)^2} - 0,225 \gamma_m \dfrac{\sigma_{x1}}{R_y}$ $\quad$ $\lambda_T = 1 - 0,89 \gamma_m \dfrac{\sigma_{x1}}{R_y}$ **Note 2:** In testing conditions $t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{R_y}}$	

5 Top structure supporting members

5.1 General

5.1.1 The top structure supporting members consist of ordinary stiffeners (beams or longitudinals), longitudinally or transversely arranged, supported by primary supporting members which may be sustained by pillars.

5.2 Minimum net thickness of web plating

5.2.1 Ordinary stiffeners

The net thickness, in mm, of the web of ordinary stiffeners is to be not less than:

- for L < 120 m: $t = 1,63 + 0,004 L (k_0 k)^{0,5} + 4,5 s$

- for L ≥ 120 m: $t = 3,9 (k_0 k)^{0,5} + s$

5.2.2 Primary supporting members

The net thickness, in mm, of plating which forms the web of primary supporting members is to be not less than the value obtained from the following formula:

$t = 3,8 + 0,016 L (k_0 k)^{0,5}$

5.3 Net scantlings of structural members

5.3.1 Net section modulus and net shear sectional area

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of top structure structural members in service conditions are to be obtained from Tab 5.

5.4 Arrangement of hatch supporting structure

5.4.1 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.

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

5.4.3 The details of connection of deck transverses to longitudinal girders and web frames are to be submitted to the Society.

5.5 Coaming of separate hatchways

5.5.1 Height

The coaming upper edge is not to be less than 300 mm above the deck.

Furthermore, the height of the hatch coaming, h_C, above the deck is to comply with the following:

$z_C \geq T + h_2 + 0,15$

5.5.2 Net thickness

The net thickness of the coaming boundaries is not to be less than:

$t = 0,25 \, a + 3 \leq 5$ mm,

a being the greater dimension of the hatchway, in m.

The Society reserves the right to increase the scantlings required here before where range of navigation **IN(1,2 ≤ x ≤ 2)** is assigned.

Table 5 : Net scantlings of top structure supporting members

Item	w, in cm^3	A$_{Sh}$, in cm^2
Deck beams	$w = \dfrac{\gamma_R\gamma_m\beta_b p}{mR_y}s\ell^2 10^3$	$A_{Sh} = 10\gamma_R\gamma_m\beta_s\dfrac{p}{R_y}\eta s\ell$
Trunk vertical stiffeners **(1)**	$w = \dfrac{\gamma_R\gamma_m\lambda_b\beta_b p}{mR_y}s\ell^2 10^3$	$A_{Sh} = 10\gamma_R\gamma_m\lambda_s\beta_s\dfrac{p}{R_y}\eta s\ell$
Deck longitudinals Stringer plate longitudinals Trunk longitudinals Hatch coaming longitudinals	$w = \dfrac{\gamma_R\gamma_m\beta_b p}{m(R_y-\gamma_R\gamma_m\sigma_{X1})}s\ell^2 10^3$	$A_{Sh} = 10\gamma_R\gamma_m\beta_s\dfrac{p}{R_y}\eta s\ell$
Deck transverses Reinforced deck beams Trunk web frames **(2)**	$w = \dfrac{\gamma_R\gamma_m\beta_b p}{mR_y}S\ell^2 10^3$	$A_{Sh} = 10\gamma_R\gamma_m\beta_s\dfrac{p}{R_y}S\ell$
Deck girders	$w = \dfrac{\gamma_R\gamma_m\beta_b p}{m(R_y-\gamma_R\gamma_m\sigma_{X1})}S\ell^2 10^3$	$A_{Sh} = 10\gamma_R\gamma_m\beta_s\dfrac{p}{R_y}S\ell$

(1) Scantlings of trunk vertical stiffeners are not to be less than those of deck beams connected to them

(2) Scantlings of trunk web frames are not to be less than those of deck transverses connected to them.

Note 1:

m : Boundary coefficient, to be taken, in general, equal to:
- m = 12 for ordinary stiffeners
- m = 8 for primary supporting members.

5.5.3 Stiffening

The coaming boundaries are to be stiffened with an horizontal stiffening member close to the coaming upper edge. In the case the coaming is higher than 750 mm, a second stiffener is to be fitted at about 0,75 times the hatch coaming height.

The coaming boundaries are to be stiffened with stays, the ends of which are to be connected to the deck and to the upper horizontal stiffeners.

Where necessary, stiffeners are to be provided under deck in way of the stays.

5.5.4 Strength continuity

Arrangements are to be made to ensure strength continuity of the top structure, at the end of large-size hatchways, mainly by extending the deck girders along the hatchway, beyond the hatchways, up to the end bulkhead or over two frame spacings, whichever is greater.

6 Transversely framed deck

6.1 Deck beams

6.1.1 General

In general, deck beams or deck half-beams are to be fitted at each frame.

6.1.2 Open deck vessels

In the hatchway region, it is recommended to replace the half-beams by brackets, extending to the hatch coaming, as shown on Fig 1.

6.2 Reinforced deck beams

6.2.1 Reinforced deck beams are to be fitted in way of side webs.

6.3 Deck girders

6.3.1 Where deck beams are fitted in a hatched deck, they are to be effectively supported by longitudinal girders located in way of hatch side girders to which they are to be connected by brackets and/or clips.

6.3.2 Deck girders subjected to concentrated loads are to be adequately strengthened.

6.3.3 Deck girders are to be fitted with tripping stiffeners or brackets:

- spaced not more than 20 times the girder faceplate width

- in way of concentrated loads and pillars.

6.3.4 Where a deck girder comprises several spans and its scantlings vary from one span to another, the connection of two different parts is to be effected gradually by strengthening the weaker part over a length which, as a rule, is to be equal to 25% of its length.

6.3.5 The connection of girders to the supports is to ensure correct stress transmission. In particular, connection to the bulkheads is to be obtained by means of flanged brackets having a depth equal to twice that of the deck girder and the thickness of the girder, or by any equivalent method.

7 Longitudinally framed deck

7.1 Deck longitudinals

7.1.1 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.

The section modulus of deck longitudinals located in way of the web frames of transverse bulkheads is to be increased by 20%.

7.1.2 Frame brackets, in vessels with transversely framed sides, are generally to have their horizontal arm extended to the adjacent longitudinal ordinary stiffener.

7.2 Deck transverses

7.2.1 In general, the spacing of deck transverses is not to exceed 8 frame spacings or 4 m, whichever is the lesser.

7.2.2 Where applicable, deck transverses of reinforced scantlings are to be aligned with bottom transverses.

7.2.3 Deck and trunk deck transverses

The section modulus of transverse parts in way of the stringer plate and of the trunk sides is not to be less than the rule value obtained by determining them as deck transverses or as side shell transverses, whichever is greater.

8 Pillars

8.1 General

8.1.1 Pillars or other supporting structures are generally to be fitted under heavy concentrated loads.

8.1.2 Structural members at heads and heels of pillars as well as substructures are to be constructed according to the forces they are subjected to, taking into account the requirement of Ch 8, Sec 2, [3.7].

Where pillars are affected by tension loads doublings are not permitted.

8.1.3 Pillars in tanks are to be checked for tension. Tubular pillars are not permitted in tanks for flammable liquids.

8.1.4 Pillars are to be fitted, as far as practicable, in the same vertical line.

8.2 Buckling check

8.2.1 The buckling strength check of pillars is to be carried out according to Ch 2, Sec 7, [6].

8.3 Connections

8.3.1 Pillars are to be attached at their heads and heels by continuous welding.

8.3.2 Pillars working under pressure may be fitted by welds only, in the case the thickness of the attached plating is at least equal to the thickness of the pillar.

Where the thickness of the attached plating is smaller than the thickness of the pillar, a doubling plate is to be fitted.

8.3.3 Heads and heels of pillars which may also work under tension (such as those in tanks) are to be attached to the surrounding structure by means of brackets or insert plates so that the loads are well distributed.

8.3.4 Pillars are to be connected to the inner bottom, where fitted, at the intersection of girders and floors.

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.

8.3.5 Manholes and lightening holes may not be cut in the girders and floors below the heels of pillars.

8.3.6 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.

9 Hatch supporting structures

9.1 General

9.1.1 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.

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

9.1.3 The details of connection of deck transverses to longitudinal girders and web frames are to be submitted to the Society for approval.

SECTION 5   BULKHEAD SCANTLINGS

Symbols

A_{sh} : Net shear sectional area, in cm^2

C_a : Aspect ratio, equal to:

$$C_a = 1,21\sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell} \leq 1$$

C_r : Coefficient of curvature:

$$C_r = 1 - 0,5\frac{s}{r} \geq 0,5$$

where:

r : Radius of curvature, in m

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

- for steels in general: $E = 2,06 \cdot 10^5$ N/mm^2
- for stainless steels: $E = 1,95 \cdot 10^5$ N/mm^2
- for aluminium alloys: $E = 7,0 \cdot 10^4$ N/mm^2

k : Material factor defined in:

- Ch 2, Sec 3, [2.3] for steel
- Ch 2, Sec 3, [3.5] for aluminium alloys

k_0 : Coefficient to be taken equal to:

- $k_0 = 1$ for steel
- $k_0 = 2,35$ for aluminium alloys

l : Span, in m, of ordinary stiffeners or primary supporting members

p : Design lateral pressure, in kN/m^2, defined in Ch 5, Sec 1, [2.1]

R_y : Minimum yield stress, in N/mm^2, of the material to be taken equal to:

- $R_y = 235/k$ N/mm^2 for steel
- $R_y = 100/k$ N/mm^2 for aluminium alloys

unless otherwise specified

S : Spacing, in m, of primary supporting members

s : Spacing, in m, of ordinary stiffeners

t : Net thickness, in mm, of plating

w : Net section modulus, in cm^3, of ordinary stiffeners or primary supporting members

β_b, β_s : Span correction coefficients defined in Ch 2, Sec 4, [5.2]

γ_m : Partial safety factor covering uncertainties regarding material, defined in Ch 2, Sec 5, [2]

γ_R : Partial safety factor covering uncertainties regarding resistance, defined in Ch 2, Sec 5, [2]

η : Coefficient taken equal to: $\eta = 1 - s / (2\ l)$

λ_b, λ_s : Coefficients for pressure distribution correction defined in Ch 2, Sec 4, [6.3]

σ_{X1} : Hull girder normal stress, in N/mm^2, defined in Ch 5, Sec 1, [2.3].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the scantling and arrangement of transverse or longitudinal bulkhead structures made of steel or aluminium alloys. The bulkheads may be plane or corrugated.

The requirements applicable to specific vessel notations are defined in Part D.

1.1.2 Buckling strength check

The buckling strength check of plating, stiffeners and primary supporting members is to be performed according to the applicable requirements of Ch 2, Sec 7.

1.2 General arrangement

1.2.1 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.

2 Plating scantling

2.1 Plating net thicknesses

2.1.1 The bulkhead plating net thickness, in mm, is not to be less than the values t_1 and t_2 given in Tab 1.

3 Structural member scantlings

3.1 Minimum web net thicknesses

3.1.1 Ordinary stiffeners

The net thickness, in mm, of the web plating of ordinary stiffeners is to be not less than:

$t = 1,1 + 0,0048\ L\ (k_0 k)^{0,5} + 4,8\ s$

Table 1 : Bulkhead plating net thickness t

Bulkheads		t, in mm
Transverse	Collision bulkhead	$t_1 = 0{,}026\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ $t_2 = 14{,}9\,C_a C_r s\sqrt{\dfrac{\gamma_R \gamma_m p_T}{R_y}}$
	Watertight bulkhead and hold bulkhead	$t_1 = 0{,}026\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ $t_2 = 14{,}9\,C_a C_r s\sqrt{\dfrac{\gamma_R \gamma_m p_T}{R_y}}$
	Tank bulkhead	$t_1 = 2 + 0{,}003\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ with $t_1 \geq 4{,}4$ $t_2 = 14{,}9\,C_a C_r s\sqrt{\dfrac{\gamma_R \gamma_m p_T}{R_y}}$
	Wash bulkhead	$t_1 = 2 + 0{,}003\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ with $t_1 \geq 4{,}4$
Longitudinal	Watertight bulkhead	$t_1 = 2 + 0{,}003\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ • vertical stiffening: $\quad t_2 = 17{,}2\,C_a C_r s\sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$ • longitudinal stiffening: $\quad t_2 = 14{,}9\,C_a C_r s\sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$
	Tank bulkhead	$t_1 = 2 + 0{,}003\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ with $t_1 \geq 4{,}4$ • vertical stiffening: $\quad t_2 = 17{,}2\,C_a C_r s\sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$ • longitudinal stiffening: $\quad t_2 = 14{,}9\,C_a C_r s\sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$
	Wash bulkhead	$t_1 = 2 + 0{,}003\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ with $t_1 \geq 4{,}4$

Note 1:

$$\lambda_L = \sqrt{1 - 0{,}95\left(\gamma_m \frac{\sigma_{x1}}{R_y}\right)^2} - 0{,}225\,\gamma_m \frac{\sigma_{x1}}{R_y}$$

$$\lambda_T = 1 - 0{,}89\,\gamma_m \frac{\sigma_{x1}}{R_y}$$

Note 2:
P_T : Lateral pressure, in kN/m², in testing conditions, defined in Ch 5, Sec 2, [3.2.1]

Note 3: In testing conditions

$$t_2 = 14{,}9\,C_a C_r s\sqrt{\dfrac{\gamma_R \gamma_m p}{R_y}}$$

3.1.2 Primary supporting members

The net thickness, in mm, of plating which forms the web of bulkhead primary supporting members is to be not less than the values obtained from the following formulae:

- for collision bulkhead:

  $t = 4{,}4 + 0{,}018\,L\,(k_0 k)^{0,5}$

- otherwise:

  - $t = 3{,}8 + 0{,}016\,L\,(k_0 k)^{0,5}$

3.2 Net section modulus and net sectional area of structural members

3.2.1 The net scantlings of bulkhead structural members are not to be less than the values obtained from Tab 2.

4 Bulkhead arrangements

4.1 General arrangement

4.1.1 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.

4.1.2 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.

Table 2 : Net scantlings of bulkhead structure

Item		w, in cm³	A_{sh}, in cm²
Transverse bulkhead	Vertical stiffeners	$w = \dfrac{\gamma_R \gamma_m \lambda_b \beta_b p}{m R_y} s\ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \dfrac{p}{R_y} \eta s\ell$
	Transverse stiffeners	$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m R_y} s\ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s\ell$
	Web frames, transverses	$w = \dfrac{\gamma_R \gamma_m \lambda_b \beta_b p}{m R_y} S\ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \dfrac{p}{R_y} S\ell$
Longitudinal bulkhead	Vertical stiffeners	$w = \dfrac{\gamma_R \gamma_m \lambda_b \beta_b p}{m R_y} s\ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \dfrac{p}{R_y} \eta s\ell$
	Longitudinal stiffeners	$w = \beta_b \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} s\ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s\ell$
	Web frames	$w = \dfrac{\gamma_R \gamma_m \lambda_b \beta_b p}{m R_y} S\ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \dfrac{p}{R_y} S\ell$
	Stringers	$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} S\ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} S\ell$

Note 1:

m : Boundary coefficient, to be taken, in general, equal to:
- m = 12 for ordinary stiffeners
- m = 8   for primary supporting members.
- m = 10.6 for the stiffeners which are fixed at one end and simply supported/sniped at the other end

Note 2: The value of σ_{X1} is to be taken in relation with the pressure p considered.

4.1.3 The structural continuity of the bulkhead vertical and horizontal primary supporting members with the surrounding supporting structures is to be carefully ensured.

4.1.4 The height of vertical primary supporting members of longitudinal bulkheads may be gradually tapered from bottom to deck.

Requirements in Ch 5, Sec 3, [6.3] or Ch 5, Sec 3, [7.3] are to be complied with too.

5 Plane bulkheads

5.1 General

5.1.1 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.

5.1.2 Bulkheads are to be stiffened in way of deck girders.

5.1.3 The stiffener webs of side tank watertight bulkheads are generally to be aligned with the webs of inner hull longitudinal stiffeners.

5.1.4 Floors are to be fitted in the double bottom in way of plane transverse bulkheads.

5.1.5 In way of the sterntube, the thickness of the after peak bulkhead plating is to be increased by 60%.

Instead of the thickness increase required herebefore, a doubling plate of the same thickness as the bulkhead plating may be fitted.

5.2 Bulkhead stiffeners

5.2.1 As a rule, stiffeners are to be fitted in way of structural components likely to exert concentrated loads, such as deck girders and pillars, and for engine room end bulkheads, at the ends of the engine seatings.

5.2.2 On vertically framed watertight bulkheads, where stiffeners are interrupted in way of the watertight doors, stanchions are to be fitted on either side of the door, carlings are to be fitted to support the interrupted stiffeners.

5.3 End connections

5.3.1 In general, end connections of ordinary stiffeners are to be welded directly to the plating or bracketed. However, stiffeners may be sniped, provided the scantlings of such stiffeners are modified accordingly.

Sniped ends may be accepted where the hull lines make it mandatory in the following cases:

- liquid compartment boundaries
- collision bulkhead.

5.3.2 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.

Moreover, the thickness of the bulkhead plating supported by the stiffener is to be in compliance with Ch 2, Sec 4, [4.5.3].

5.4 Bracketed ordinary stiffeners

5.4.1 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:

  $b = 80\sqrt{\dfrac{w+20}{t}}$

  $b = \alpha\dfrac{ps\ell}{t}$

where:

ℓ : Span, in m, of the stiffener measured between supports

w : Net section modulus, in cm³, of the stiffener

t : Net thickness, in mm, of the bracket

p : Design pressure, in kN/m², calculated at mid-span

α : $\alpha = 4,9$ for tank bulkheads

$\alpha = 3,6$ for watertight bulkheads.

Figure 1 : Bracket at upper end of ordinary stiffener on plane bulkhead
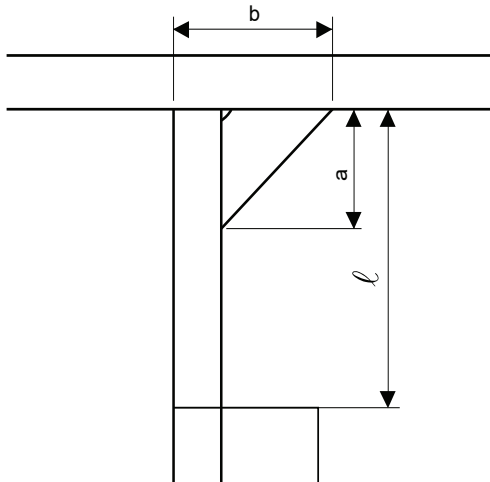
5.4.2 The connection between the stiffener and the bracket is to be such that the section modulus of the connection is not less than that of the stiffener.

The brackets are to extend up to the next stiffener where the framing is transverse, or connect the stiffener to a longitudinal stiffener where the framing is longitudinal.

Figure 2 : Bracket at lower end of ordinary stiffener on plane bulkhead
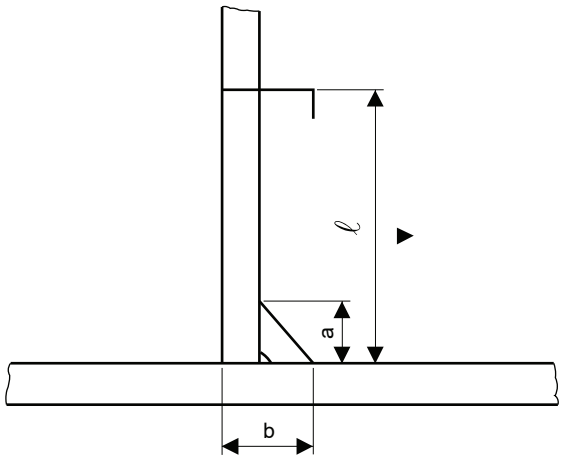
6 Corrugated bulkheads

6.1 General

6.1.1 The main dimensions a, b, c and d of corrugated bulkheads are defined in Fig 3.

6.1.2 Unless otherwise specified, the following requirement is to be complied with:

$a \le 1,2d$

Moreover, in some cases, the Society may prescribe an upper limit for the ratio b/t.

Figure 3 : Corrugated bulkhead
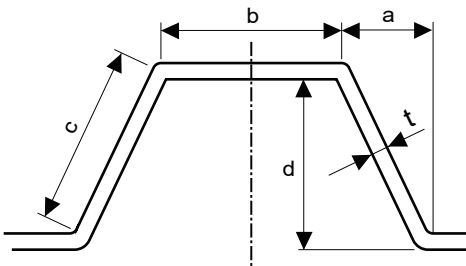
6.1.3 In general, the bending internal radius R_i is to be not less than the following values, in mm:

- for normal strength steel:

  $R_i = 2,5\,t$

- for high tensile steel:

  $R_i = 3,0\,t$

where t is the gross thickness, in mm, of the corrugated plate.

6.1.4 When butt 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.

6.1.5 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.

6.1.6 In general, where girders or vertical primary supporting members are fitted on corrugated bulkheads, they are to be arranged symmetrically.

6.2 Bulkhead scantlings

6.2.1 Bulkhead plating

The bulkhead plating net thickness is to be determined as specified in [3], substituting the stiffener spacing by the greater of the two values b and c, in m, as per [6.1.1].

6.2.2 Corrugations

The section modulus of a corrugation is to be not less than that of the equivalent stiffener having the same span as the corrugation and an attached plating width equal to (b + a).

The actual section modulus of a corrugation is to be obtained according to Ch 2, Sec 4, [4.4.2].

Moreover, where the ratio b / t ≥ 46, the net section modulus required for a bulkhead is to be in accordance with the following formula:

$$w = 206\,c_k\left(\frac{b+a}{E}\right)p\left(\frac{\ell b}{80t}\right)^2$$

where:

c_k : Coefficient defined in Tab 3

p : Bulkhead design pressure, in kN/m², calculated at mid-span.

Table 3 : Values of coefficient c_k

Boundary conditions	Collision bulkhead	Watertight bulkhead	Cargo hold bulkhead
simply supported	1,73	1,38	1,04
simply supported (at one end)	1,53	1,20	0,92
clamped	1,15	0,92	0,69

6.2.3 Stringers and web frames

It is recommended to fit stringers or web frames symmetrically with respect to the bulkhead. In all cases, their section modulus is to be determined in the same way as for a plane bulkhead stringer or web frame.

6.3 Structural arrangement

6.3.1 The strength continuity of corrugated bulkheads is to be ensured at ends of corrugations.

6.3.2 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.

6.3.3 In general, where vertically corrugated transverse bulkheads are welded on the inner bottom, 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.

6.3.4 Where stools are fitted at the lower part of transverse bulkheads, the thickness of adjacent plate floors is to be not less than that of the stool plating.

6.3.5 In general, where vertically corrugated longitudinal bulkheads are welded on the inner bottom, girders are to be fitted in double bottom in way of the flanges of corrugations.

However, other arrangements ensuring adequate structural continuity may be accepted by the Society.

6.3.6 In general, the upper and lower parts of horizontally corrugated bulkheads are to be flat over a depth equal to 0,1 D.

6.4 Bulkhead stool

6.4.1 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.

6.4.2 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.

6.4.3 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 thickness and yield stress as those of the lower strake of the bulkhead.

7 Hold bulkheads of open deck vessels

7.1 Special arrangements

7.1.1 The upper end of vertical stiffeners is to be connected either to a box beam or a stringer located at the stringer plate level or above.

7.1.2 As far as practicable, the bottom of the box beam or the bulkhead end stringer is to be located in the same plane as the stringer plate.

Where this is not the case, the bulkhead plating or the box beam sides are to be fitted with an efficient horizontal framing at that level.

7.1.3 The upper part of horizontally framed bulkheads are to be subject of a special review by the Society.

8 Non-tight bulkheads

8.1 General

8.1.1 Definition

A bulkhead is considered to be acting as a pillar when besides the lateral loads, axial loads are added.

8.2 Non-tight bulkheads not acting as pillars

8.2.1 Non-tight bulkheads not acting as pillars are to be provided with vertical stiffeners with a maximum spacing equal to:

- for transverse bulkheads: 0,9 m

- for longitudinal bulkheads: 2-frame spacings with a maximum of 1,5 m.

8.3 Non-tight bulkheads acting as pillars

8.3.1 Non-tight bulkheads acting as pillars are to be provided with vertical stiffeners with a maximum spacing equal to:

- 2-frame spacing, when the frame spacing does not exceed 0,75 m

- 1-frame spacing, when the frame spacing is greater than 0,75 m.

8.3.2 Each vertical stiffener, in association with a width of plating equal to 35 times the plating thickness, is to comply with the applicable requirements for pillars in Ch 5, Sec 4, [8], the load supported being determined in accordance with the same requirements.

8.3.3 In the case of non-tight bulkheads supporting longitudinally framed decks, web frames are to be provided in way of deck transverses.

9 Wash bulkheads

9.1 General

9.1.1 The requirements in [8.2] apply to transverse and longitudinal wash bulkheads whose main purpose is to reduce the liquid motions in partly filled tanks.

9.2 Openings

9.2.1 The total area of openings in a transverse wash bulkhead is generally to be less than 10% 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 4.

9.2.2 In any case, the distribution of openings is to fulfill the strength requirements specified in [8.3].

9.2.3 In general, large openings may not be cut within 0,15 D from bottom and from deck.

Table 4 : Areas of openings in transverse wash bulkheads

Bulkhead portion	Lower limit	Upper limit
Upper	10%	15%
Central	10%	50%
Lower	2%	10%

SECTION 6 — ALTERNATIVE REQUIREMENTS APPLICABLE TO VESSELS WITH LENGTH L < 40 M - METALLIC HULLS

Symbols

A_{sh} : Net web sectional area, in cm².

C_a : Aspect ratio, equal to:

$$C_a = 1,21 \sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell} \leq 1$$

C_r : Coefficient of curvature, equal to:

$$C_r = 1 - 0,5\frac{s}{r} \geq 0,5$$

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

k : Material factor defined in:

- for steel:

  Ch 2, Sec 3, [2.3]

- for aluminium alloys:

  Ch 2, Sec 3, [3.5]

k_0 : Coefficient to be taken equal to:

- for steel:

  $k_0 = 1$

- for aluminium alloys:

  $k_0 = 2,35$

n : Navigation coefficient defined in Ch 3, Sec 1, [5.2]

p : Design lateral pressure, in kN/m², defined in Ch 5, Sec 1, [2.1]

R_y : Minimum yield stress, in N/mm², of the material to be taken equal to:

- for steel:

  $R_y = 235/k$ N/mm²

- for aluminium alloys

  $R_y = 100/k$ N/mm²

  unless otherwise specified

R_{eH} : • for hull structural steels:

  R_{eH} is the nominal yield point, in N/mm²

- for aluminium alloys:

  R_{eH} is 0,2% proof stress, in N/mm²

r : Radius of curvature, in m

S : Spacing, in m, of primary supporting members

s : Spacing, in m, of ordinary stiffeners

t : Net thickness, in mm, of plating

w : Net section modulus, in cm³, of ordinary stiffeners or primary supporting members

β_b, β_s : Span correction coefficients defined in Ch 2, Sec 4, [5.2]

γ_R : Partial safety factor covering uncertainties regarding resistance, defined in Ch 2, Sec 5, [2]

γ_m : Partial safety factor covering uncertainties regarding material, defined in Ch 2, Sec 5, [2]

η : Coefficient taken equal to:

  $\eta = 1 - s / (2 l)$

ℓ : Span, in m, of ordinary stiffeners or primary supporting members.

1 General

1.1 Application

1.1.1 As an alternative to the provisions of Ch 5, Sec 2 to Ch 5, Sec 5, this Section contains the requirements for the determination of the hull scantlings applicable to the central part of all types of vessels with length L < 40 m, of normal design and dimensions, made of steel or aluminium alloys.

Cargo carriers covered by these requirements have their machinery aft and are assumed to be loaded and unloaded in two runs.

1.1.2 Arrangement and scantlings not covered by this Section are to be as specified in Ch 5, Sec 2 to Ch 5, Sec 5.

Table 1 : Values of coefficient K_M

Range of navigation	Vessel type	Bottom and inner bottom plating	Top plating	Stiffeners
IN	Self-propelled cargo carriers and passenger vessels	1,08	1,056	1,08
	Non-propelled cargo carriers	1,0	1,0	1,0
	Other vessels	1,2	1,5	1,5
IN(x ≤ 2)	Self-propelled cargo carriers and passenger vessels	0,83 + 3,6 n	0,88 + 2,58 n	0,83 + 3,6 n
	Non-propelled cargo carriers	0,385 + 7,73 n	0,75 + 2,73 n	0,385 + 7,73 n
	Other vessels	1 + 3,6 n	1 + 7,73 n	1 + 7,73 n

2 Strength deck sectional area

2.1 Strength deck

2.1.1 The strength deck is the uppermost continuous deck.

2.1.2 The sectional area of the strength deck is the sum of the sectional area of members contributing to the longitudinal strength.

This sectional area includes:

- deck plating abreast hatchways

- stringer plates

- trunk structure

- deck longitudinal girders, provided their continuity is ensured

- where the deck is framed longitudinally, deck longitudinals, provided their continuity is ensured.

2.2 Gross sectional area of flush deck and trunk deck

2.2.1 Within the central part, the gross sectional area, in cm^2, of the deck structure in way of the hatchways is not to be less than:

$A = 6 \, B \, s \, K_{MZ} \, (k_0 k \, L)^{0,5}$

where:

$K_{MZ} = \sqrt{\dfrac{K_M}{K_Z}}$

K_M : Coefficient defined in Tab 1

K_Z : Coefficient defined in Tab 2.

Table 2 : Values of coefficient K_Z

Range of navigation	K_Z
IN	1,0
IN(x ≤ 2)	1 + 0,814 n

3 Plating scantling

3.1 Plating net thicknesses

3.1.1 In the central part, the hull plating net thicknesses, in mm, are not to be less than the values t_1, t_2 and t_3 given in Tab 3.

4 Structural member scantlings

4.1 Net section modulus and net sectional area of structural members

4.1.1 The net scantlings of contributing hull structural members are not to be less than the values given in Tab 4.

In addition, hatch coaming stiffener scantlings are to comply with the following formulae:

- for longitudinal stiffeners:

$$i_e = 20 \sqrt{\dfrac{R_{eH}}{E}} \ell$$

- for stays:

$$I_{eS} = 13 \left(\dfrac{h_C}{\ell}\right)^3 I_e$$

where:

h_C : Actual hatch coaming height above the deck, in m

b_e : Width of attached plating of longitudinal stiffener:

$b_e = \min(0,2 \, \ell \, ; \, s)$

i_e : Radius of gyration, in cm:

$$i_e = \sqrt{\dfrac{I_e}{A_e}}$$

I_e : Net moment of inertia, in cm^4, of the stiffener with attached plating

A_e : Net cross sectional area, in cm^2, of the stiffener with attached plating.

Table 3 : Hull plating net thicknesses, in mm

Item		Transverse framing	Longitudinal framing
Bottom		$t_1 = 1,85 + 0,03\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 17,2 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$ $t_3 = 44,4 s K_{MZ} \sqrt{\dfrac{R_{eH} L}{E}}$	$t_1 = 1,1 + 0,03\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$ $t_3 = 25,5 s K_{MZ} \sqrt{\dfrac{R_{eH} L}{E}}$
Inner bottom		$t_1 = 1,5 + 0,016\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 17,2 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$ $t_3 = 44,4 s K_{MZ} \sqrt{\dfrac{R_{eH} L}{E}}$	$t_1 = 1,5 + 0,016\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$ $t_3 = 25,5 s K_{MZ} \sqrt{\dfrac{R_{eH} L}{E}}$
Side		$t_1 = 1,68 + 0,025\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 17,2 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t_1 = 1,25 + 0,02\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$
Inner side Longitudinal bulkhead		$t_1 = 2 + 0,003\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 17,2 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t_1 = 2 + 0,003\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$
Open deck	Stringer plate	$t_1 = 2 + 0,02\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 17,2 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$ $t_3 = 39,4 s K_{MZ} \sqrt{\dfrac{R_{eH} L}{E}}$	$t_1 = 2 + 0,02\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$ $t_3 = 36,8 s K_{MZ} \sqrt{\dfrac{R_{eH} L}{E}}$
	Hatch coaming	$t_1 = 1,6 + 0,04\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 17,2 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$ $t_3 = (1 + h_C / D)\ t_0$	$t_1 = 1,6 + 0,04\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$ $t_3 = (1 + h_C / D)\ t_0$
Flush deck and trunk deck		$t_1 = 0,9 + 0,034\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 17,2 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$ $t_3 = 39,4 s K_{MZ} \sqrt{\dfrac{R_{eH} L}{E}}$	$t_1 = 0,57 + 0,031\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$ $t_3 = 36,8 s K_{MZ} \sqrt{\dfrac{R_{eH} L}{E}}$
Sheerstrake		- for doubling strake: $t_1 = 2,6 + 0,076\ L\ (k_0 k)^{0,5} + 3,6\ s$ - for inserted strake: $t_1 = 3,6 + 0,11\ L\ (k_0 k)^{0,5} + 3,6\ s$	

Note 1:

t_0 : Rule stringer plate thickness, in mm

h_C : Actual hatch coaming height above the deck, in m

$K_{MZ} = \sqrt{\dfrac{K_M}{K_Z}}$

K_M : Coefficient defined in Tab 1

K_Z : Coefficient defined in Tab 2.

Note 2: In testing conditions

$t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{R_y}}$

Note 3:

$\lambda_L = \sqrt{1 - 0,95\left(\gamma_m \dfrac{\sigma_{for}}{R_y}\right)^2} - 0,225 \gamma_m \dfrac{\sigma_{for}}{R_y}$

$\lambda_T = 1 - 0,89 \gamma_m \dfrac{\sigma_{for}}{R_y}$

σ_{for} : Parameter, in N/mm², taken equal to
- σ_{for} = 100 N/mm² for steel
- σ_{for} = 45 N/mm² for aluminium alloys

Table 4 : Net scantlings of contributing structural members

Item	w (cm³)	A$_{sh}$ (cm²)
Bottom, side, inner side and deck longitudinals	$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m R_y (1 - 0,18 \gamma_R \gamma_m K_{MZ})} s \ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$
Side and inner side stringers, bottom and deck girders **(1)**	$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m R_y (1 - 0,18 \gamma_R \gamma_m K_{MZ})} S \ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} S \ell$

(1) The span ℓ is to be taken equal to the side transverse spacing or web frame spacing.

Note 1:

m : Boundary coefficient to be taken, in general, equal to:
- m = 12 for ordinary stiffeners
- m = 8 for primary supporting members

$K_{MZ} = \sqrt{\dfrac{K_M}{K_Z}}$

K$_M$: Coefficient defined in Tab 1

K$_Z$: Coefficient defined in Tab 2

Chapter 6
OTHER STRUCTURES

SECTION 1   FORE PART

Symbols

A_{sh} : Net shear sectional area, in cm²

C_a : Aspect ratio, equal to:

$$C_a = 1,21\sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell} \leq 1$$

C_r : Coefficient of curvature:

$$C_r = 1 - 0,5\frac{s}{r} \geq 0,5$$

where:

r : Radius of curvature, in m

f : Coefficient defined as follows:

f = 1,0   for **IN(1,2 < x ≤ 2)**

f = 0,9   for **IN(x ≤ 1,2)**

f = 0,8   for **IN**

I_Y : Moment of inertia, in cm⁴, of the hull girder transverse section defined in Ch 4, Sec 1, [2.1], about its horizontal neutral axis

k : Material factor defined in:

- Ch 2, Sec 3, [2.3] for steel
- Ch 2, Sec 3, [3.5] for aluminium alloys

k_0 : Coefficient to be taken equal to:

- k_0= 1 for steel
- k_0= 2,35 for aluminium alloys

M_H : Design still water bending moment in hogging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_S : Design still water vertical bending moment in sagging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_{WV} : Vertical wave bending moment, in kN.m, defined in Ch 3, Sec 2, [3.2]

m : Boundary coefficient to be taken, in general, equal to:

- m = 12 for ordinary stiffeners
- m = 8   for primary supporting members.

Other values of m may be considered, on a case by case basis, for other boundary conditions

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section

n : Navigation coefficient defined in Ch 3, Sec 1, [5.2]

p : Design load, in kN/ m²

R_y : Minimum yield stress, in N/mm², of the material to be taken equal to:

- R_y= 235/k N/mm² for steel
- R_y= 100/k N/mm² for aluminium alloys

unless otherwise specified

S : Spacing, in m, of primary supporting members

s : Spacing, in m, of ordinary stiffeners

t : Thickness, in mm, of plating

w : Net section modulus, in cm³, of ordinary stiffeners or primary supporting members

z : Z co-ordinate, in m, of the calculation point of a structural element.

β_b, β_s : Span correction coefficients defined in Ch 2, Sec 4, [5.2]

γ_m : Partial safety factor covering uncertainties regarding material:

γ_m = 1,02

γ_R : Partial safety factor covering uncertainties regarding resistance, defined in Tab 1

γ_{W1} : Partial safety factor covering uncertainties regarding wave hull girder loads

- γ_{W1} = 1,0   for **IN**
- γ_{W1} = 1,15 for **IN(x ≤ 2)**

γ_{W2} : Partial safety factor covering uncertainties regarding wave local loads

- γ_{W2} = 1,0   for **IN**
- γ_{W2} = 1,2   for **IN(x ≤ 2)**

η : Coefficient taken equal to:

η = 1 − s / (2 l)

λ_b, λ_s : Coefficients for pressure distribution correction defined in Ch 2, Sec 4, [6.3]

ℓ : Span, in m, of ordinary stiffeners or primary supporting members defined in Ch 2, Sec 4, [4.2] or Ch 2, Sec 4, [5.2].

1   General

1.1   Application

1.1.1 The requirements of this Section apply to the scantling and arrangement of fore part structures as defined in Ch 1, Sec 1, [2.1], for all vessels made of steel or aluminium alloy.

As to the requirements which are not explicitly dealt with in the present Section, refer to the previous Chapters.

1.1.2   Buckling strength check

The buckling strength check of plating, stiffeners and primary supporting members is to be performed according to the applicable requirements of Ch 2, Sec 7.

1.1.3 Vessels with length L < 40 m

Where alternative requirements in Ch 5, Sec 6 have been adopted for the vessel central part, the associated fore part structure scantlings are to be determined from this Section considering a hull girder normal stress $\sigma_{X1} = 0$.

1.2 Net scantlings

1.2.1 As specified in Ch 2, Sec 5, all scantlings referred to in this Section, with the exception of those indicated in [7], are net scantlings, i.e. they do not include any margin for corrosion.

1.3 Resistance partial safety factor

1.3.1 The resistance partial safety factor γ_R to be considered for the checking of the fore part structures is specified in Tab 1.

Table 1 : Resistance partial safety factor γ_R

Structures	Plating	Ordinary stiffeners	Primary supporting members
In general			
Fore peak structures	1,20	1,40	1,60
Structures located aft of the collision bulkhead	1,20	1,02	1,20
In testing conditions			
All fore peak structures	1,05	1,02	1,02
In flooding conditions			
All fore peak structures (1)	1,05	1,02	1,02
(1) For collision bulkhead structural members: $\gamma_R = 1,25$			

1.4 Connections of the fore peak with structures located aft of the collision bulkhead

1.4.1 Tapering

Adequate tapering is to be ensured between the scantlings in the fore peak and those aft of the collision bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

2 Design loads

2.1 Local loads

2.1.1 Strength check in service conditions

The design pressure in service conditions is to be determined in compliance with applicable requirements of Ch 3, Sec 4.

2.1.2 Strength check in flooding conditions

The design pressure in flooding conditions is to be determined according to Ch 3, Sec 4, [4].

2.1.3 Strength check in testing conditions

The lateral pressure in testing conditions is taken equal to:

- $p_{ST} - p_S$ for bottom and side structures, if the testing is carried out afloat

- p_{ST} otherwise

where:

p_{ST} : Testing pressure defined in Ch 3, Sec 4, [5]

p_S : Still water river pressure defined in Ch 3, Sec 4, [2.1] for the draught T_1 at which the testing is carried out.

   If T_1 is not known, it may be taken as specified in Ch 3, Sec 1, [2.4.3].

2.2 Hull girder normal stresses

2.2.1 The requirements in Pt D, Ch 2, Sec 12, [4.2] apply in addition to vessels assigned the range of navigation **IN(1,2 < x ≤ 2)**.

2.2.2 The hull girder normal stresses to be considered for the strength check of plating, ordinary stiffeners and primary supporting members are obtained, in N/mm2, from the following formulae:

- in general

   $\sigma_{X1} = \sigma_{S1} + \gamma_{W1} C_{FV} \sigma_{WV1}$

- for structural members not contributing to the hull girder longitudinal strength:

   $\sigma_{X1} = 0$

where:

$\sigma_{S1}, \sigma_{WV1}$: Hull girder normal stresses, in N/mm^2, defined in:

- Tab 3, for plating subjected to lateral loads

- Tab 4, for plating in-plane hull girder compression normal stresses

- Tab 5, for ordinary stiffeners and primary supporting members subjected to lateral pressure

C_{FV} : Combination factors defined in Tab 2.

Table 2 : Combination factors C_{FV}

Load case	C_{FV}
"a"	0
"b"	1,0
"c"	Except vessels assigned a range of navigation **IN(1,2 < x ≤ 2)**, the hull girder wave loads in inclined condition may generally be disregarded.
"d"	
Flooding	0,6

Table 3 : Hull girder normal stresses - Plating subjected to lateral loads

Condition	σ_{S1} , in N/mm^2	σ_{WV1} , in N/mm^2
$\dfrac{M_S + \gamma_W\gamma_{W1}C_{FV}M_{WV}}{M_H + \gamma_W\gamma_{W1}C_{FV}M_{WV}} \geq 1$	$\left\|\dfrac{M_S}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
$\dfrac{M_S + \gamma_W\gamma_{W1}C_{FV}M_{WV}}{M_H + \gamma_W\gamma_{W1}C_{FV}M_{WV}} < 1$	$\left\|\dfrac{M_H}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$

(1) When the vessel in still water is always in hogging condition, M_S is to be taken equal to 0. **(1)**
Note 1:
- For range of navigation **IN**, $\gamma_W = 1,00$
- For range of navigation **IN(x ≤ 2)**, $\gamma_W = 0,625$

Table 4 : In-plane hull girder compression normal stresses - Plating

Condition	σ_{S1} , in N/mm^2	σ_{WV1} , in N/mm^2
$z \geq N$	$\left\|\dfrac{M_S}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
$z < N$	$\left\|\dfrac{M_H}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$

Note 1:
- For range of navigation **IN**, $\gamma_W = 1,00$
- For range of navigation **IN(x ≤ 2)**, $\gamma_W = 0,625$

Table 5 : Hull girder normal stresses -
Ordinary stiffeners and primary supporting members subjected to lateral pressure

Condition	σ_{S1} , in N/mm^2 **(1)**	σ_{WV1} , in N/mm^2
Lateral pressure applied on the side opposite to the ordinary stiffener, with respect to the plating:		
• $z \geq N$ in general $z < N$ for stiffeners simply supported at both ends	$\left\|\dfrac{M_S}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
• $z < N$ in general $z \geq N$ for stiffeners simply supported at both ends	$\left\|\dfrac{M_H}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
Lateral pressure applied on the same side as the ordinary stiffener:		
• $z \geq N$ in general ; $z < N$ for stiffeners simply supported at both ends	$\left\|\dfrac{M_H}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
• $z < N$ in general ; $z \geq N$ for stiffeners simply supported at both ends	$\left\|\dfrac{M_S}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$

(1) When the vessel in still water is always in hogging condition, M_S is to be taken equal to 0.
Note 1:
- For range of navigation **IN**, $\gamma_W = 1,00$
- For range of navigation **IN(x ≤ 2)**, $\gamma_W = 0,625$

3 Bottom scantlings and arrangements

3.1 Longitudinally framed bottom

3.1.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from Tab 6.

3.1.2 Bottom transverses

Bottom transverses are to be fitted at every 8 frame spacings and generally spaced no more than 4 m apart.

The arrangements of bottom transverses are to be as required in the midship region.

Their scantlings are not to be less than required in Tab 7 nor lower than those of the corresponding side transverses, as defined in [4.2.2].

3.1.3 Fore peak arrangement

Where no centreline bulkhead is fitted, a centre bottom girder having the same dimensions and scantlings as required for bottom transverses is to be provided.

The centre bottom girder is to be connected to the collision bulkhead by means of a large end bracket.

Side girders, having the same dimensions and scantlings as required for bottom transverses, 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.

3.2 Transversely framed bottom

3.2.1 Plating

The scantling of plating is to be not less than the value obtained from the formulae in Tab 6.

3.2.2 Floors

Floors are to be fitted at every frame spacing.

The floor net scantlings are to be not less than those derived from Tab 7.

A relaxation from the Rules of dimensions and scantlings may be granted by the Society for very low draught vessels.

3.2.3 Where no centreline bulkhead is fitted, a centre bottom girder is to be provided according to [3.1.3].

3.3 Keel plate

3.3.1 The thickness of the keel plate is to be not less than that of the adjacent bottom plating.

Adequate tapering is to be ensured between the bottom and keel plating in the central part and the stem.

Table 6 : Net scantlings of bottom plating and structural members

Item	Strength characteristic		Minimum net thickness (mm)
Bottom plating	Net thickness, in mm:	$t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda R_y}}$	Plating net thickness: • longitudinal framing: $\quad t_1 = 1,1 + 0,03\, L\, (k_0 k)^{0,5} + 3,6\, s$ • transverse framing: $\quad t_1 = 1,85 + 0,03\, L\, (k_0 k)^{0,5} + 3,6\, s$
Bottom longitudinals	Net section modulus, in cm³:	$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} s \ell^2 10^3$	Web net thickness: $t = 1,63 + 0,004\, L\, (k_0 k)^{0,5} + 4,5\, s$
	Net shear sectional area, in cm²:	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$	
Floors Bottom transverses/reinforced floors	Net section modulus, in cm³:	$w = \gamma_R \gamma_m \beta_b \dfrac{p}{m R_y} a \ell^2 10^3$	Web net thickness: $t = 3,8 + 0,016\, L\, (k_0 k)^{0,5}$
	Net shear sectional area, in cm²: **(1)**	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta a \ell$	
Bottom girders	Net section modulus, in cm³:	$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} S \ell^2 10^3$	Web net thickness: $t = 3,8 + 0,016\, L\, (k_0 k)^{0,5}$
	Net shear sectional area, in cm²:	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} S \ell$	

Note 1:

a : Structural member spacing, in m
    a = s   for floors
    a = S   for bottom transverses and reinforced floors

λ : Coefficient taken equal to:
• In service conditions
   for longitudinally framed bottom $\lambda = \lambda_L$

$$\lambda_L = \sqrt{1 - 0,95\left(\gamma_m \frac{\sigma_{x1}}{R_y}\right)^2} - 0,225 \gamma_m \frac{\sigma_{x1}}{R_y}$$

   for transversely framed bottom $\lambda = \lambda_T$

$$\lambda_T = 1 - 0,89 \gamma_m \frac{\sigma_{x1}}{R_y}$$

• In testing and flooding conditions
   λ = 1, in general

(1) η = 1 for bottom transverses and reinforced floors

Table 7 : Net scantling of side plating and structural members

Item		Strength characteristic	Minimum net thickness (mm)
Plating		Net thickness, in mm: $$t_2 = 14,9 C_a C_r s \sqrt{\frac{\gamma_R \gamma_m p}{\lambda R_y}}$$	Plating net thickness: • longitudinal framing: $t_1 = 1,25 + 0,02\ L\ (k_0 k)^{0,5} + 3,6\ s$ • transverse framing: $t_1 = 1,68 + 0,025\ L\ (k_0 k)^{0,5} + 3,6\ s$
Side longitudinals		Net section modulus, in cm³: $$w = \frac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} s \ell^2 10^3$$ Net shear sectional area, in cm²: $$A_{sh} = 10 \gamma_R \gamma_m \beta_s \frac{p}{R_y} \eta s \ell$$	Web net thickness: $t = 1,63 + 0,004\ L\ (k_0 k)^{0,5} + 4,5\ s$
Side frames	• if $\ell_0 \leq \ell$	Net section modulus, in cm³: $$w = \gamma_R \gamma_m \beta_b \frac{s}{m R_y}(6 \ell \ell_0^2 + 1,45 \lambda_W p_F \ell_F^2)10^3$$ Net shear sectional area, in cm²: $$A_{sh} = 68 \gamma_R \gamma_m \beta_s \frac{\ell}{R_y} \eta s \ell_0$$	Web net thickness: $t = 1,63 + 0,004\ L\ (k_0 k)^{0,5} + 4,5\ s$
	• if $\ell_0 > \ell$	Net section modulus, in cm³: $$w = \gamma_R \gamma_m \beta_b \frac{s}{m R_y}(\lambda_b p \ell^2 + 1,45 \lambda_W p_F \ell_F^2)10^3$$ Net shear sectional area, in cm²: $$A_{sh} = 10 \lambda_S \gamma_R \gamma_m \beta_s \frac{p}{R_y} \eta s \ell$$	
Intermediate side frames	• if $\ell_0 \leq \ell$	Net section modulus, in cm³: $$w = 6 \gamma_R \gamma_m \beta_b \frac{\ell}{m R_y} s \ell_0^2 10^3$$ Net shear sectional area, in cm²: $$A_{sh} = 68 \gamma_R \gamma_m \beta_s \frac{\ell}{R_y} \eta s \ell_0$$	Web net thickness: $t = 1,63 + 0,004\ L\ (k_0 k)^{0,5} + 4,5\ s$
	• if $\ell_0 > \ell$	Net section modulus, in cm³: $$w = \gamma_R \lambda_b \gamma_m \beta_b \frac{p}{m R_y} s \ell^2 10^3$$ Net shear sectional area, in cm²: $$A_{sh} = 10 \lambda_S \gamma_R \gamma_m \beta_s \frac{p}{R_y} \eta s \ell$$	
Side transverses and side web frames	• if $\ell_0 \leq \ell$	Net section modulus, in cm³: $$w = 6 \gamma_R \gamma_m \beta_b \frac{\ell}{m R_y} S \ell_0^2 10^3$$ Net shear sectional area, in cm²: $$A_{sh} = 68 \gamma_R \gamma_m \beta_s \frac{\ell}{R_y} S \ell_0$$	Web net thickness: $t = 3,8 + 0,016\ L\ (k_0 k)^{0,5}$
	• if $\ell_0 > \ell$	Net section modulus, in cm³: $$w = \gamma_R \lambda_b \gamma_m \beta_b \frac{p}{m R_y} S \ell^2 10^3$$ Net shear sectional area, in cm²: $$A_{sh} = 10 \lambda_S \gamma_R \gamma_m \beta_s \frac{p}{R_y} S \ell$$	

Item	Strength characteristic	Minimum net thickness (mm)
Side stringers	Net section modulus, in cm³: $w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} S \ell^2 10^3$ Net shear sectional area, in cm²: $A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} S \ell$	Web net thickness: $t = 3{,}8 + 0{,}016\ L\ (k_0 k)^{0,5}$

Note 1:

ℓ_0 : Span parameter, in m: $\ell_0 = p_d / g$

p_d : Total pressure, in kN/m², at the lower end of the stiffener

ℓ_F : Floor span, in m

p_F : Floor design load, in kN/ m²

λ_W : In transverse framing system: $\lambda_W = 0{,}08$

      In combination framing system: $\lambda_W = 0$

λ : Coefficient taken equal to:

- In service conditions
  for longitudinally framed bottom $\lambda = \lambda_L$

  $\lambda_L = \sqrt{1 - 0{,}95 \left(\gamma_m \dfrac{\sigma_{x1}}{R_y} \right)^2} - 0{,}225 \gamma_m \dfrac{\sigma_{x1}}{R_y}$

  for transversely framed bottom $\lambda = \lambda_T$

  $\lambda_T = 1 - 0{,}89 \gamma_m \dfrac{\sigma_{x1}}{R_y}$

- In testing and flooding conditions
  $\lambda = 1$, in general

4 Side scantlings and arrangements

4.1 Arrangement

4.1.1 In way of the anchors, the side plating thickness is to be increased by 50%, or a doubling plate is to be provided.

Where a break is located in the fore part deck, the thickness of the sheerstrake is to be increased by 40% in the region of the break.

4.1.2 The foreship of the vessels shall be built in such a way that the anchors do not stick out of the side shell.

4.2 Longitudinally framed side

4.2.1 Plating and ordinary stiffeners

The scantlings of plating and ordinary stiffeners are to be not less than the values obtained from Tab 7.

4.2.2 Side transverses

Side transverses are to be located in way of bottom transverses 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 derived from Tab 7.

4.3 Transversely framed side

4.3.1 Plating and ordinary stiffeners (side frames)

Side frames fitted at every frame space are to have the same vertical extension as the collision bulkhead.

Where, due to the hull design, the distance between transverse stiffeners, measured on the plating, is quite greater than the frame spacing, this latter should be reduced, or intermediate frames with scantlings in compliance with Tab 7 are to be provided.

It is recommended to provide a side stringer where intermediate frames are fitted over a distance equal to the breadth B of the vessel.

The net scantlings of plating and side stiffeners are to be not less than the values obtained from the formulae in Tab 7.

The value of the side frame section modulus is generally to be maintained for the full extension of the side frame.

4.3.2 Web frames

The web frames in a transverse framing system are to be spaced not more than 4 m apart.

The web frame section modulus is to be equal to the section modulus of the floor connected to it.

4.3.3 Fore peak arrangement

Depending on the hull body shape and structure aft of the collision bulkhead, one or more adequately spaced side stringers per side are to be fitted.

The side stringer net section modulus w, in cm³, and shear sectional area A_{sh}, in cm², are to be not less than the values obtained from Tab 7.

Non-tight platforms may be fitted in lieu of side girders. Their openings and scantlings are to be in accordance with [6.1] and their spacing is to be not greater than 2,5 m.

4.3.4   Access to fore peak

Manholes may be cut in the structural members to provide convenient access to all parts of the fore peak.

These manholes are to be cut smooth along a well rounded design and are not to be greater than that strictly necessary to provide the man access. Where manholes of greater sizes are needed, edge reinforcement by means of flat bar rings or other suitable stiffeners may be required.

5   Decks

5.1   Deck scantlings and arrangements

5.1.1 The scantlings of deck plating and structural members are to be not less than the values obtained from the formulae in Tab 8.

5.1.2 Where the hatchways form corners, the deck plating is to have the same thickness as the stringer plate.

The deck plating is to be reinforced in way of the anchor windlass and other deck machinery, bollards, cranes, masts and derrick posts.

5.1.3   Supporting structure of windlasses and chain stoppers

For the supporting structure under windlasses and chain stoppers the permissible stresses as stated in Ch 7, Sec 4, [4.3.3] are to be observed.

The acting forces are to be calculated for 80% or 45% of the rated breaking load of the chain cable as follows:

a)   for chain stoppers: 80%

b)   for windlasses:

 • 80% when no chain stopper is fitted

 • 45% when a chain stopper is fitted.

5.2   Stringer plate

5.2.1 The net thickness of stringer plate, in mm, is to be not less than the greater of:

• t = 2 + 0,032 L $(k_0 k)^{0,5}$ + 3,6 s

• t = t_0

where t_0 is the deck plating net thickness.

6   Non-tight bulkheads and platforms

6.1   Arrangements and scantlings

6.1.1 Non-tight platforms or bulkheads located inside the peak are to be provided with openings having a total area not less than 10% of that of the platforms, respectively bulkheads.

The scantlings of bulkheads and platforms are to comply with the requirements of non-tight bulkheads (see Ch 5, Sec 5, [8]).

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.

7   Stems

7.1   General

7.1.1   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.

7.2   Plate stems

7.2.1   Thickness

The gross thickness, in mm, of the plate stem is to be not less than the value obtained, in mm, from the following formula:

$$t = 1,37(0,95 + \sqrt{L})\sqrt{k_0 k} \le 15\sqrt{k_0}$$

For non-propelled vessels, this value may be reduced by 20%.

This thickness is to be maintained from 0,1 m at least aft of the forefoot till the load waterline. Above the load waterline, this thickness may be gradually tapered towards the stem head, where it is to be not less than the local value required for the side plating or, in case of pontoon-shaped foreship, the local value required for the bottom plating.

7.2.2   Centreline stiffener

If considered necessary, and particularly where the stem radius is large, a centreline stiffener or web of suitable scantlings is to be fitted.

Where the stem plating is reinforced by a centreline stiffener or web, its thickness may be reduced by 10%.

7.2.3   Horizontal diaphragms

The plating forming the stems is to be supported by horizontal diaphragms spaced not more than 500 mm apart and connected, as far as practicable, to the adjacent frames and side stringers.

The diaphragm plate is to be at least 500 mm deep and its thickness is to be not less than 0,7 times that of the stem.

Table 8 : Net scantling of deck plating and structural members

Item	Strength characteristic	Minimum net thickness (mm)
Plating	Net thickness: $t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda R_y}}$	Plating net thickness: • longitudinal framing: $t_1 = 0,57 + 0,031\ L\ (k_0 k)^{0,5} + 3,6\ s$ • transverse framing: $t_1 = 0,9 + 0,034\ L\ (k_0 k)^{0,5} + 3,6\ s$
Deck beams	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \dfrac{p}{m R_y} s \ell^2 10^3$ Net shear sectional area, in cm²: $A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$	Web net thickness: $t = 1,63 + 0,004\ L\ (k_0 k)^{0,5} + 4,5\ s$
Deck longitudinals	Net section modulus, in cm³: $w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} s \ell^2 10^3$ Net shear sectional area, in cm²: $A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$	Web net thickness: $t = 1,63 + 0,004\ L\ (k_0 k)^{0,5} + 4,5\ s$
Deck transverses	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \dfrac{p}{m R_y} S \ell^2 10^3$ Net shear sectional area, in cm²: $A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} S \ell$	Web net thickness: $t = 3,8 + 0,016\ L\ (k_0 k)^{0,5}$
Deck girders	Net section modulus, in cm³: $w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} S \ell^2 10^3$ Net shear sectional area, in cm²: $A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} S \ell$	Web net thickness: $t = 3,8 + 0,016\ L\ (k_0 k)^{0,5}$

Note 1:

λ : Coefficient taken equal to:

• In service conditions
for longitudinally framed bottom $\lambda = \lambda_L$

$\lambda_L = \sqrt{1 - 0,95\left(\gamma_m \dfrac{\sigma_{x1}}{R_y}\right)^2} - 0,225 \gamma_m \dfrac{\sigma_{x1}}{R_y}$

for transversely framed bottom $\lambda = \lambda_T$

$\lambda_T = 1 - 0,89 \gamma_m \dfrac{\sigma_{x1}}{R_y}$

• In testing and flooding conditions
$\lambda = 1$, in general

Table 9 : Stiffened bar stem

Sectional area A_p (cm²) of the plate stiffener	Reduction on sectional area of the bar stem
$1,50\,t \geq A_p > 0,95\,t$	10%
$A_p > 1,50\,t$	15%
Note 1: t : Web thickness, in mm, of the plate stiffener.	

7.2.4 Pushing transom

Where self-propelled vessels are equipped for pushing other vessels in case of pontoon-shaped foreship, a pushing transom is to be fitted in compliance with Ch 7, Sec 6, [2.2].

7.3 Bar stems

7.3.1 Sectional area

The sectional area of bar stems constructed of forged or rolled steel is to be not less than the value obtained, in cm², from the following formula:

$A_p = k_0 k\, f\, (0,006\, L^2 + 12)$

7.3.2 Thickness

The gross thickness of the bar stems constructed of forged or rolled steel, is to be not less than the value obtained, in mm, from the following formula:

$t = 0,33\, L\, (k_0 k)^{0,5} + 10$

7.3.3 Extension

The bar stem is to extend beyond the forefoot over about 1 m.

Its cross-sectional area may be gradually tapered from the load waterline to the upper end.

7.3.4 Stiffened bar stem

Where the bar stem is reinforced by a flanged plate or a bulb flat stiffener, its sectional area may be reduced according to Tab 9.

8 Thruster tunnel

8.1 Scantlings of the thruster tunnel and connection with the hull

8.1.1 Net thickness of tunnel plating

The net thickness, in mm, of the tunnel plating is not to be less than that of the adjacent part of the hull, nor than that obtained from the following formula:

$t = 4,4 + 0,024\, L\, (k_0 k)^{0,5}$

8.1.2 Connection with the hull

The tunnel is to be fully integrated in the bottom structure.

Adequate continuity with the adjacent bottom structure is to be ensured.

SECTION 2   AFT PART

Symbols

A_{sh} : Net shear sectional area, in cm^2

C_a : Aspect ratio, equal to:

$$C_a = 1,21\sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell} \leq 1$$

C_r : Coefficient of curvature:

$$C_r = 1 - 0,5\frac{s}{r} \geq 0,5$$

where:

r : Radius of curvature, in m

f : Coefficient defined as follows:

f = 1,0 for **IN(1,2 < x ≤ 2)**

f = 0,9 for **IN(x ≤ 1,2)**

f = 0,8 for **IN**

k : Material factor defined in:

• Ch 2, Sec 3, [2.3] for steel

• Ch 2, Sec 3, [3.5] for aluminium alloys

k_0 : Coefficient to be taken equal to:

• k_0= 1 for steel

• k_0= 2,35 for aluminium alloys

I_Y : Moment of inertia, in cm^4, of the hull girder transverse section defined in Ch 4, Sec 1, [2.1], about its horizontal neutral axis

M_H : Design still water bending moment in hogging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_S : Design still water vertical bending moment in sagging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_{WV} : Vertical wave bending moment, in kN.m, defined in Ch 3, Sec 2, [3.2]

m : Boundary coefficient to be taken, in general, equal to:

• m = 12 for ordinary stiffeners

• m = 8 for primary supporting members.

Other values of m may be considered, on a case by case basis, for other boundary conditions

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section

n : Navigation coefficient defined in Ch 3, Sec 1, [5.2]

p : Design load, in kN/ m^2

R_y : Minimum yield stress, in N/mm^2, of the material to be taken equal to:

• R_y= 235/k N/mm^2 for steel

• R_y= 100/k N/mm^2 for aluminium alloys

unless otherwise specified

S : Spacing, in m, of primary supporting members

s : Spacing, in m, of ordinary stiffeners

t : Thickness, in mm, of plating

w : Net section modulus, in cm^3, of ordinary stiffeners or primary supporting members

z : Z co-ordinate, in m, of the calculation point of a structural element.

β_b, β_s : Span correction coefficients defined in Ch 2, Sec 4, [5.2]

γ_m : Partial safety factor covering uncertainties regarding material: $\gamma_m = 1,02$

γ_R : Partial safety factor covering uncertainties regarding resistance, defined in Ch 6, Sec 1, Tab 1

γ_{W1} : Partial safety factor covering uncertainties regarding wave hull girder loads

• $\gamma_{W1} = 1,0$ for **IN**

• $\gamma_{W1} = 1,15$ for **IN(x ≤ 2)**

γ_{W2} : Partial safety factor covering uncertainties regarding wave local loads

• $\gamma_{W2} = 1,0$ for **IN**

• $\gamma_{W2} = 1,2$ for **IN(x ≤ 2)**

η : Coefficient taken equal to: $\eta = 1 - s / (2\ l)$

λ_b, λ_s : Coefficients for pressure distribution correction defined in Ch 2, Sec 4, [6.3]

ℓ : Span, in m, of ordinary stiffeners or primary supporting members defined in Ch 2, Sec 4, [4.2] or Ch 2, Sec 4, [5.2].

1   General

1.1   Application

1.1.1 The requirements of this Section apply to scantling and arrangement of structures located aft of the after peak bulkhead, for all vessels made of steel or aluminium alloy.

As to the requirements which are not explicitly dealt with in the present Section, refer to the previous Chapters.

1.1.2   Buckling strength check

The buckling strength check of plating, stiffeners and primary supporting members is to be performed according to the applicable requirements of Ch 2, Sec 7.

1.1.3   Vessels with length L < 40 m

Where alternative requirements in Ch 5, Sec 6 have been adopted for the vessel central part, the associated aft part structure scantlings are to be determined from this Section considering a hull girder normal stress $\sigma_{X1} = 0$.

1.2   Net scantlings

1.2.1 As specified in Ch 2, Sec 5, all scantlings referred to in this Section, with the exception of those indicated in [4], are net scantlings, i.e. they do not include any margin for corrosion.

1.3   Resistance partial safety factor

1.3.1 The resistance partial safety factor γ_R to be considered for the checking of the aft peak structures is specified in Tab 1.

Table 1 : Resistance partial safety factor γ_R

Conditions	Plating	Ordinary stiffeners	Primary supporting members
In general	1,20	1,40	1,60
In testing and flooding conditions	1,05	1,02	1,02

1.4   Connections of the aft part with structures located fore of the after bulkhead

1.4.1   Tapering

Adequate tapering is to be ensured between the scantlings in the aft part and those fore of the after bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

2   Design loads

2.1   Local loads

2.1.1   Strength check in service conditions

The design pressure in service conditions is to be determined in compliance with applicable requirements of Ch 3, Sec 4.

2.1.2   Strength check in flooding conditions

The design pressure in flooding conditions is to be determined according to Ch 3, Sec 4, [4].

2.1.3   Strength check in testing conditions

The lateral pressure in testing conditions is taken equal to:

- $p_{ST} - p_S$ for bottom and side structures, if the testing is carried out afloat
- p_{ST} otherwise

where:

p_{ST} : Testing pressure defined in Ch 3, Sec 4, [5]

p_S : Still water river pressure defined in Ch 3, Sec 4, [2.1] for the draught T_1 at which the testing is carried out.

  If T_1 is not known, it may be taken as specified in Ch 3, Sec 1, [2.4.3].

2.2   Hull girder normal stresses

2.2.1 The requirements in Pt D, Ch 2, Sec 12, [4.2] apply in addition to vessels assigned the range of navigation **IN(1,2 < x ≤ 2)**.

2.2.2 The hull girder normal stresses to be considered for the strength check of plating, ordinary stiffeners and primary supporting members are obtained, in N/mm², from the following formulae:

- in general $\sigma_{X1} = \sigma_{S1} + \gamma_{W1}C_{FV}\,\sigma_{WV1}$

- for structural members not contributing to the hull girder longitudinal strength: $\sigma_{X1} = 0$

where:

$\sigma_{S1}, \sigma_{WV1}$: Hull girder normal stresses, in N/mm², defined in:

- Tab 3, for plating subjected to lateral loads

- Tab 4, for plating in-plane hull girder compression normal stresses

- Tab 5, for ordinary stiffeners and primary supporting members subjected to lateral pressure

C_{FV} : Combination factors defined in Tab 2.

Table 2 : Combination factors C_{FV}

Load case	C_{FV}
"a"	0
"b"	1,0
"c"	Except vessels assigned a range of navigation **IN(1,2 < x ≤ 2)**, the hull girder wave loads in inclined condition may generally be disregarded.
"d"	
Flooding	0,6

Table 3 : Hull girder normal stresses - Plating subjected to lateral loads

Condition	σ_{S1} , in N/mm² **(1)**	σ_{WV1} , in N/mm²
$\dfrac{M_S + \gamma_W \gamma_{W1} C_{FV} M_{WV}}{M_H + \gamma_W \gamma_{W1} C_{FV} M_{WV}} \geq 1$	$\left\|\dfrac{M_S}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
$\dfrac{M_S + \gamma_W \gamma_{W1} C_{FV} M_{WV}}{M_H + \gamma_W \gamma_{W1} C_{FV} M_{WV}} < 1$	$\left\|\dfrac{M_H}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
(1) When the vessel in still water is always in hogging condition, M_S is to be taken equal to 0. **Note 1:** - For range of navigation **IN**, $\gamma_W = 1,00$ - For range of navigation **IN(x ≤ 2)**, $\gamma_W = 0,625$		

Table 4 : In-plane hull girder compression normal stresses - Plating

Condition	σ_{S1} , in N/mm^2	σ_{WV1} , in N/mm^2
$z \geq N$	$\left\lvert\dfrac{M_S}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\rvert 10^{-3}$
$z < N$	$\left\lvert\dfrac{M_H}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\rvert 10^{-3}$
Note 1: • For range of navigation **IN**, $\gamma_W = 1{,}00$ • For range of navigation **IN(x ≤ 2)**, $\gamma_W = 0{,}625$		

Table 5 : Hull girder normal stresses -
Ordinary stiffeners and primary supporting members subjected to lateral pressure

Condition	σ_{S1} , in N/mm^2 **(1)**	σ_{WV1} , in N/mm^2
Lateral pressure applied on the side opposite to the ordinary stiffener, with respect to the plating: • $z \geq N$ in general $z < N$ for stiffeners simply supported at both ends	$\left\lvert\dfrac{M_S}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\rvert 10^{-3}$
• $z < N$ in general $z \geq N$ for stiffeners simply supported at both ends	$\left\lvert\dfrac{M_H}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\rvert 10^{-3}$
Lateral pressure applied on the same side as the ordinary stiffener: • $z \geq N$ in general ; $z < N$ for stiffeners simply supported at both ends	$\left\lvert\dfrac{M_H}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\rvert 10^{-3}$
• $z < N$ in general ; $z \geq N$ for stiffeners simply supported at both ends	$\left\lvert\dfrac{M_S}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\rvert 10^{-3}$
(1) When the vessel in still water is always in hogging condition, M_S is to be taken equal to 0. **Note 1:** • For range of navigation **IN**, $\gamma_W = 1{,}00$ • For range of navigation **IN(x ≤ 2)**, $\gamma_W = 0{,}625$		

3 After peak

3.1 Arrangement

3.1.1 General

The after peak is, in general, to be transversely framed.

3.1.2 Floors

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 an 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 and propeller post, higher floors of increased thickness are to be fitted. The increase will be considered by the Society on a case by case basis, depending on the arrangement proposed.

3.1.3 Side frames

Side frames are to be extended up to the deck.

Where, due to the hull design, the actual spacing between transverse stiffeners, measured on the plating, is quite greater than the frame spacing, this later should be reduced, or intermediate frames with scantlings in compliance with Tab 7 are to be provided.

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.

3.1.5 Longitudinal bulkheads

A longitudinal non-tight bulkhead is to be fitted on the centreline of the vessel, in general in the upper part of the peak, and stiffened at each frame spacing.

Where no longitudinal bulkhead is fitted, centre line bottom and deck girders having the same dimensions and scantlings as required respectively for bottom and deck transverses are to be provided.

Table 6 : Net scantlings of bottom plating and structural members

Item	Strength characteristic		Minimum net thickness (mm)
Bottom plating	Net thickness, in mm:	$t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda R_y}}$	Plating net thickness: • longitudinal framing: $t_1 = 1,1 + 0,03\, L\, (k_0 k)^{0,5} + 3,6\, s$ • transverse framing: $t_1 = 1,85 + 0,03\, L\, (k_0 k)^{0,5} + 3,6\, s$
Bottom longitudinals	Net section modulus, in cm³:	$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} s \ell^2 10^3$	Web net thickness: $t = 1,63 + 0,004\, L\, (k_0 k)^{0,5} + 4,5\, s$
	Net shear sectional area, in cm²:	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$	
Floors	Net section modulus, in cm³:	$w = \gamma_R \gamma_m \beta_b \dfrac{p}{m R_y} s \ell^2 10^3$	Web net thickness: $t = 1,63 + 0,004\, L\, (k_0 k)^{0,5} + 4,5\, s$
	Net shear sectional area, in cm²:	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$	
Bottom transverses / reinforced floors	Net section modulus, in cm³:	$w = \gamma_R \gamma_m \beta_b \dfrac{p}{m R_y} S \ell^2 10^3$	Web net thickness: $t = 3,8 + 0,016\, L\, (k_0 k)^{0,5}$
	Net shear sectional area, in cm²:	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} S \ell$	
Bottom girders	Net section modulus, in cm³:	$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} S \ell^2 10^3$	Web net thickness: $t = 3,8 + 0,016\, L\, (k_0 k)^{0,5}$
	Net shear sectional area, in cm²:	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} S \ell$	

Note 1:

λ : Coefficient taken equal to:
  • In service conditions
    for longitudinally framed bottom $\lambda = \lambda_L$

$$\lambda_L = \sqrt{1 - 0{,}95 \left(\gamma_m \frac{\sigma_{x1}}{R_y} \right)^2} - 0{,}225 \gamma_m \frac{\sigma_{x1}}{R_y}$$

for transversely framed bottom $\lambda = \lambda_T$

$$\lambda_T = 1 - 0{,}89 \gamma_m \frac{\sigma_{x1}}{R_y}$$

  • In testing and flooding conditions
    $\lambda = 1$, in general

3.1.6 Local reinforcement

The deck plating is to be reinforced in way of the anchor windlass, steering gear and other deck machinery, bollards, cranes, masts and derrick posts.

3.2 Bottom scantlings

3.2.1 Bottom plating and structural members

The net scantlings of bottom plating and structural members are to be not less than those obtained from formulae in Tab 6.

The floor scantlings are to be increased satisfactorily in way of the rudder stock.

3.3 Side scantlings

3.3.1 Plating and structural members

The net scantlings of plating and structural members are to be not less than those obtained from formulae in Tab 7.

3.3.2 Side transverses

Side transverses are to be located in way of bottom transverses and are to extend to the upper deck. Their ends are to be amply faired in way of bottom and deck transverses.

3.3.3 Side stringers

Where the vessel depth exceeds 2 m, a side stringer is to be fitted at about mid-depth.

Table 7 : Net scantlings of side plating and structural members

Item		Strength characteristic	Minimum net thickness (mm)
Side plating		Net thickness: $t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda R_y}}$	Plating net thickness: • longitudinal framing: $\quad t_1 = 1,25 + 0,02\ L\ (k_0 k)^{0,5} + 3,6\ s$ • transverse framing: $\quad t_1 = 1,68 + 0,025\ L\ (k_0 k)^{0,5} + 3,6\ s$
Transom plating		Net thickness: $t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{R_y}}$	Plating net thickness: $t_1 = 1,68 + 0,025\ L\ (k_0 k)^{0,5} + 3,6\ s$
Side longitudinals		Net section modulus, in cm³: $w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} s \ell^2 10^3$ Net shear sectional area, in cm²: $A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$	Web net thickness: $t = 1,63 + 0,004\ L\ (k_0 k)^{0,5} + 4,5\ s$
Transom horizontal stiffeners		Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \dfrac{p}{m R_y} s \ell^2 10^3$ Net shear sectional area, in cm²: $A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$	Web net thickness: $t = 1,63 + 0,004\ L\ (k_0 k)^{0,5} + 4,5\ s$
Side frames	• if $\ell_0 \leq \ell$	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \dfrac{s}{m R_y} (6 \ell \ell_0^2 + 1,45 \lambda_W p_F \ell_F^2) 10^3$ Net shear sectional area, in cm²: $A_{sh} = 68 \gamma_R \gamma_m \beta_s \dfrac{\ell}{R_y} \eta s \ell_0$	Web net thickness: $t = 1,63 + 0,004\ L\ (k_0 k)^{0,5} + 4,5\ s$
	• if $\ell_0 > \ell$	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \dfrac{s}{m R_y} (\lambda_b p \ell^2 + 1,45 \lambda_W p_F \ell_F^2) 10^3$ Net shear sectional area, in cm²: $A_{sh} = 10 \lambda_s \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$	
Intermediate side frames Transom vertical stiffeners	• if $\ell_0 \leq \ell$	Net section modulus, in cm³: $w = 6 \gamma_R \gamma_m \beta_b \dfrac{\ell}{m R_y} s \ell_0^2 10^3$ Net shear sectional area, in cm²: $A_{sh} = 68 \gamma_R \gamma_m \beta_s \dfrac{\ell}{R_y} \eta s \ell_0$	Web net thickness: $t = 1,63 + 0,004\ L\ (k_0 k)^{0,5} + 4,5\ s$
	• if $\ell_0 > \ell$	Net section modulus, in cm³: $w = \gamma_R \gamma_m \lambda_b \beta_b \dfrac{p}{m R_y} s \ell^2 10^3$ Net shear sectional area, in cm²: $A_{sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \dfrac{p}{R_y} \eta s \ell$	

Item		Strength characteristic	Minimum net thickness (mm)
Side transverses Side web frames	• if $\ell_0 \le \ell$	Net section modulus, in cm³: $$w = 6\gamma_R\gamma_m\beta_b\frac{\ell}{mR_y}S\ell_0^2 10^3$$ Net shear sectional area, in cm²: $$A_{sh} = 68\gamma_R\gamma_m\beta_s\frac{\ell}{R_y}S\ell_0$$	Web net thickness: $t = 3{,}8 + 0{,}016\,L\,(k_0 k)^{0,5}$
	• if $\ell_0 > \ell$	Net section modulus, in cm³: $$w = \gamma_R\gamma_m\lambda_b\beta_b\frac{p}{mR_y}S\ell^2 10^3$$ Net shear sectional area, in cm²: $$A_{sh} = 10\gamma_R\gamma_m\lambda_s\beta_s\frac{p}{R_y}S\ell$$	
Side stringers		Net section modulus, in cm³: $$w = \frac{\gamma_R\gamma_m\beta_b p}{m(R_y - \gamma_R\gamma_m\sigma_{x1})}S\ell^2 10^3$$ Net shear sectional area, in cm²: $$A_{sh} = 10\gamma_R\gamma_m\beta_s\frac{p}{R_y}S\ell$$	Web net thickness: $t = 3{,}8 + 0{,}016\,L\,(k_0 k)^{0,5}$

Note 1:

ℓ_0 : Span parameter, in m:
$$\ell_0 = p_d / g$$

p_d : Total pressure, in kN/m², at the lower end of the stiffener

ℓ_F : Floor span, in m

p_F : Floor design load, in kN/m²

λ_W : In transverse framing system: $\lambda_W = 0{,}08$
In combination framing system: $\lambda_W = 0$

λ : Coefficient taken equal to:
- In service conditions
  for longitudinally framed bottom $\lambda = \lambda_L$
  $$\lambda_L = \sqrt{1 - 0{,}95\left(\gamma_m\frac{\sigma_{x1}}{R_y}\right)^2} - 0{,}225\gamma_m\frac{\sigma_{x1}}{R_y}$$
  for transversely framed bottom $\lambda = \lambda_T$
  $$\lambda_T = 1 - 0{,}89\gamma_m\frac{\sigma_{x1}}{R_y}$$
- In testing and flooding conditions
  $\lambda = 1$, ιν γενεραλ

3.4 Deck scantlings and arrangements

3.4.1 Plating and ordinary stiffeners

The net scantlings of deck plating and structural members are not to be less than those obtained from the formulae in Tab 8.

Where a break is located in the after part deck, the thickness of the sheerstrake is to be increased by 40% in the region of the break.

3.4.2 The deck plating is to be reinforced in way of the anchor windlass and other deck machinery, bollards, cranes, masts and derrick posts.

The supporting structure of windlasses and chain stoppers is to be in compliance with Ch 6, Sec 1, [5.1.3].

3.4.3 Stringer plate

The net thickness of stringer plate, in mm, is to be not less than the greater of:

- $t = 2 + 0{,}032\,L\,(k_0 k)^{0,5} + 3{,}6\,s$

- $t = t_0$

where t_0 is the deck plating net thickness.

Table 8 : Net scantlings of deck plating and structural members

Item	Strength characteristic	Minimum net thickness (mm)
Deck plating	Net thickness: $t_2 = 14,9 C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda R_y}}$	Plating net thickness: • longitudinal framing: $t_1 = 0,57 + 0,031\ L\ (k_0 k)^{0,5} + 3,6\ s$ • transverse framing: $t_1 = 0,90 + 0,034\ L\ (k_0 k)^{0,5} + 3,6\ s$
Deck beams	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \dfrac{p}{m R_y} s \ell^2 10^3$ Net shear sectional area, in cm²: $A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$	Web net thickness: $t = 1,63 + 0,004\ L\ (k_0 k)^{0,5} + 4,5\ s$
Deck longitudinals	Net section modulus, in cm³: $w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} s \ell^2 10^3$ Net shear sectional area, in cm²: $A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$	Web net thickness: $t = 1,63 + 0,004\ L\ (k_0 k)^{0,5} + 4,5\ s$
Deck transverses	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \dfrac{p}{m R_y} S \ell^2 10^3$ Net shear sectional area, in cm²: $A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} S \ell$	Web net thickness: $t = 3,8 + 0,016\ L\ (k_0 k)^{0,5}$
Deck girders	Net section modulus, in cm³: $w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} S \ell^2 10^3$ Net shear sectional area, in cm²: $A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} S \ell$	Web net thickness: $t = 3,8 + 0,016\ L\ (k_0 k)^{0,5}$

Note 1:

λ :   Coefficient taken equal to:

- In service conditions
  for longitudinally framed bottom $\lambda = \lambda_L$

  $\lambda_L = \sqrt{1 - 0,95\left(\gamma_m \dfrac{\sigma_{x1}}{R_y}\right)^2} - 0,225 \gamma_m \dfrac{\sigma_{x1}}{R_y}$

  for transversely framed bottom $\lambda = \lambda_T$

  $\lambda_T = 1 - 0,89 \gamma_m \dfrac{\sigma_{x1}}{R_y}$

- In testing and flooding conditions
  $\lambda = 1$, in general

4 Sternframes

4.1 General

4.1.1 Sternframes may be made of cast or forged steel, with a hollow section, or fabricated from plate.

4.2 Connections

4.2.1 Heel

Sternframes are to be effectively attached to the aft structure. The propeller post heel is to extend forward over a length, in m, including the scarf, at least equal to:

$$d = 0,01\ L + 0,6 \quad \text{with } 1,2 \leq d \leq 1,8$$

in order to provide an effective connection with the keel. However, the sternframe need not extend beyond the after peak bulkhead.

The value of d may, however, be reduced to 1 m where no centreline propeller is fitted.

4.2.2 Connection with hull structure

The thickness of shell plating connected with the sternframe is to be not less than the rule thickness of the bottom plating amidships.

4.2.3 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.

4.2.4 Connection with transom floors

Propeller post and rudder post should in their upper part be led and connected in suited and safe manner to the vessel structure. In the range where the forces of the rudder post are led into the vessel structure, the shell plating has to be strengthened.

The shape of the vessel's stern, the thickness of the rudder and of the propeller well should be such that forces coming from the propeller are as small as possible.

In vessel's transverse direction, the propeller post has to be fastened to strengthened and higher floor plates, which are connected by a longitudinal girder in plane of the propeller post over a range of several frames. Plates of longitudinal webs supporting floorplates, which the propeller post is directly connected to, should have a thickness of 0,30 times the thickness of the bar propeller post according to [4.3.1].

4.2.5 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.

4.3 Propeller posts

4.3.1 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 and twin screw vessels.

These scantlings are to be maintained from the bottom to above the propeller boss. At the upper part, the scantlings may be reduced gradually to those of the rudder post, where the latter joins the propeller post.

In vessels having a high engine power with respect to their size, or subjected to abnormal stresses, strengthening of the propeller post may be called for by the Society.

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.

4.3.2 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 8, Sec 2, [3.4.1].

4.4 Propeller shaft bossing

4.4.1 Thickness

In single screw vessels, the thickness of the propeller shaft bossing, included in the propeller post, in mm, is to be not less than:

$$t = 6\sqrt{fk_0 k(0,7L+6)} \qquad \text{for} \quad L \leq 40$$
$$t = 6\sqrt{fk_0 k(L-6)} \qquad \text{for} \quad L > 40$$

where:
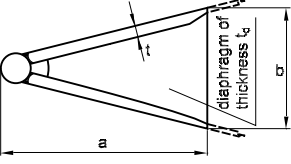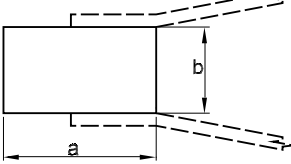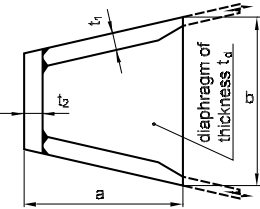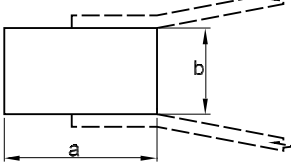
f : Coefficient defined in the head of the Section.

4.5 Stern tubes

4.5.1 The stern tube thickness is to be considered by the Society on a case by case basis. In no case, it may be less than the thickness of the side plating adjacent to the sternframe.

Where the materials adopted for the stern tube and the plating adjacent to the sternframe are different, the stern tube thickness is to be at least equivalent to that of the plating.

Table 9 : Gross scantlings of propeller posts

Single screw vessels		Twin screw vessels	
Fabricated propeller post	Bar propeller post, cast or forged, having rectangular section	Fabricated propeller post	Bar propeller post, cast or forged, having rectangular section
a (mm) = 29 $L^{1/2}$	a (mm) = 14,1 $A^{1/2}$	a (mm) = 29 $L^{1/2}$	a (mm) = 14,1 $A^{1/2}$
b/a = 0,7	b/a = 0,5	b/a = 0,7	b/a = 0,5
t (mm) = 2,5 $(k_0 kL)^{1/2}$ with t ≥ 1,3 $t_{bottom\ midship}$	thickness: NA	t_1 (mm) = 2,5 $(k_0 kL)^{1/2}$ with t_1 ≥ 1,3 $t_{bottom\ midship}$ t_2 (mm) = 3,2 $(k_0 kL)^{1/2}$ with t_2 ≥ 1,3 $t_{bottom\ midship}$	thickness: NA
sectional area: NA	for L ≤ 40:A(cm^2) =f(1,4k_0k L+12) for L > 40: A(cm^2) =f(2 k_0kL−12)	sectional area: NA	A (cm^2) = f(0,005 k_0kL^2 + 20)
t_d (mm) = 1,3 $(k_0 kL)^{1/2}$	t_d : NA	t_d (mm) = 1,3 $(k_0 kL)^{1/2}$	t_d : NA
Note 1: f : Coefficient defined in the head of the Section A : Sectional area, in cm^2, of the propeller post. **Note 2:** NA = not applicable.			

SECTION 3   MACHINERY SPACE

Symbols

A_{sh} : Net shear sectional area, in cm^2

C_a : Aspect ratio, equal to:

$$C_a = 1,21 \sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell} \le 1$$

C_r : Coefficient of curvature:

$$C_r = 1 - 0,5\frac{s}{r} \ge 0,5$$

where:

r : Radius of curvature, in m

I_Y : Moment of inertia, in cm^4, of the hull girder transverse section defined in Ch 4, Sec 1, [2.1], about its horizontal neutral axis

k : Material factor defined in:
- Ch 2, Sec 3, [2.3] for steel
- Ch 2, Sec 3, [3.5] for aluminium alloys

k_0 : Coefficient to be taken equal to:
- $k_0 = 1$ for steel
- $k_0 = 2,35$ for aluminium alloys

M_H : Design still water bending moment in hogging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_S : Design still water vertical bending moment in sagging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_{WV} : Vertical wave bending moment, in kN.m, defined in Ch 3, Sec 2, [3.2]

m : Boundary coefficient to be taken, in general, equal to:
- m = 12 for ordinary stiffeners
- m = 8 for primary supporting members

Other values of m may be considered, on a case by case basis, for other boundary conditions

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section

n : Navigation coefficient defined in Ch 3, Sec 1, [5.2]

p : Design load, in kN/m^2

R_y : Minimum yield stress, in N/mm^2, of the material to be taken equal to:
- $R_y = 235/k$ N/mm^2 for steel
- $R_y = 100/k$ N/mm^2 for aluminium alloys

unless otherwise specified

S : Spacing, in m, of primary supporting members

s : Spacing, in m, of ordinary stiffeners

t : Thickness, in mm, of plating

w : Net section modulus, in cm^3, of ordinary stiffeners or primary supporting members

z : Z co-ordinate, in m, of the calculation point of a structural element

β_b, β_s : Span correction coefficients defined in Ch 2, Sec 4, [5.2]

γ_{W1} : Partial safety factor covering uncertainties regarding wave hull girder loads
- $\gamma_{W1} = 1,0$ for **IN**
- $\gamma_{W1} = 1,15$ for **IN(x ≤ 2)**

γ_{W2} : Partial safety factor covering uncertainties regarding wave local loads
- $\gamma_{W2} = 1,0$ for **IN**
- $\gamma_{W2} = 1,2$ for **IN(x ≤ 2)**

γ_R : Partial safety factor covering uncertainties regarding resistance, defined in Tab 1

γ_m : Partial safety factor covering uncertainties regarding material: $\gamma_m = 1,02$

η : Coefficient taken equal to: $\eta = 1 - s/(2\ell)$

λ_b, λ_s : Coefficients for pressure distribution correction defined in Ch 2, Sec 4, [6.3]

ℓ : Span, in m, of ordinary stiffeners or primary supporting members defined in Ch 2, Sec 4, [4.2] or Ch 2, Sec 4, [5.2].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to scantling and arrangement of machinery space structures for all vessels made of steel or aluminium alloy.

As to the requirements which are not explicitly dealt with in the present Section, refer to the previous Chapters.

1.1.2 Alternative arrangements and scantlings on the basis of direct calculations are to be submitted to the Society on a case by case basis.

1.1.3 Buckling strength check

The buckling strength check of plating, stiffeners and primary supporting members is to be performed according to the applicable requirements of Ch 2, Sec 7.

1.1.4 Vessels with length L < 40 m

On vessels with machinery space located in the aft part, where alternative requirements in Ch 5, Sec 6 have been adopted for the vessel central part, the associated machinery space structure scantlings are to be determined from this Section considering a hull girder normal stress $\sigma_{X1} = 0$.

1.2 Net scantlings

1.2.1 As specified in Ch 2, Sec 5, all scantlings referred to in this Section are net scantlings, i.e. they do not include any margin for corrosion.

1.3 Resistance partial safety factor

1.3.1 The resistance partial safety factor γ_R to be considered for the checking of the fore part structures is specified in Tab 1.

Table 1 : Resistance partial safety factor γ_R

Machinery space structures	Plating	Ordinary stiffeners	Primary supporting members
In general			
Bottom and side girders **(1)**	1,20	1,02	1,15
Other primary supporting members			1,02
In testing / flooding conditions			
All structures	1,05	1,02	1,02
(1) Includes bottom girders, bottom transverses, reinforced floors, side stringers, side transverses and web frames.			

1.4 Connections of the machinery space with the structures located aft and forward

1.4.1 Tapering

Adequate tapering is to be ensured between the scantlings in the machinery space and those located aft and forward. The tapering is to be such that the scantling requirements for all areas are fulfilled.

1.4.2 Deck discontinuities

a) Decks which are interrupted in the machinery space are to be tapered on the side by means of horizontal brackets.

   Where the deck is inclined, the angle of inclination is to be limited. The end of slope is to be located in way of reinforced ring.

b) Where the inclination of deck is limited by transverse bulkheads, the continuity of the longitudinal members is to be ensured.

   In way of breaks in the deck, the continuity of longitudinal strength is to be ensured. To that effect, the stringer of the lower deck is to:

   • extend beyond the break, over a length at least equal to three times its width

   • stop at a web frame of sufficient scantlings.

c) At the ends of the sloped part of the deck, suitable arrangements are required to take into account the vertical component of the force generated in the deck.

1.5 Arrangements

1.5.1 Every engine room must normally have two exits. The second exit may be an emergency exit. If a skylight is permitted as an escape, it must be possible to open it from the inside. See also Pt C, Ch 4, Sec 5, [3.1].

1.5.2 For the height of entrances to machinery space, see Ch 2, Sec 1, [5.4].

2 Design loads

2.1 Local loads

2.1.1 Strength check in service conditions
The design pressure in service conditions is to be determined in compliance with applicable requirements of Ch 3, Sec 4.

2.1.2 Strength check in flooding conditions
The design pressure in flooding conditions is to be determined according to Ch 3, Sec 4, [4].

2.1.3 Strength check in testing conditions
The lateral pressure in testing conditions is taken equal to:
- $p_{ST} - p_S$ for bottom and side structures, if the testing is carried out afloat
- p_{ST} otherwise

where:

p_{ST} : Testing pressure defined in Ch 3, Sec 4, [5]

p_S : Still water river pressure defined in Ch 3, Sec 4, [2.1] for the draught T_1 at which the testing is carried out

      If T_1 is not known, it may be taken as specified in Ch 3, Sec 1, [2.4.3].

2.2 Hull girder normal stresses

2.2.1 The requirements in Pt D, Ch 2, Sec 12, [4.2] apply in addition to vessels assigned the range of navigation **IN(1,2 < x ≤ 2)**.

2.2.2 The hull girder normal stresses to be considered for the strength check of plating, ordinary stiffeners and primary supporting members are obtained, in N/mm2, from the following formulae:
- in general: $\sigma_{X1} = \sigma_{S1} + \gamma_{W1} C_{FV}\, \sigma_{WV1}$
- for structural members not contributing to the hull girder longitudinal strength: $\sigma_{X1} = 0$

Table 2 : Combination factors C_{FV}

Load case	C_{FV}
"a"	0
"b"	1,0
"c"	Except vessels assigned a range of navigation **IN(1,2 < x ≤ 2)**, the hull girder wave loads in inclined condition may generally be disregarded.
"d"	
Flooding	0,6

Table 3 : Hull girder normal stresses - Plating subjected to lateral loads

Condition	σ_{S1}, in N/mm² (1)	σ_{WV1}, in N/mm²
$\dfrac{M_S + \gamma_W \gamma_{W1} C_{FV} M_{WV}}{M_H + \gamma_W \gamma_{W1} C_{FV} M_{WV}} \geq 1$	$\left\|\dfrac{M_S}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
$\dfrac{M_S + \gamma_W \gamma_{W1} C_{FV} M_{WV}}{M_H + \gamma_W \gamma_{W1} C_{FV} M_{WV}} < 1$	$\left\|\dfrac{M_H}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
(1) When the vessel in still water is always in hogging condition, M_S is to be taken equal to 0. **Note 1:** • For range of navigation **IN**, $\gamma_W = 1{,}00$ • For range of navigation **IN(x ≤ 2)**, $\gamma_W = 0{,}625$		

Table 4 : In-plane hull girder compression normal stresses - Plating

Condition	σ_{S1}, in N/mm²	σ_{WV1}, in N/mm²
$z \geq N$	$\left\|\dfrac{M_S}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
$z < N$	$\left\|\dfrac{M_H}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
Note 1: • For range of navigation **IN**, $\gamma_W = 1{,}00$ • For range of navigation **IN(x ≤ 2)**, $\gamma_W = 0{,}625$		

Table 5 : Hull girder normal stresses -
Ordinary stiffeners and primary supporting members subjected to lateral pressure

Condition	σ_{S1}, in N/mm² (1)	σ_{WV1}, in N/mm²
Lateral pressure applied on the side opposite to the ordinary stiffener, with respect to the plating: • $z \geq N$ in general $z < N$ for stiffeners simply supported at both ends	$\left\|\dfrac{M_S}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
• $z < N$ in general $z \geq N$ for stiffeners simply supported at both ends	$\left\|\dfrac{M_H}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
Lateral pressure applied on the same side as the ordinary stiffener: • $z \geq N$ in general $z < N$ for stiffeners simply supported at both ends	$\left\|\dfrac{M_H}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
• $z < N$ in general $z \geq N$ for stiffeners simply supported at both ends	$\left\|\dfrac{M_S}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\|10^{-3}$
(1) When the vessel in still water is always in hogging condition, M_S is to be taken equal to 0. **Note 1:** • For range of navigation: **IN**, $\gamma_W = 1{,}00$ • For range of navigation: **IN(x ≤ 2)**, $\gamma_W = 0{,}625$		

where:

σ_{S1}, σ_{WV1}:   Hull girder normal stresses, in N/mm², defined in:
- Tab 3, for plating subjected to lateral loads
- Tab 4, for plating in-plane hull girder compression normal stresses
- Tab 5, for ordinary stiffeners and primary supporting members subjected to lateral pressure

C_{FV} :   Combination factors defined in Tab 2.

3   Hull scantlings

3.1   Shell plating

3.1.1 Where the machinery space is located aft, the shell plating thickness is to be determined as specified in Tab 6.

Otherwise, the requirements of Ch 5, Sec 2, Ch 5, Sec 3 and Ch 5, Sec 4 are to be complied with.

Table 6 : Hull plating net scantlings

Item	Transverse framing	Longitudinal framing
Bottom plating	$t = \max(t_1, t_2)$ $t_1 = 1{,}85 + 0{,}03\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ $t_2 = 17{,}2\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t = \max(t_1, t_2)$ $t_1 = 1{,}1 + 0{,}03\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ $t_2 = 14{,}9\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$
Side plating	$t = \max(t_1, t_2)$ $t_1 = 1{,}68 + 0{,}025\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ $t_2 = 17{,}2\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t = \max(t_1, t_2)$ $t_1 = 1{,}25 + 0{,}02\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ $t_2 = 14{,}9\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$
Deck plating	$t = \max(t_1, t_2)$ $t_1 = 0{,}9 + 0{,}034\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ $t_2 = 17{,}2\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t = \max(t_1, t_2)$ $t_1 = 0{,}57 + 0{,}031\,L\,(k_0 k)^{0,5} + 3{,}6\,s$ $t_2 = 14{,}9\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$

Note 1:

$$\lambda_L = \sqrt{1 - 0{,}95\left(\gamma_m \frac{\sigma_{x1}}{R_y}\right)^2} - 0{,}225\,\gamma_m \frac{\sigma_{x1}}{R_y}$$

$$\lambda_T = 1 - 0{,}89\,\gamma_m \frac{\sigma_{x1}}{R_y}$$

Note 2: In testing and flooding conditions

$$t_2 = 14{,}9\,C_a C_r s \sqrt{\frac{\gamma_R \gamma_m p}{R_y}}$$

Table 7 : Hull structural member net scantlings

Item		Strength characteristic **(1)**	Minimum web thickness
Bottom longitudinals Side longitudinals Deck longitudinals		$w = \dfrac{\gamma_R \gamma_m \beta_b p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} s\ell^2 10^3$ $A_{sh} = 10\,\gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$	• for $L < 120$ m: $t = 1{,}63 + 0{,}004\,L\,(k_0 k)^{0,5} + 4{,}5\,s$ • for $L \geq 120$ m: $t = 3{,}9\,(k_0 k)^{0,5} + s$
Deck beams		$w = \gamma_R \gamma_m \beta_b \dfrac{p}{m R_y} s\ell^2 10^3$ $A_{sh} = 10\,\gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta s \ell$	• for $L < 120$ m: $t = 1{,}63 + 0{,}004\,L\,(k_0 k)^{0,5} + 4{,}5\,s$ • for $L \geq 120$ m: $t = 3{,}9\,(k_0 k)^{0,5} + s$
Floors Bottom transverses/reinforced floors Deck transverses **(2)**		$w = \gamma_R \gamma_m \beta_b \dfrac{p}{m R_y} a\ell^2 10^3$ $A_{sh} = 10\,\gamma_R \gamma_m \beta_s \dfrac{p}{R_y} \eta a \ell$	$t = 3{,}8 + 0{,}016\,L\,(k_0 k)^{0,5}$
Side frames	• if $\ell_0 \leq \ell$	$w = \gamma_R \gamma_m \beta_b \dfrac{s}{m R_y}(6\ell\ell_0^2 + 1{,}45\lambda_W p_F \ell_F^2)10^3$ $A_{sh} = 68\,\gamma_R \gamma_m \beta_s \dfrac{\ell}{R_y} \eta s \ell_0$	• for $L < 120$ m: $t = 1{,}63 + 0{,}004\,L\,(k_0 k)^{0,5} + 4{,}5\,s$ • for $L \geq 120$ m: $t = 3{,}9\,(k_0 k)^{0,5} + s$
	• if $\ell_0 > \ell$	$w = \gamma_R \gamma_m \beta_b \dfrac{s}{m R_y}(\lambda_b p\ell^2 + 1{,}45\lambda_W p_F \ell_F^2)10^3$ $A_{sh} = 10\,\gamma_R \gamma_m \lambda_s \beta_s \dfrac{p}{R_y} \eta s \ell$	

Item		Strength characteristic **(1)**	Minimum web thickness
Side web frames Side transverses	• if $\ell_0 \leq \ell$	$w = 6\gamma_R\gamma_m\beta_b\dfrac{\ell}{mR_y}S\ell_0^2 10^3$ $A_{sh} = 68\gamma_R\gamma_m\beta_s\dfrac{\ell}{R_y}S\ell_0$	$t = 3,8 + 0,016\ L\ (k_0k)^{0,5}$
	• if $\ell_0 > \ell$	$w = \gamma_R\gamma_m\lambda_b\beta_b\dfrac{p}{mR_y}S\ell^2 10^3$ $A_{sh} = 10\gamma_R\gamma_m\lambda_s\beta_s\dfrac{p}{R_y}S\ell$	$t = 3,8 + 0,016\ L\ (k_0k)^{0,5}$
Side stringers		$w = \dfrac{\gamma_R\gamma_m\beta_b p}{m(R_y - \gamma_R\gamma_m\sigma_{X1})}S\ell^2 10^3$ $A_{sh} = 10\gamma_R\gamma_m\beta_s\dfrac{p}{R_y}S\ell$	$t = 3,8 + 0,016\ L\ (k_0k)^{0,5}$
Bottom girders		$w = \dfrac{\gamma_R\gamma_m\beta_b p}{m(R_y - \gamma_R\gamma_m\sigma_{X1})}b\ell^2 10^3$ $A_{sh} = 10\gamma_R\gamma_m\beta_s\dfrac{p}{R_y}b\ell$	$t = 3,8 + 0,016\ L\ (k_0k)^{0,5}$

(1) w : Net section modulus, in cm³
     A_{sh} : Net shear sectional area, in cm².
(2) $\eta = 1$ for transverses and reinforced floors
Note 1:
a   : Structural member spacing, in m:
             a = s for floors
             a = S for transverses and reinforced floors
p_F : Floor design load, in kN/m²
ℓ_0 : Span parameter, in m:
             $\ell_0 = p_d / 9,81$
p_d : Total pressure, in kN/m², at the lower end of the stiffener
ℓ_F : Floor span, in m
λ_W : In transverse framing system:
             $\lambda_W = 0,08$
             In combination framing system:
             $\lambda_W = 0$
b   : Bottom girder parameter, in m, to be obtained from the following formula:
             $b = \dfrac{B_1 - n_E S_E}{2(n_E + 1)} + \dfrac{S_E}{2}$
n_E : Number of engines
S_E : Spacing of longitudinal girders under main engines
B_1 : Width of the machinery space, in m.

3.2 Shell structure

3.2.1 Where the machinery space is located aft, the scantlings of ordinary stiffeners and primary supporting members are to be as required by Tab 7.

Otherwise, the requirements of Ch 5, Sec 2, Ch 5, Sec 3 and Ch 5, Sec 4 are to be complied with.

3.3 Topside structure

3.3.1 The scantlings and arrangement of the topside structure are to be in compliance with Ch 5, Sec 4, [3.1] and Ch 5, Sec 4, [3.3].

4 Bottom structure

4.1 General

4.1.1 Where the hull is shaped, the bottom is to be transversely framed. In all other cases, it may be transversely or longitudinally framed.

4.2 Transversely framed bottom

4.2.1 Arrangement of floors

Where the bottom in the machinery space is transversely framed, floors are to be arranged at every frame. Furthermore, reinforced floors are to be fitted in way of important

machinery and at the end of keelsons not extending up to the transverse bulkhead.

The floors are to be fitted with welded face plates, which are preferably to be symmetrical. Flanges are forbidden.

4.3 Longitudinally framed bottom

4.3.1 Arrangement of transverses

Where the bottom in the machinery space is longitudinally framed, transverses are to be arranged every 4 frame spacings. Additional transverses are to be fitted in way of important machinery.

The bottom transverses are to be fitted with welded face plates, which are preferably to be symmetrical. Flanges are forbidden.

5 Side structure

5.1 General

5.1.1 The type of side framing in machinery spaces is generally to be the same as that adopted in the adjacent areas. In any case, it is to be continuous over the full length of the machinery space.

5.2 Transversely framed side

5.2.1 Web frames

In vessels built on transverse system, web frames 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.

The mean web frame spacing in the machinery space is in general not more than 5 frame spacings.

5.2.2 Side stringers

In the machinery space, where the mean value of the depth exceeds 2 m, a side stringer is generally to be fitted at half the vessel's depth. Its scantlings are to be the same as those of the web frames.

The plate connecting the stringer to the shell plating is to be an intercostal plate between web frames.

Stringer strength continuity in way of the web frames is to be obtained by a suitable assembly.

Stringers located in fuel bunkers are determined in the same way as bulkhead stringers.

In the case a side stringer is fitted in the engine room, it is to be continued behind the aft bulkhead by a bracket at least over two frame spacings.

5.3 Longitudinally framed side

5.3.1 Extension of the hull longitudinal structure within the machinery space

For vessels 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.

5.3.2 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.

The side transverse spacing is to be not greater than 4 frame spacings.

6 Machinery casing

6.1 Arrangement

6.1.1 Ordinary stiffener spacing

Ordinary stiffeners are to be located:

- at each frame, in longitudinal bulkheads
- at a distance of not more than 750 mm, in transverse bulkheads.

6.2 Openings

6.2.1 General

All machinery space openings, which are to comply with the requirements in Ch 2, Sec 1, [5], are to be enclosed in a steel casing leading to the highest open deck. Casings are to be reinforced at the ends by deck transverses 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.

6.2.2 Access doors

Access doors to casings are to comply with Ch 2, Sec 1, [5.4].

6.3 Scantlings

6.3.1 Design loads

Design loads for machinery casing scantling are to be determined as stated under Ch 6, Sec 4, [4].

6.3.2 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 6, Sec 4.

7 Engine foundation

7.1 Arrangement

7.1.1 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.

7.1.2 Floors

Floor strength continuity is to be obtained as shown in Fig 1 or Fig 2, or according to any other method considered equivalent by the Society.

7.2 Scantlings

7.2.1 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 8.

7.2.2 Longitudinal girders

The net scantlings of longitudinal girders in way of engine foundation are not to be less than the values derived from Tab 8.

The section modulus of longitudinal girders in way of engine foundation may be reduced when additional bottom girders are provided over the full length of the engine room.

7.2.3 Floors

The net scantlings of floors in way of the engine foundation, are not to be less than the values derived from Tab 8.

The section modulus of the floors in the section A-A (see Fig 1 and Fig 2) is to be at least 0,6 times that determined according to the formula given in Tab 8.

7.2.4 Bottom plating

The minimum net thickness of bottom plating in way of engine foundation is given in Tab 8.

7.2.5 Longitudinal girders

The longitudinal girders under the engine are to extend over the full length of the engine room and extend beyond the bulkheads, at least for one frame spacing, by means of thick brackets.

Where such an arrangement is not practicable aft, because of the lines, the girders may end at a deep floor strengthened to that effect and in way of which the frames are to be fitted.

As a rule, longitudinal girders under the engine are to be continuous and the floors are to be intercostal, except for large size engine rooms. Strength continuity is anyhow to be ensured over the full girder length. More specially, cutouts and other discontinuities are to be carefully compensated.

Figure 1 : Floor in way of main engine seating: 1st version
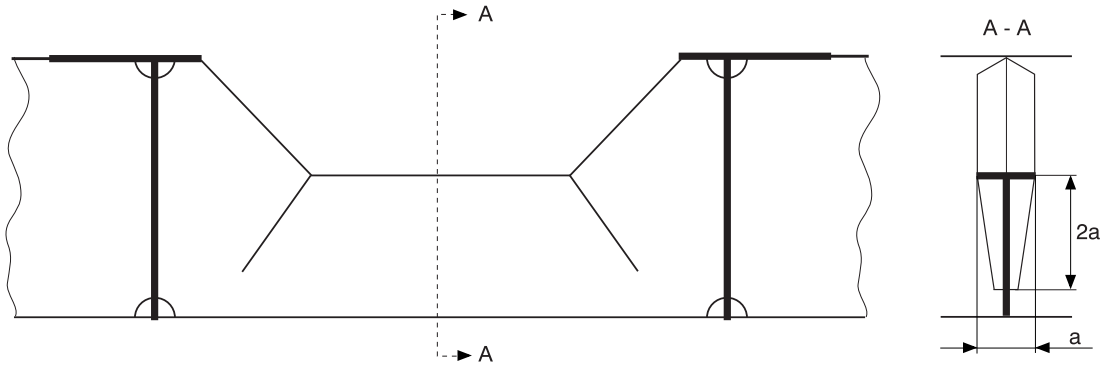
Figure 2 : Floor in way of main engine seating: 2nd version
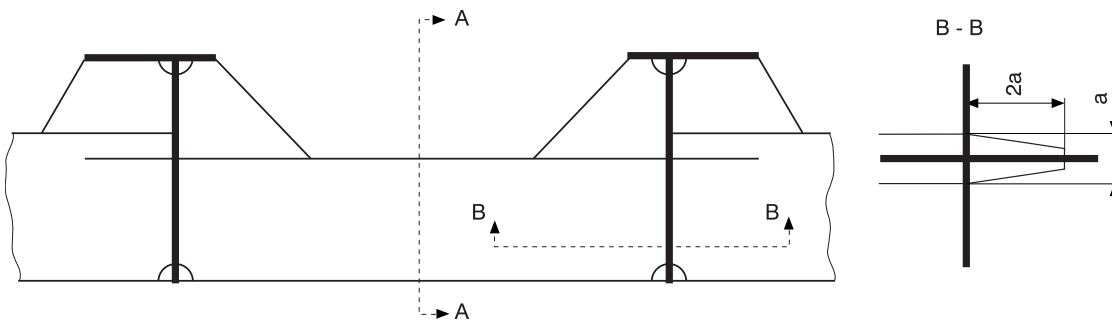
Table 8 : Minimum net scantlings of the structural elements in way of engine foundation

Foundation item	Strength characteristic
Cross-sectional area, in cm², of each bedplate of the seatings	$S = 40 + 70k_0 k \dfrac{P}{n_r L_E}$
Thickness, in mm, of each bedplate of the seatings	$t = \sqrt{240 + 175 k_0 k \dfrac{P}{n_r L_E}}$
Web thickness, in mm, of girders fitted in way of each bedplate of the seatings	$t = \sqrt{\left(95 + 65 k_0 k \dfrac{P}{n_r L_E}\right)}$
Section modulus of floors, in cm³	$w = \gamma_R \gamma_m \beta_b \dfrac{p}{m R_y} s \ell^2 10^3 + 175 k_0 k \dfrac{P}{n_r L_E}$
Web thickness, in mm, of transverse members fitted in way of bedplates of the seating	$t = \sqrt{55 + 40 k_0 k \dfrac{P}{n_r L_E}}$
Thickness of bottom plating, in mm	$t = t_0 + 2, 3 \dfrac{P}{n_r} \sqrt{k_0 k}$
Note 1: 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 t_0 : Net thickness of the bottom plating, in mm, in the central part.	

SECTION 4   SUPERSTRUCTURES AND DECKHOUSES

Symbols

A_{sh} : Net shear sectional area, in cm²

C_a : Aspect ratio, equal to:

$$C_a = 1,21\sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell} \leq 1$$

C_r : Coefficient of curvature:

$$C_r = 1 - 0,5\frac{s}{r} \geq 0,5$$

where:

r : Radius of curvature, in m

k : Material factor defined in:
- Ch 2, Sec 3, [2.3] for steel
- Ch 2, Sec 3, [3.5] for aluminium alloys

k_0 : Coefficient to be taken equal to:
- $k_0 = 1$ for steel
- $k_0 = 2,35$ for aluminium alloys

I_Y : Moment of inertia, in cm⁴, of the hull girder transverse section defined in Ch 4, Sec 1, [2.1], about its horizontal neutral axis

M_H : Design still water bending moment in hogging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_S : Design still water vertical bending moment in sagging condition, in kN.m, defined in Ch 3, Sec 2, [1]

M_{WV} : Vertical wave bending moment, in kN.m, defined in Ch 3, Sec 2, [3.2]

m : Boundary coefficient to be taken, in general, equal to:
- m = 12 for ordinary stiffeners
- m = 8 for primary supporting members.

Other values of m may be considered, on a case by case basis, for other boundary conditions

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section

n : Navigation coefficient defined in Ch 3, Sec 1, [5.2]

p : Design load, in kN/m²

R_y : Minimum yield stress, in N/mm², of the material to be taken equal to:
- $R_y = 235/k$ N/mm² for steel
- $R_y = 100/k$ N/mm² for aluminium alloys

unless otherwise specified

S : Spacing, in m, of primary supporting members

s : Spacing, in m, of ordinary stiffeners

t : Thickness, in mm, of plating

w : Net section modulus, in cm³, of ordinary stiffeners or primary supporting members

z : Z co-ordinate, in m, of the calculation point of a structural element

β_b, β_s : Span correction coefficients defined in Ch 2, Sec 4, [5.2]

γ_R : Partial safety factor covering uncertainties regarding resistance, defined in Tab 1

γ_{W1} : Partial safety factor covering uncertainties regarding wave hull girder loads
- $\gamma_{W1} = 1,0$ for **IN**
- $\gamma_{W1} = 1,15$ for **IN(x ≤ 2)**

γ_{W2} : Partial safety factor covering uncertainties regarding wave local loads
- $\gamma_{W2} = 1,0$ for **IN**
- $\gamma_{W2} = 1,2$ for **IN(x ≤ 2)**

η : Coefficient taken equal to:

η = 1 − s / (2 l)

λ_b, λ_s : Coefficients for pressure distribution correction defined in Ch 2, Sec 4, [6.3]

ℓ : Span, in m, of ordinary stiffeners or primary supporting members defined in Ch 2, Sec 4, [4.2] or Ch 2, Sec 4, [5.2].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to scantling and arrangement of superstructures and deckhouses, which may or may not contribute to the longitudinal strength, on vessels made of steel or aluminium alloy.

As to the requirements which are not explicitly dealt with in the present Section, refer to the previous Chapters.

1.1.2 Buckling strength check

For superstructures and deckhouses contributing to the hull girder strength, the buckling strength check of plating, stiffeners and primary supporting members is to be performed according to the applicable requirements of Ch 2, Sec 7.

1.2 Definitions

1.2.1 Superstructures and deckhouses

Superstructures and deckhouses are defined in Ch 1, Sec 2, [2.8] and Ch 1, Sec 2, [2.9], respectively.

A closed deckhouse is a construction consisting of strong bulkheads permanently secured to the deck and made watertight. The openings are to be fitted with efficient weathertight means of closing.

Superstructures and deckhouses may be:

- closed, where they are enclosed by front, side and aft bulkheads complying with the requirements of this Section, the openings of which are fitted with weathertight means of closing

- open, where they are not enclosed.

1.2.2 Superstructures and deckhouses contributing to the longitudinal strength

A superstructure or deckhouse may be considered as contributing to the longitudinal strength if its deck satisfies the basic criteria given in Ch 4, Sec 1, [2.2].

1.2.3 Tiers of superstructures and deckhouses

The lowest tier is normally that which is directly situated above the strength deck defined in Ch 1, Sec 2, [2.10].

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

1.3 Net scantlings

1.3.1 All scantlings referred to in this Section are net scantlings, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 2, Sec 5.

1.4 Partial safety factors

1.4.1 The partial safety factors γ_R and γ_m to be considered for the checking of the superstructure and deckhouse structures are specified in Tab 1.

Table 1 : Superstructures and deckhouses Partial safety factors γ_R and γ_m

Uncertainties regarding:	Symbol	Plating	Ordinary stiffeners	Primary supporting members
Resistance	γ_R	1,20	1,02	1,02
Material	γ_m	1,02	1,02	1,02

2 Arrangements

2.1 Connections of superstructures and deckhouses with the hull structure

2.1.1 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.

2.1.2 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.

2.1.3 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.

2.1.4 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.

2.2 Structural arrangement of superstructures and deckhouses

2.2.1 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 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.

2.2.2 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.

2.2.3 Openings

Openings are to be in accordance with Ch 4, Sec 1, [2.1.6] Ch 4, Sec 1, [2.1.8].

Continuous coamings are to be fitted above and below doors or similar openings.

2.2.4 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.

2.2.5 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.

2.2.6 Gastight bulkheads

The accommodation shall be separated from engine rooms, boiler rooms and holds by gastight bulkheads.

2.2.7 Local reinforcements

Local reinforcements are to be foreseen in way of areas supporting cars or ladders.

3 Design loads

3.1 Local loads

3.1.1 Strength check in service conditions

The design pressure in service conditions is to be determined in compliance with applicable requirements of Ch 3, Sec 4.

The design pressure, in kN/m², on sides and external bulkheads is to be taken not less than:

$P = 2 + p_{WD}$

Where p_{WD} is the wind pressure defined in Ch 3, Sec 4, [2.1.3] Ch 3, Sec 4, [2.1.3].

3.2 Hull girder normal stresses

3.2.1 The requirements in Pt D, Ch 2, Sec 12, [4.2] apply in addition to vessels assigned the range of navigation **IN(1,2 < x ≤ 2)**.

3.2.2 The hull girder normal stresses to be considered for the strength check of plating, ordinary stiffeners and primary supporting members are obtained, in N/mm², from the following formulae:

- in general

    $\sigma_{X1} = \sigma_{S1} + \gamma_{W1} C_{FV} \, \sigma_{WV1}$

- for structural members not contributing to the hull girder longitudinal strength:

    $\sigma_{X1} = 0$

where:

$\sigma_{S1}, \sigma_{WV1}$: Hull girder normal stresses, in N/mm², defined in:

- Tab 3, for plating subjected to lateral loads

- Tab 4, for plating in-plane hull girder compression normal stresses

- Tab 8, for ordinary stiffeners and primary supporting members subjected to lateral pressure

C_{FV} : Combination factors defined in Tab 2.

Table 2 : Combination factors C_{FV}

Load case	C_{FV}
"a"	0
"b"	1,0
"c"	Except vessels assigned a range of navigation **IN(1,2 < x ≤ 2)**, the hull girder wave loads in inclined condition may generally be disregarded.
"d"	

Table 3 : Hull girder normal stresses - Plating subjected to lateral loads

Condition	σ_{S1}, in N/mm² **(1)**	σ_{WV1}, in N/mm²
$\dfrac{M_S + \gamma_W \gamma_{W1} C_{FV} M_{WV}}{M_H + \gamma_W \gamma_{W1} C_{FV} M_{WV}} \geq 1$	$\left\|\dfrac{M_S}{I_Y}(z-N)\right\| 10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\| 10^{-3}$
$\dfrac{M_S + \gamma_W \gamma_{W1} C_{FV} M_{WV}}{M_H + \gamma_W \gamma_{W1} C_{FV} M_{WV}} < 1$	$\left\|\dfrac{M_H}{I_Y}(z-N)\right\| 10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\| 10^{-3}$

(1) When the vessel in still water is always in hogging condition, M_S is to be taken equal to 0.
Note 1:
- For range of navigation **IN**, $\gamma_W = 1,00$
- For range of navigation **IN(x ≤ 2)**, $\gamma_W = 0,625$

Table 4 : In-plane hull girder compression normal stresses - Plating

Condition	σ_{S1}, in N/mm²	σ_{WV1}, in N/mm²
$z \geq N$	$\left\|\dfrac{M_S}{I_Y}(z-N)\right\| 10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\| 10^{-3}$
$z < N$	$\left\|\dfrac{M_H}{I_Y}(z-N)\right\| 10^{-3}$	$\left\|\dfrac{\gamma_W M_{WV}}{I_Y}(z-N)\right\| 10^{-3}$

Note 1:
- For range of navigation **IN**, $\gamma_W = 1,00$
- For range of navigation **IN(x ≤ 2)**, $\gamma_W = 0,625$

4 Scantlings

4.1 Scantling requirements

4.1.1 General

The Society may ask additional arrangements deemed necessary in order to keep, in acceptable limits, the level of stresses liable to occur in the superstructure structural members.

4.1.2 Web plating of ordinary stiffeners

The net thickness, in mm, of the web plating of ordinary stiffeners is not to be less than:

- for $L < 120$ m: $t = 1,63 + 0,004\ L\ (k_0 k)^{0,5} + 4,5\ s$

- for $L \geq 120$ m: $t = 3,9\ (k_0 k)^{0,5} + s$

Table 5 : Net scantlings for non-contributing superstructures and deckhouses

Item	Strength characteristic	Scantling
Plating of sides Plating of aft end bulkheads Plating of not exposed deck	thickness, in mm	$t = \max\ (t_1\ ;\ t_2)$ $t_1 = 3,5 + 0,01\ L\ (k_0 k)^{0,5}$ $t_2 = 11\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{R_y}}$
Plating of exposed decks Plating of front bulkheads	thickness, in mm	$t = \max\ (t_1\ ;\ t_2)$ $t_1 = 4 + 0,01\ L\ (k_0 k)^{0,5}$ $t_2 = 14,9\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{R_y}}$
Ordinary stiffeners	section modulus, in cm³	$w = k_1 \gamma_R \gamma_m \beta_b \dfrac{p}{m R_y} s \ell^2 10^3$
Primary supporting members	section modulus, in cm³	$w = k_1 \gamma_R \gamma_m \beta_b \dfrac{p}{m R_y} S \ell^2 10^3$
Note 1: k_1 : • in general: $k_1 = 1$ • for vertical stiffeners: $k_1 = 1 + 0,1\ n_t$ n_t : Number of tiers above the tier considered.		

Table 6 : Plating net thickness, in mm, for contributing superstructures and deckhouses

Item	Transverse framing	Longitudinal framing
Side plating	$t = \max\ (t_1\ ;\ t_2)$ $t_1 = 1,68 + 0,025\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 17,2\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t = \max\ (t_1\ ;\ t_2)$ $t_1 = 1,25 + 0,02\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 14,9\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$
Deck plating	$t = \max\ (t_1\ ;\ t_2)$ $t_1 = 0,9 + 0,034\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 17,2\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_T R_y}}$	$t = \max\ (t_1\ ;\ t_2)$ $t_1 = 0,57 + 0,031\ L\ (k_0 k)^{0,5} + 3,6\ s$ $t_2 = 14,9\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{\lambda_L R_y}}$
Plating of aft end bulkheads	$t = \max\ (t_1\ ;\ t_2)$ $t_1 = 3,5 + 0,01\ L\ (k_0 k)^{0,5}$ $t_2 = 14,9\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{R_y}}$	
Plating of front bulkheads	$t = \max\ (t_1\ ;\ t_2)$ $t_1 = 4 + 0,01\ L\ (k_0 k)^{0,5}$ $t_2 = 14,9\,C_a C_r s \sqrt{\dfrac{\gamma_R \gamma_m p}{R_y}}$	
Note 1: $\lambda_L = \sqrt{1 - 0,95\left(\gamma_m \dfrac{\sigma_{X1}}{R_y}\right)^2} - 0,225\,\gamma_m \dfrac{\sigma_{X1}}{R_y}$ $\lambda_T = 1 - 0,89\,\gamma_m \dfrac{\sigma_{X1}}{R_y}$		

Table 7 : Structural member net scantlings for contributing superstructures

Item	w, in cm³	A_{Sh}, in cm²
Longitudinal ordinary stiffeners	$w = \gamma_R \gamma_m \beta_b \dfrac{p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} s\ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} s\ell$
Other ordinary stiffeners	$w = k_1 \gamma_R \gamma_m \beta_b \dfrac{p}{mR_y} s\ell^2 10^3$	
Longitudinal primary supporting members	$w = \gamma_R \gamma_m \beta_b \dfrac{p}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} S\ell^2 10^3$	$A_{sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{p}{R_y} S\ell$
Other primary supporting members	$w = k_1 \gamma_R \gamma_m \beta_b \dfrac{p}{mR_y} S\ell^2 10^3$	

Note 1:
k_1 : • $k_1 = 1,0$ in general
 • $k_1 = 1 + 0,1 \, n_t$ for vertical stiffeners,
 with n_t : Number of tiers above the tier considered

Table 8 : Hull girder normal stresses -
Ordinary stiffeners and primary supporting members subjected to lateral pressure

Condition	σ_{S1}, in N/mm² **(1)**	σ_{WV1}, in N/mm²
Lateral pressure applied on the side opposite to the ordinary stiffener, with respect to the plating:		
• $z \geq N$ in general $z < N$ for stiffeners simply supported at both ends	$\left\| \dfrac{M_S}{I_Y}(z-N) \right\| 10^{-3}$	$\left\| \dfrac{\gamma_W M_{WV}}{I_Y}(z-N) \right\| 10^{-3}$
• $z < N$ in general $z \geq N$ for stiffeners simply supported at both ends	$\left\| \dfrac{M_H}{I_Y}(z-N) \right\| 10^{-3}$	$\left\| \dfrac{\gamma_W M_{WV}}{I_Y}(z-N) \right\| 10^{-3}$
Lateral pressure applied on the same side as the ordinary stiffener:		
• $z \geq N$ in general ; $z < N$ for stiffeners simply supported at both ends	$\left\| \dfrac{M_H}{I_Y}(z-N) \right\| 10^{-3}$	$\left\| \dfrac{\gamma_W M_{WV}}{I_Y}(z-N) \right\| 10^{-3}$
• $z < N$ in general ; $z \geq N$ for stiffeners simply supported at both ends	$\left\| \dfrac{M_S}{I_Y}(z-N) \right\| 10^{-3}$	$\left\| \dfrac{\gamma_W M_{WV}}{I_Y}(z-N) \right\| 10^{-3}$

(1) When the vessel in still water is always in hogging condition, M_S is to be taken equal to 0.
Note 1:
• For range of navigation **IN**, $\gamma_W = 1,00$
• For range of navigation **IN(x ≤ 2)**, $\gamma_W = 0,625$

4.1.3 Web plating of primary supporting members

The net thickness, in mm, of plating which forms the web of primary supporting members is to be not less than the value obtained from the following formula:

$t = 3,8 + 0,016 \, L \, (k_0 k)^{0,5}$

4.1.4 Superstructures and deckhouses not contributing to the longitudinal strength

The net scantlings of superstructures and deckhouses not contributing to the longitudinal strength are to be derived from formulae given in Tab 5.

4.1.5 Superstructures and deckhouses contributing to the longitudinal strength

The net scantlings of superstructures contributing to the longitudinal strength are to be not less than those determined in accordance with Tab 6 and Tab 7.

5 Additional requirements applicable to movable wheelhouses

5.1 General

5.1.1 The structures of movable wheelhouses are to be checked in low and high position.

5.1.2 The lifting mechanism is to be designed in such a way that exceeding the terminal positions is not possible.

5.1.3 Mechanical locking devices are to be fitted in addition to hydraulic systems.

The supports or guide of movable wheelhouses, connections with the deck, under deck reinforcements and locking devices are to be checked considering the following forces:

a) Structural and non-structural inertial horizontal loads under vessel acceleration to be determined according to Ch 3, Sec 3, [2.1.4], where the roll amplitude is not to be taken less than 0,21 rad (12°)

b) Wind force, corresponding to a lateral pressure determined according to Ch 3, Sec 4, [2.1.3]

5.1.4 The wheelhouse can be fixed in different positions along the vertical axis, and the access to the wheelhouse shall be possible at any position.

Structural and non-structural still water horizontal loads under list or roll angle to be taken not less than 0,21 rad (12°)

During the movement of the wheelhouse, operations carried out from the wheelhouse shall not be hindered.

5.1.5 The safety of persons on board is to be guaranteed at any position of the wheelhouse.

Movements of the wheelhouse are to be signaled by optical and acoustic means.

5.1.6 In the case of emergency, it should be possible to lower the wheelhouse by means independent of the power drive. Emergency lowering of the wheelhouse is to be effected by its own weight and is to be smooth and control-lable. It should be possible from both inside and outside the wheelhouse and can be effected by one person under all conditions.

5.2 Arrangement

5.2.1 The hoisting mechanism is to be capable to hoist at least 1,5 times the weight of the wheelhouse fully equipped and manned.

5.2.2 The feed cables for systems inside the wheelhouse are to be arranged in such a way as to exclude the possibility of mechanical damage to them.

6 Elastic bedding of deckhouses

6.1 General

6.1.1 The structural members of elastically bedded deckhouses may, in general, be dimensioned in accordance with [4].

6.1.2 Strength calculations for the load bearing rails, elastic elements and antilift-off devices as well as for supporting structure of the deckhouse bottom and the hull are to be carried out assuming the following loads:

- vertical loads: $P = 1,2\ G$

- horizontal loads: $P = 0,3\ G$

where:

G   :   Total weight of the complete deckhouse, outfit and equipment included.

Additional loads due to vessel's heel need not be considered, in general.

SECTION 5   HATCH COVERS

Symbols

A_{sh} : Net shear sectional area, in cm²

h_2 : Reference value, in m, of the relative motion in the inclined vessel condition in Ch 3, Sec 3, [2.2.1]

m : Boundary coefficient, to be taken, in general, equal to:

  $m = 12$ for ordinary stiffeners

  $m = 8$ for primary supporting members

n : Navigation coefficient defined in Ch 3, Sec 1, [5.2]

R_y : Minimum yield stress, in N/mm², of the material to be taken equal to:

  • $R_y = 235/k$ N/mm² for steel

  • $R_y = 100/k$ N/mm² for aluminium alloys

  unless otherwise specified

S : Spacing of primary supporting members, in m

s : Spacing of ordinary stiffeners, in m

t : Net thickness, in mm

w : Net section modulus, in cm³, of ordinary stiffeners or primary supporting members

γ_m : Partial safety factor covering uncertainties regarding material

  $\gamma_m = 1,02$

ℓ : Span, in m, of ordinary stiffeners or primary supporting members.

1   General

1.1   Application

1.1.1 The requirements of this Section apply to hatchways which are closed with self-bearing hatch covers. These are to bear on coamings.

1.1.2 Hatch covers supported by hatchway beams and other supporting systems are to be considered by the Society on a case by case basis. In any case, they are to ensure the same degree of strength and weathertightness.

1.2   Definitions

1.2.1   Weathertightness

Weathertightness is ensured when, for all the navigation conditions envisaged, the closing devices are in compliance with Ch 2, Sec 2, [1.2.7].

Systems to ensure the weathertightness are mentioned in [2.1.3].

1.2.2   Watertightness

Watertightness is ensured when, for all the navigation conditions envisaged, the closing devices are in compliance with Ch 2, Sec 2, [1.2.8].

1.3   Materials

1.3.1 Hatch covers are to be made of steel or aluminium alloy. The use of other materials is to be considered by the Society on a case by case basis.

2   Arrangements

2.1   General

2.1.1   Hatch covers on exposed decks

Hatchways on exposed decks are to be fitted with weathertight hatch covers of adequate strength and rigidity.

The height of the hatch coaming above the deck h_C, in m, is to be such that:

$$z_{hc} \geq T + h_2 + 0,15$$

where:

z_{hc} : z co-ordinate, in m, of the top of hatch coaming.

2.1.2   Hatch covers in closed superstructures

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.

2.1.3   Weathertightness of hatch covers

The hatch cover tightness is not subjected to a test.

Tightness may be obtained by fitting of flanged metal hatchcovers which constitute baffles intended to prevent water penetrating into the hold below.

Hatch covers are to have a mean slope of not less than 0,1, unless they are covered by tarpaulins. Where tarpaulins are fitted, they are to have adequate characteristics of strength and weathertightness. The tarpaulin is to be secured by means of batten, cleats and wedges.

2.1.4   Securing of hatch covers

The positioning and securing of hatch covers are to be ensured by supports or guides of efficient construction. Where metallic broaches or bolts are used, their diameter is to be such that the mean shearing stress, under the action of design loads does not exceed 44 N/mm².

Efficient arrangements are to be made to prevent unexpected displacement or lifting of the hatch covers.

2.1.5 The width of each bearing surface for hatch covers is to be at least 65 mm.

2.1.6 Hatch covers carrying containers

The design, construction and arrangement of hatch covers carrying containers are to be in compliance with Pt D, Ch 1, Sec 4.

2.1.7 Hatch covers carrying wheeled loads

The design, construction and arrangement of hatch covers carrying wheeled loads are to be in compliance with Pt D, Ch 1, Sec 5.

3 Design loads

3.1 Design loads

3.1.1 General

The design loads to be considered for the scantling of hatch covers are, on one hand, the structural weight of the items themselves, and on the other, the expected deck load, if any, defined in [3.1.2].

3.1.2 Hatch covers carrying uniform cargoes

The pressure due to uniform load carried on hatch covers, in kN/m², is given by the formula:

$p = p_S + \gamma_{W2}\, p_W$

where:

p_S : Expected hatch cover still water pressure, in kN/m², to be defined by the Designer.
In any case, p_S is not to be taken less than:
$p_S = \max\,(1,5\,;\,31y - 1,5)$
whith:
y : Coefficient to be taken as:
- $y = 0,099$ fof **IN**
- $y = n$ for **IN(x ≤ 2)**

γ_{W2} : Partial safety factor covering uncertainties regarding wave local loads
- $\gamma_{W2} = 1,0$ for **IN**
- $\gamma_{W2} = 1,2$ for **IN(x ≤ 2)**

p_W : Inertial pressure, in kN/m²:

$$p_W = p_S \frac{a_{Z1}}{9,81}$$

with:

a_{Z1} : Reference value of the acceleration in Z direction, defined in Ch 3, Sec 3, [2.3].

4 Scantlings

4.1 Application

4.1.1 The following scantling rules are applicable to rectangular hatch covers subjected to a uniform pressure.

In the case of hatch covers arranged with primary supporting members as a grillage, the scantlings are to be determined by direct calculations.

4.2 Plating of hatch covers

4.2.1 Minimum net thickness of hatch covers

In any case, the thickness of hatch covers is not to be less than:

- for steel
  - galvanized steel: 2 mm
  - other cases: 3 mm.
- for aluminium alloys: 4,5 mm.

4.2.2 Net thickness of metal hatch covers

The net thickness of metal hatch covers subjected to lateral uniform load is not to be less than:

$$t = 16,3\,s\,\sqrt{\frac{\gamma_R \gamma_m p}{R_y}}$$

where:

γ_R : Partial safety factor covering uncertainties regarding resistance, equal to:

$\gamma_R = 1,20$

4.3 Stiffening members of hatch covers

4.3.1 Width of attached plating

The width of the attached plating is to be in compliance with Ch 2, Sec 4, [4.3] or Ch 2, Sec 4, [5.3], as applicable.

4.3.2 Minimum web thickness

The minimum thickness of the web of the stiffeners, in mm, is to be not less than the thickness of the plating of the hatch covers, given in [4.2].

4.3.3 Section modulus and shear sectional area

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of self-bearing hatch cover ordinary stiffeners and primary supporting members are not to be less than those obtained from the following formulae:

$$w = \frac{\gamma_R \gamma_m p}{m R_y} a \ell^2 10^3$$

$$A_{sh} = 10 \gamma_R \gamma_m \frac{p}{R_y} a \ell$$

where:

a : Stiffener spacing, in m:

a = s   for ordinary stiffeners

a = S   for primary supporting members

γ_R : Partial safety factor covering uncertainties regarding resistance, equal to:

$\gamma_R = 1,02$

SECTION 6   MOVABLE DECKS AND RAMPS

1 Movable decks and inner ramps

1.1 Materials

1.1.1 The movable decks and inner ramps are to be made of steel or aluminium alloys complying with the requirements of Ch 2, Sec 3. Other materials of equivalent strength may be used, subject to a case by case examination by the Society.

1.2 Net scantlings

1.2.1 As specified in Ch 2, Sec 5, [2]**, all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.**

The gross scantlings are to be obtained as specified in Ch 2, Sec 5, [2].

1.3 Plating

1.3.1 The net thickness of plate panels subjected to wheeled loads is not to be less than the value obtained from Pt D, Ch 1, Sec 5, [4.3], where $(n_P \cdot F)$ is not to be taken less than 50 kN,

with:

n_P :   Number of wheels on the plate panel, taken equal to:

- 1 in the case of a single wheel
- the number of wheels in the case of double or triple wheels

F :   Wheeled force, in kN.

1.4 Ordinary stiffeners

1.4.1 The net section modulus and the net shear sectional area of ordinary stiffeners subjected to wheeled loads are not to be less than the value obtained from Pt D, Ch 1, Sec 5, [4.4.1].

1.5 Primary supporting members

1.5.1 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 in navigation conditions
- movable deck in service, loaded, in lower position, resting on supports or supporting legs and locked in navigation conditions

- 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, in navigation conditions.

1.5.2 Loading cases

The scantlings of the structure are to be verified in both navigation 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/m^2, taken equal to $p_0 + p_1$
- empty movable deck under uniformly distributed masses corresponding to a pressure, in kN/m^2, taken equal to p_0,

where:

$$p_0 = \frac{P_P}{A_P}$$

$$p_1 = \frac{n_V P_V}{A_P}$$

P_P :   Weight of the movable deck or inner ramp, in kN

P_V :   Weight of a vehicle, in kN

n_V :   Maximum number of vehicles loaded on the movable deck or inner ramp

A_P :   Effective area of the movable deck or inner ramp, in m^2.

1.5.3 Lateral pressure

The lateral pressure is constituted by still water pressure and inertial pressure. The lateral pressure is to be obtained, in kN/m^2, from the following formula:

$$p = p_S + \gamma_{W2} \, p_W$$

where:

p_S, p_W :   Still water and inertial pressures transmitted to the movable deck or inner ramp structures, obtained, in kN/m^2, from Tab 1.

γ_{W2} :   Partial safety factor covering uncertainties regarding wave local loads

- $\gamma_{W2} = 1,0$ for **IN**
- $\gamma_{W2} = 1,2$ for **IN(x ≤ 2)**

1.5.4 Checking criteria

It is to be checked that the combined stress σ_{VM}, in N/mm^2, is in compliance with the criteria defined in Ch 2, Sec 8, [2.4.4], item c).

**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/m²	
Still water condition		$p_S = p_0$ in harbour condition during lifting $p_S = p_0 + p_1$ in other cases	
Upright navigation condition	"a"	No inertial pressure	
	"b"	$p_{W,X} = \dfrac{a_{X1}}{g}(p_0 + p_1)$	in x direction
		$p_{W,Z} = \dfrac{a_{Z1}}{g}(p_0 + \alpha p_1)$	in z direction
Inclined navigation condition (negative roll angle)	"c"	$p_{W,Y} = \dfrac{C_{FA}a_{Y2}}{g}(p_0 + p_1)$	in y direction
	"d"	$p_{W,Z} = \dfrac{C_{FA}a_{Z2}}{g}(p_0 + \alpha p_1)$	in z direction
Harbour condition (1)	during lifting	$p_{W,X} = 0{,}035\ p_0$ $p_{W,Y} = 0{,}087\ p_0$ $p_{W,Z} = 0{,}200\ p_0$	in x direction in y direction in z direction
	at rest	$p_{W,X} = 0{,}035\ (p_0 + p_1)$ $p_{W,Y} = 0{,}087\ (p_0 + p_1)$ $p_{W,Z} = 0{,}100\ (p_0 + p_1)$	in x direction in y direction 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.

Note 1:

p_0, p_1 : Pressures, in kN/m², to be calculated according to [1.5.2] for the condition considered

α : Coefficient taken equal to 0,5

a_{X1}, a_{Z1}, a_{Y2}, a_{Z2}: Reference values of the accelerations defined in Ch 3, Sec 3, Tab 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"

1.5.5 Allowable deflection

The scantlings of main stiffeners and the distribution of supports are to be such that the deflection of the movable deck or inner ramp does not exceed 5 mm/m.

1.6 Supports, suspensions and locking devices

1.6.1 Scantlings of supports and wire suspensions are to be determined by direct calculation on the basis of the loads in [1.5.2] and [1.5.3], taking account of a safety factor at least equal to 5.

1.6.2 It is to be checked that the combined stress σ_{VM}, in N/mm², in rigid supports and locking devices is in compliance with the criteria defined in Ch 2, Sec 8, [2.4.4], item c).

1.7 Tests and trials

1.7.1 Tests and trials defined in [1.7.2] to [1.7.4] 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.

1.7.2 The wire ropes are to be submitted to a tensile test on test-piece.

1.7.3 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 Certification of Lifting Appliances on board Ships and Offshore Units.

1.7.4 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 external ramps are to be able to operate with a heel angle of 5° and a trim angle of 2°.

2.1.2 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.

2.1.3 The external ramps are to be examined for their watertightness, if applicable.

2.1.4 The locking of external ramps in stowage position in navigation conditions is examined by the Society on a case by case basis.

2.1.5 The vessel's structure under the reactions due to the ramp is examined by the Society on a case by case basis.

SECTION 7   MISCELLANEOUS FITTINGS

Symbols

k : Material factor defined in:
- Ch 2, Sec 3, [2.3] for steel
- Ch 2, Sec 3, [3.5] for aluminium alloys

R_y : Minimum yield stress, in N/mm², of the material to be taken equal to:
- R_y= 235/k N/mm² for steel
- R_y= 100/k N/mm² for aluminium alloys

unless otherwise specified

s : Spacing, in m, of stiffeners

γ_R : Partial safety factor covering uncertainties regarding resistance
- γ_R =1,20, for plating
- γ_R =1,02, for ordinary stiffeners and primary supporting members

γ_m : Partial safety factor covering uncertainties regarding material: γ_m =1,02

ℓ : Span, in m, of stiffeners, defined in Ch 2, Sec 4, [4.2]

1 Sidescuttles, windows and skylights

1.1 General

1.1.1 Application
The requirements in [1.1] and [1.3] apply to sidescuttles and rectangular windows providing light and air, located on exposed hull structures.

1.1.2 Sidescuttle definition
Sidescuttles are round or oval openings with an area not exceeding 0,16 m². Round or oval openings having areas exceeding 0,16 m² are to be treated as windows.

1.1.3 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 m².

1.1.4 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 vessel.

1.2 Watertight sidescuttles and windows

1.2.1 General
Windows and sidescuttles may be situated below the bulkhead deck if they are watertight, cannot be opened and comply with [1.2.2] and [1.2.3], or equivalent requirements.

Only pre-stressed glass complying with International Standard ISO 614 :2012 shall be used.

1.2.2 Sidescuttles
The construction and strength of sidescuttles fitted below the bulkhead deck are to be in compliance with ISO 1751:2012, series B: medium heavy-duty windows type: non-opening windows.

1.2.3 Windows
The construction and strength of windows fitted below the bulkhead deck are to be in compliance with ISO 3903:2012, series E: heavy-duty windows type: non-opening windows.

1.2.4 Manholes and flush scuttles
Manholes and flush scuttles exposed to the weather 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.

1.3 Glasses

1.3.1 General
In general, toughened glasses or laminated 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.

1.3.2 Design loads
The design load, p, is to be determined in accordance with the applicable requirements of Ch 3, Sec 4, [2] or Ch 2, Sec 5, [3.1].

1.3.3 Scantling
The windows and sidescuttles scantling defined in this sub-article are equivalent to Standard ISO 11336-1:2012.

Window scantling defined in this Sub-article are provided for the following types of window:
- monolithic window (see [1.3.4])
- laminated window (see [1.3.5])
- double windows unit with gap (see [1.3.9]).

The edge condition of window and sidescuttle are considered as supported.

1.3.4 Thickness of monolithic windows
The thicknesses, in mm, of monolithic windows and sidescuttles are not to be less than 6 mm nor than the values obtained from the following formulae:

- rectangular window or sidescuttle:

$$t = 31,6s \sqrt{\frac{\beta p S_f}{R_m}}$$

- circular window or sidescuttle:

$$t = 17,4d \sqrt{\frac{p S_f}{R_m}}$$

where:

s : Shorter side, in m, of rectangular window or sidescuttle

d : Diameter, in m, of circular window or sidescuttle

β : Aspect ratio coefficient of the rectangular window or sidescuttle, defined in Tab 1, where:

ℓ : Longer side, in m, of rectangular window or sidescuttle

Where the window is supported only by 2 edges, β is to be taken equal to 1,0.

p : Design load, in kN/m^2 (see [1.3.2])

S_f : Safety factor taken equal to:

- 4,0 for thermally or chemically toughened glass:

- 3,5 for polymethylmethacrilate (PMMA) or polycarbonate (PC) glass

R_m : Guaranteed minimum flexural strength, in N/mm^2, of material used. For guidance only, the guaranteed minimum flexural strength R_m for glass window is:
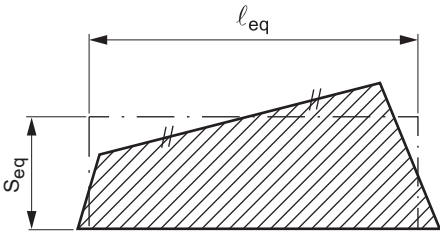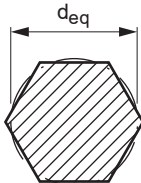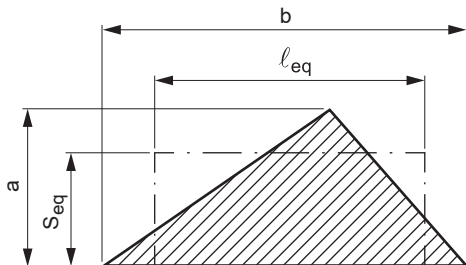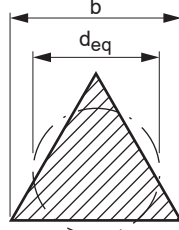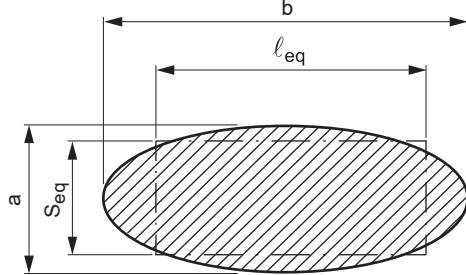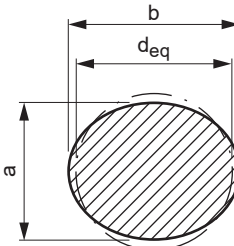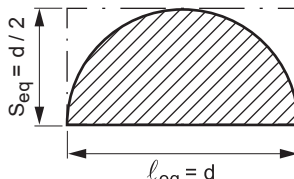
- for thermally or chemically toughened glass:

$R_m = 160 \ N/mm^2$

- for polymethylmethacrilate (PMMA) glass:

$R_m = 100 \ N/mm^2$

- for polycarbonate (PC) glass:

$R_m = 90 \ N/mm^2$

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
$\geq 4,0$	0,750

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
$s_{eq} = d/2$
$l_{eq} = d$

1.3.5 Laminated windows

Laminated windows are windows realized by placing a layer of resin (polyvinyle 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 [1.3.6].

- 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 [1.3.7].

When the laminated window is made with plies of different materials, they are considered as mechanically independent, and the eq.uivalent thickness is to be calculated as defined in [1.3.8].

1.3.6 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 [1.3.4].

1.3.7 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_l 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):

$$\Gamma = \frac{1}{1 + 9,6 \frac{E}{G} \cdot \frac{I_s}{hs^2} \cdot \frac{t_l}{s^2} \cdot \frac{1}{10^6}}$$

$$t_{s1} = \frac{hs \cdot t_1}{t_1 + t_2}$$

$$t_{s2} = \frac{hs \cdot t_2}{t_1 + t_2}$$

$$I_s = t_1 t_{s2}^2 + t_2 t_{s1}^2$$

$$hs = 0,5(t_1 + t_2) + t_l$$

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.

1.3.8 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 $t_{eq,j}$.

1.3.9 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 [1.3.2] is to be calculated as per monolithic windows according to [1.3.4].

1.3.10 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.

1.4 Skylights

1.4.1 Fixed or opening skylights are to have glass thickness appropriate to their size and position as required for windows and sidescuttles. Skylight glasses in any position are to be protected from mechanical damage. They are to be provided with permanently attached robust deadlights.

2 River chests

2.1 Shell plating

2.1.1 The shell plate gross thickness, in mm, in way of river chests as well as the gross thickness of all boundary walls of the river chests are not to be less than:

$$t = 17,2 s \sqrt{\frac{\gamma_R \gamma_m p}{R_y}} + 1,5$$

where:

p   :   Pressure at the safety relief valve, in kN/m^2:

- in general: $p \geq 200$ kN/m^2
- for river chests without any compressed air connection and which are accessible at any time: $p \geq 100$ kN/m^2.

2.2 Stiffeners

2.2.1 The gross section modulus, in cm^3, of river chest stiffeners is not to be less than:

$$w = \frac{\gamma_R \gamma_m p}{8 R_y} s \ell^2 10^3$$

where:

p   :   Design pressure, in kN/m^2, defined in [2.1.1].

3 Independent tanks

3.1 General

3.1.1 These requirements for scantling apply to steel tanks not forming part of the vessel's structure. Scantling of tanks not made of steel will be given special consideration.

The meaning of the symbols used in this sub-article is as follows:

p_{ST} :   Testing pressure defined in Ch 3, Sec 4, [5], to be determined in way of the calculation point (see Ch 2, Sec 4, [6.3])

λ_b :
- for horizontal stiffeners: $\lambda_b = 1,0$
- for other stiffeners: $\lambda_b = 1,2$

λ_S :
- for horizontal stiffeners: $\lambda_b = 1,0$
- for other stiffeners: $\lambda_b = 1,4$

3.2 Net thickness of plating

3.2.1 The net thickness, in mm, of plating of tanks not forming part of the vessel's structure is not to be less than t1 nor than t2 derived from the following:

$$t_1 = 2,5$$

$$t_2 = 14,9 s \sqrt{\frac{\gamma_R \gamma_m p_{ST}}{R_y}}$$

3.3 Scantling of ordinary stikffeners

3.3.1 Scantlings of ordinary stiffeners

For tanks not forming part of the vessel's structure, the net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of ordinary stiffeners are not to be less than:

$$w = \frac{\gamma_R \gamma_m p_{ST}}{8 R_y} s \ell^2 10^3$$

$$A_{sh} = 10 \gamma_R \gamma_m \frac{p_{ST}}{R_y} s \ell$$

where:

p   :   Testing pressure, in kN/m^2, defined in Ch 3, Sec 4, [5].

4 Scuppers and discharges

4.1 Material

4.1.1 The scuppers and discharge pipes are to be constructed of steel. Other equivalent materials are considered by the Society on a case by case basis.

4.2 Pipe connections at the shell plating

4.2.1 Scupper pipes and valves are to be connected to the shell by weld flanges. Instead of weld flanges short-flanged sockets with an adequate thickness may be used if they are welded to the shell in an appropriate manner.

4.3 Wall thickness

4.3.1 The wall gross thickness of scuppers and discharge pipes is to be not less than the shell plating thickness in way of the scuppers, respectively discharge pipes, but need not exceed 8 mm.

SECTION 8   HELICOPTER DECKS AND PLATFORMS

Symbols

g : Gravitational acceleration:

$g = 9,81 \text{ m/s}^2$

k : Material factor defined in:
- Ch 2, Sec 3, [2.3] for steel
- Ch 2, Sec 3, [3.5] for aluminium alloys

R_y : Minimum yield stress, in N/mm², of the material to be taken equal to:
- $R_y = 235/k$ N/mm² for steel
- $R_y = 100/k$ N/mm² for aluminium alloys

unless otherwise specified

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 wheels or helicopters with 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 the checking of helicopter decks and platforms structures are specified in Tab 1.

Table 1 : Helicopter decks and platforms Partial safety factors γ_{S2} and γ_{W2}

Uncertainties regarding:	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

Table 2 : Helicopter platforms - Still water and inertial forces

Vessel condition	Still water force F_S and inertial force F_W, in kN	
Still water condition	$F_S = (W_H + W_P) g$	
Upright condition	$F_{W, x} = (W_H + W_P) a_{X1} + 1{,}2\, A_{HX}$	in x direction
	$F_{W, z} = (W_H + W_P) a_{Z1}$	in z direction
Inclined condition (negative roll angle) **(1)**	$F_{W, Y} = 0{,}7 (W_H + W_P) a_{Y2} + 1{,}2\, A_{HY}$	in y direction
	$F_{W, z} = 0{,}7 (W_H + W_P) a_{Z2}$	in z direction

(1) Inclined condition is not applicable for vessels less than 40 m in length.

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 m^2, of the entire landing area

a_{X1}, a_{Z1} :   Accelerations, in m/s^2, determined at the helicopter centre of gravity for the upright vessel condition, and defined in Ch 3, Sec 3, [2.3]

a_{Y2}, a_{Z2} :   Accelerations, in m/s^2, determined at the helicopter centre of gravity for the inclined vessel condition, and defined in Ch 3, Sec 3, [2.3]

A_{HX}, A_{HY} :   Vertical areas, in m^2, of the helicopter platform in x and y directions respectively. Unless otherwise specified, A_{HX} and A_{HY} may be taken equal to $A_H / 3$.

5 Design loads

5.1 Emergency landing load

5.1.1 The emergency landing force F_{EL} resulting from the crash of the helicopter, and transmitted trough one wheel or a group of wheels or one skid to the helicopter deck or platform, is to be obtained, in kN, from the following formula:

$F_{EL} = 1{,}25g\, W_H$

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 3, Sec 4, [3.5], 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:

  $M = \dfrac{1{,}25}{n} W_H$

  where n is the total number of landing gears

- for helicopter with landing skids:

  $M = 0{,}5\, W_H$

5.3 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 for steel and aluminium deck and platform structure

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 river pressures.

6.1.2 As specified in Ch 2, Sec 5, 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 2, Sec 5.

6.2 Plating

6.2.1 Load model

The following forces P_0 are to be considered independently:

- $P_0 = F_L$

  where F_L is the force corresponding to the landing load, as defined in [4.1]

- $P_0 = \gamma_{S2}\, F_S + \gamma_{W2}\, F_{W, z}$

  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 Pt D, Ch 1, Sec 5, [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 Pt D, Ch 1, Sec 5, [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 $v > \ell$, the skid print outside of the plate panel is to be disregarded. In such a case, the load is to be considered as being fully distributed on the span ℓ only (see Fig 1).

Figure 1 : Skid print with v > ℓ
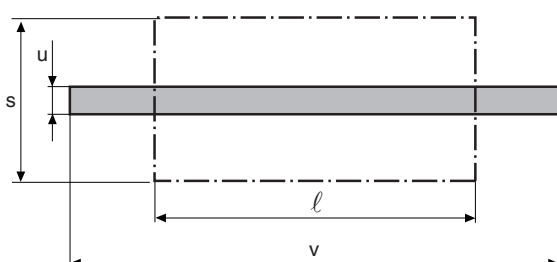
6.3 Ordinary stiffeners

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:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0,5 \frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

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:
- for landing area located above accommodation spaces:

  $\gamma_R = 1,30$
- for landing area located outside a zone covering accommodation spaces:

  $\gamma_R = 1,05$
- for emergency condition:

  $\gamma_R = 1,00$

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
- specific loads as defined in [5.3], for an helicopter platform.

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 2, 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 2, 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:

- for garage load: $\gamma_R = 1,02$

- for emergency landing load.: $\gamma_R = 1,00$

7 Scantlings for composite deck structure

7.1 Bending moments and transverse shear forces calculation for deck panel

7.1.1 Bending moments and transverse shear forces in deck panels are to be calculated taking into account the forces defined in [6.2] by direct calculation.

The panel analysis is to be carried out by a "ply by ply" analysis of the laminate taking into account the maximum stress criteria combined stress in each layer criteria as defined in NR546 Composite Ships, Sec 6 [5.1.2].

7.2 Bending moment and shear forces calculation for secondary stiffeners

7.2.1 The bending moment M, in KN.m, and the shear force T, in KN, induced by forces defined in [6.3.1] in an ordinary stiffener of an helicopter deck are obtained, in N/mm², as follows:

$$M = \frac{P_0 l}{m}$$

$$T = P_0$$

where:

m : Coefficient to be taken equal to:
- for an helicopter with wheels:

  m = 6
- for an helicopter with landing skids:

  m = 10

The strains and stresses induced by the bending moment and shear force in the secondary stiffener are to be calculated as defined in NR546 Composite Ships, Sec 7 [3.1].

7.3 Primary supporting members

7.3.1 The primary structure check is to be carried out by direct calculation as defined in [6.4.1].

The strains and stresses induced by the bending moment and shear force in the primary supporting members are to be calculated as defined in NR546 Composite Ships, Sec 7 [3.1].

7.4 Checking criteria

7.4.1 The structure check is to be carried out as defined in NR546 Composite Ships for deck panels and stiffeners, taking into account the safety factors defined for local loads in Ch 2, Sec 6, [4.2].

<div align="right">

Part B
Hull Design and Construction

</div>

<div align="right">

Chapter 7
HULL OUTFITTING

</div>

SECTION 1 RUDDERS

Symbols

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 centre-line of the rudder pintles, if any

C_R : Rudder force, in N, acting on the rudder blade, defined in [2.1.2]

k : Material factor defined in:
- Ch 2, Sec 3, [2.3] for steel
- Ch 2, Sec 3, [3.5] for aluminium alloys

k_0 : Coefficient to be taken equal to:
- $k_0 = 1$ for steel
- $k_0 = 2,35$ for aluminium alloys

k_1 : Material factor, defined in [1.4.1]
- [1.4.1] for steel
- [1.4.2] for aluminium alloys

M_B : Bending moment, in N.m, in the rudder stock, defined in [5.1]

M_{TR} : Rudder torque, in N.m, acting on the rudder blade, defined in [2.1.3]

n : Navigation coefficient defined in Ch 3, Sec 1, [5.2]

R_{eH} : • for hull steel:

R_{eH} is the nominal yield point, in N/mm^2

• for aluminium alloys:

R_{eH} is 0,2% proof stress, $R_{P0,2}$, in N/mm^2

T : Scantling draught, in m, defined in Ch 1, Sec 2, [2.4]

V_{AD} : Maximum astern speed, in km/h, to be taken not less than $0,5 V_{AV}$

V_{AV} : Maximum ahead service speed, in km/h, at maximum draught, T; this value is not to be taken less than 8.

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 vessel 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 greater than 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 vessel 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 [8].

1.1.4 Special rudder types

Rudders others than those in [1.1.1], [1.1.2] and [1.1.3] will be considered by the Society on a case-by- case basis.

1.2 Gross scantlings

1.2.1 With reference to Ch 2, Sec 5, [2], 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, [5.6.1].

1.3.3 In rudder trunks which are open to the river/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 Steel rudders

a) 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 of NR216 Materials and Welding, Chapter 2.

b) The material used for rudder stocks, pintles, keys and bolts is to have a specified minimum yield stress not less than 200 N/mm².

c) The requirements relevant to the determination of scantlings contained in this Section apply to steels having a specified 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 specified 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:

where:

$$k_1 = \left(\frac{235}{R_{eH}}\right)^{n_1}$$

R_{eH} : Specified yield stress, in N/mm², of the steel used, and not exceeding the lower of 0,7 R_m and 450 N/mm²

R_m : Tensile strength, in N/mm², of the steel used

n_1 : Coefficient to be taken equal to:
- $n_1 = 0,75$ for $R_{eH} > 235$ N/mm²
- $n_1 = 1,00$ for $R_{eH} \leq 235$ N/mm².

d) Significant reductions in rudder stock diameter due to the application of steels with specified 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 [3.2.1]).

1.4.2 Aluminium alloy rudders

For rudder built in aluminium alloys, the material factor k_1 to be taken into account in the scantling formulae of rudder stocks, pintles, coupling bolts, keys and cast parts of rudders is to be taken equal to:

$$k_1 = \frac{235}{R_y}$$

where:

R_y : Minimum yield stress of aluminium, in N/mm², defined in Ch 2, Sec 3, [3.4].

1.4.3
Welded parts of rudders are to be made of approved rolled hull materials. For these members, the material factor k defined is to be used.

1.4.4 Rudders in composite materials

Rudders built in composite materials are to be examined on a case-by-case basis by the Society taking into account safety factor criteria defined in Ch 2, Sec 6, [4.2] where Rules safety factors are to be increased by a coefficient to be taken at least equal to 1,3.

2 Force and torque acting on the rudder

2.1 Rudder blade

2.1.1 Rudder blade description
A rudder blade 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:

$$C_R = 28,86 \, (1 + 5,15 \, y)^{0,15} \, A \, V^2 \, r_1 \, r_2 \, r_3$$

where:

y : Coefficient to be taken as:
- Range of navigation **IN**:
  $y = 0,099$
- Range of navigation **IN(x ≤ 2)**:
  $y = n$

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 1

r_3 : Coefficient to be taken equal to:
- $r_3 = 0,80$ for rudders outside the propeller jet (centre rudders on twin screw vessels, or similar cases)
- $r_3 = 1,15$ for rudders behind a fixed propeller nozzle
- $r_3 = 1,00$ in the other cases.

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

A_F : Area, in m², of the rudder blade portion in front of the centreline of rudder stock (see Fig 1).

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:
- α = 0,33 for ahead condition
- α = 0,66 for astern condition

Figure 1 : Geometry of rudder blade without cut-outs
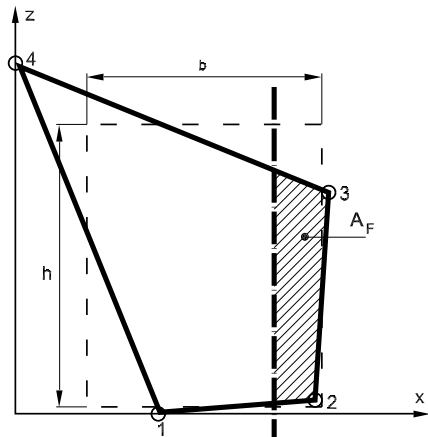
Table 1 : Values of coefficient r_2

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

3 Rudder stock scantlings

3.1 Rudder stock diameter

3.1.1 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:

$$\sigma_E \leq \sigma_{E,ALL}$$

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 [5.1], for each type of rudder.

3.1.2 Rudder stock subjected to torque only

For rudder stocks subjected to torque only, the diameter is to be not less than the value obtained, in mm, from the following formula:

$$d_T = 4,2 (M_{TR} k_1)^{1/3}$$

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:

$$\tau_T \leq \tau_{ALL}$$

where:

τ_{ALL} : Allowable torsional shear stress, in N/mm²:

$$\tau_{ALL} = 68 / k_1$$

τ_T : Torsional stress, in N/mm², defined in [3.1.1].

Table 2 : 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 [3]
Rudder stock couplings	• either torque only, or • both, torque and bending moment See [4]
Rudder stock bearings	Horizontal reaction forces, F_{Ai}, See [5.2]
Pintle bearings	Horizontal reaction forces, F_{Ai}, See [5.3]
Scantling of pintles	Horizontal reaction forces, F_{Ai}, See [5.4]
Rudder blade scantlings	Bending moment and shear force See [6]
Solepiece scantlings	Bending moment and shear force See [7]

3.1.3 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:

$$d_{TF} = 4,2 (M_{TR} k_1)^{1/3} \left[1 + \frac{4}{3} \left(\frac{M_B}{M_{TR}} \right)^2 \right]^{1/6}$$

where:

M_B : Maximum absolute value of bending moment M_{Bi} over the rudder stock length, to be obtained according to [5.1].

If not otherwise specified, the notation d_1 used in this Section is equivalent to d_{TF}.

3.1.4 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.

3.2 Deformation criterion

3.2.1 Rudder stock slope in way of the 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 [5.2.3]) and bearing clearances (see [5.2.4]).

4 Rudder stock couplings

4.1 Horizontal flange couplings

4.1.1 General

In general, the coupling flange and the rudder stock are to be forged from a solid piece. A shoulder radius as large as prac-

ticable 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 the rudder stock diameter defined in [3.1.3].

4.1.2 Welding

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 material used is to be of weldable quality. 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 [3.1.2]

• 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).

4.1.3 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 [3.1.3]

e_M : Mean distance, in mm, of the bolt axes from the centre of the bolt system

k_{1B} : Material factor k_1 for the material used for the bolts

k_{1S} : Material factor k_1 for the material used for the rudder stock

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 $(0,25 \, d_T \times 0,10 \, d_T)$ mm² 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 $1,2 \, d_B$.

4.1.4 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:

- $t_P = d_B \sqrt{\dfrac{k_{1F}}{k_{1B}}}$

- $t_p = 0,9\, d_B$

where:

d_B : Bolt diameter, in mm, calculated in accordance with [4.1.3], where the number of bolts n_B is to be taken not greater than 8

k_{1B} : Material factor k_1 for the material used for the bolts

k_{1F} : Material factor k_1 for the material used for the flange.

4.1.5 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

4.2 Couplings between rudder stocks and tillers

4.2.1 Application

The requirements of this sub-Article apply in addition to those specified in Pt C, Ch 1, Sec 11.

The requirements specified in [4.2.3] and [4.2.4] 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 other 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/mm² for steel
  - $E = 1,67.10^5$ N/mm² 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 [4.2.3]
- 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/mm², 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/mm², induced by the grip pressure

  τ : Shear stress, in N/mm², induced by the torque M_{TR}.

4.2.2 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.

4.2.3 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 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:

$\Delta_0 = 6,2 \dfrac{M_{TR}\eta\gamma}{c\, d_M t_i \mu_A \beta} 10^{-3}$

$\Delta_1 = \dfrac{2\eta + 5}{1,8} \dfrac{\gamma d_0 R_{eH}}{c} 10^{-6}$

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:

  $c = (d_U - d_0) / \ell_C$

t_i, ℓ_C, d_U, d_0 : Geometrical parameters of the coupling, defined in Fig 2

β : Coefficient to be taken equal to:

  $\beta = 1 - \left(\dfrac{d_M}{d_E}\right)^2$

d_M : Mean diameter, in mm, of the conical bore, to be obtained from the following formula:

  $d_M = d_U - 0,5\, c\, \ell_C$

d_E : External boss diameter, in mm

μ_A : Coefficient to be taken equal to:

  $\mu_A = \sqrt{\mu^2 - 0,25\, c^2}$

μ, γ : Coefficients to be taken equal to:

- for rudder stocks and bosses made of steel:

    $\mu = 0,15$

    $\gamma = 1,0$

- for rudder stocks made of steel and bosses made of SG iron:

    $\mu = 0,13$

    $\gamma = 1,24 - 0,1\,\beta$

4.2.4 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:

$$\frac{1,8}{2\eta + 5}\frac{\Delta_E c}{\gamma d_0}10^6 \le R_{eH}$$

where:

Δ_E : Push-up length adopted, in mm

c, η, γ : Defined in [4.2.3]

d_0 : Defined in Fig 2.

4.2.5 Cylindrical couplings by shrink fit

It is to be checked that the diametral shrinkage allowance δ_E is in compliance with the following formula:

$$\delta_0 \le \delta_E \le \delta_1$$

where:

$$\delta_0 = 6,2\frac{M_{TR}\eta\gamma}{d_U t_i \mu \beta_1}10^{-3}$$

$$\delta_1 = \frac{2\eta + 5}{1,8}\gamma d_U R_{eH}10^{-6}$$

η, μ, γ : Defined in [4.2.3]

d_U : Defined in Fig 2

β_1 : Coefficient to be taken equal to:

$$\beta_1 = 1 - \left(\frac{d_U}{d_E}\right)^2$$

4.2.6 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 are to comply with [4.2.1]

- instructions provided by the manufacturer are to be complied with, notably concerning the pre-stressing of the tightening screws.

Figure 2 : Geometry of cone coupling
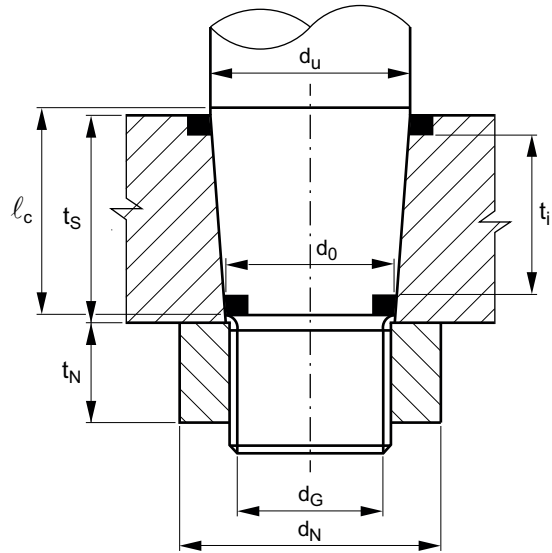
4.3 Cone couplings between rudder stocks and rudder blades

4.3.1 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:

$$\frac{1}{12} \le \frac{d_U - d_0}{l_C} \le \frac{1}{8}$$

- for cone couplings with hydraulic arrangements for assembling and disassembling the coupling (assembling with oil injection and hydraulic nut):

$$\frac{1}{20} \le \frac{d_U - d_0}{l_C} \le \frac{1}{12}$$

where:

$d_U, \ell_C, d_0,$: Geometrical parameters of the coupling, defined in Fig 2.

4.3.2 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 [4.3.6]

d_M : Mean diameter, in mm, of the conical bore defined in [4.2.3]

t_i : Geometrical parameter of the coupling defined in Fig 2

μ_0 : Frictional coefficient, taken equal to 0,15, for contact steel/steel

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 [5.1].

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 : Minimum outer dimension (diameter or width) of the solid part in way of any horizontal cross section.

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 2.

4.3.3 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 [4.2.3].

Note 1: In case of hydraulic pressure connections, the required push-up force P_e, in N, may be determined by the following formula:

$$P_e = p_{req}\,d_M\pi t_i\left(\frac{c}{2}+0,02\right)$$

4.3.4 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 2):

$$d_G = 0,65\ d_U$$

where:

d_U : Rudder stock diameter, in mm, as defined in Fig 2.

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 2), 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 2):

- 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 2.

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.

4.3.5 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.

4.3.6 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 [3.1.2]

k_{1S} : Material factor k_1 for the material used for the rudder stock

d_k : Mean diameter of the conical part of the rudder stock at the key, in mm

R_{eH1} : Specified minimum yield stress R_{eH} for the material 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:

$$a_k = \frac{5 Q_F}{d_k R_{eH2}}$$

where:

R_{eH2} : Specified 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 [4.3.2] and [4.3.3] 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.

4.3.7 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.

4.4 Vertical flange couplings

4.4.1 Vertical flange couplings are to be connected by fitted bolts having a diameter not less than the value obtained, in mm, from the following formula:

$$d_B = \frac{0,81 d_1}{\sqrt{n_B}} \sqrt{\frac{k_{1B}}{k_{1S}}}$$

where:

d_1 : Rudder stock diameter, in mm, defined in [3.1.3]

k_{1S}, k_{1B} : Material factors, defined in [4.1.3]

n_B : Total number of bolts, which is to be not less than 8.

4.4.2 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:

$$M_S = 0,43 \, d_1^3 \, 10^{-3}$$

where:

d_1 : Rudder stock diameter, in mm, defined in [3.1.3].

4.4.3 The thickness of the coupling flange, in mm, is to be not less than d_B, where d_B is defined in [4.4.1].

4.4.4 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 [4.4.1].

4.4.5 A suitable locking device is to be provided to prevent the accidental loosening of nuts.

4.5 Couplings by continuous rudder stock welded to the rudder blade

4.5.1 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 [3.1.3].

4.5.2 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 [3.1.3]

- may not 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 Rudder stock and pintle bearings

5.1 Forces on rudder stock and pintle bearings

5.1.1 Support forces F_{Ai}, for i = 1, 2, 3 are to be obtained according to [5.1.2] and [5.1.3].

The spring constant Z_C for the support in the solepiece (see Fig 3) is to be obtained, in N/m, from the following formula:

$$Z_C = \frac{3 E J_{50}}{\ell_{50}^3} \cdot 10^{-8}$$

where:

ℓ_{50} : Length, in m, of the solepiece

J_{50} : Moment of inertia about the z axis, in cm⁴, of the solepiece.

E : Young's modulus, in N/m²

5.1.2 Rudder supported by solepiece

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:

$$p_R = \frac{C_R}{\ell_{10}}$$

with:

ℓ_{10} : Height of the rudder blade, in m.

The spring constant Z_C is to be calculated according to [5.1.1].

Figure 3 : Rudder supported by solepiece
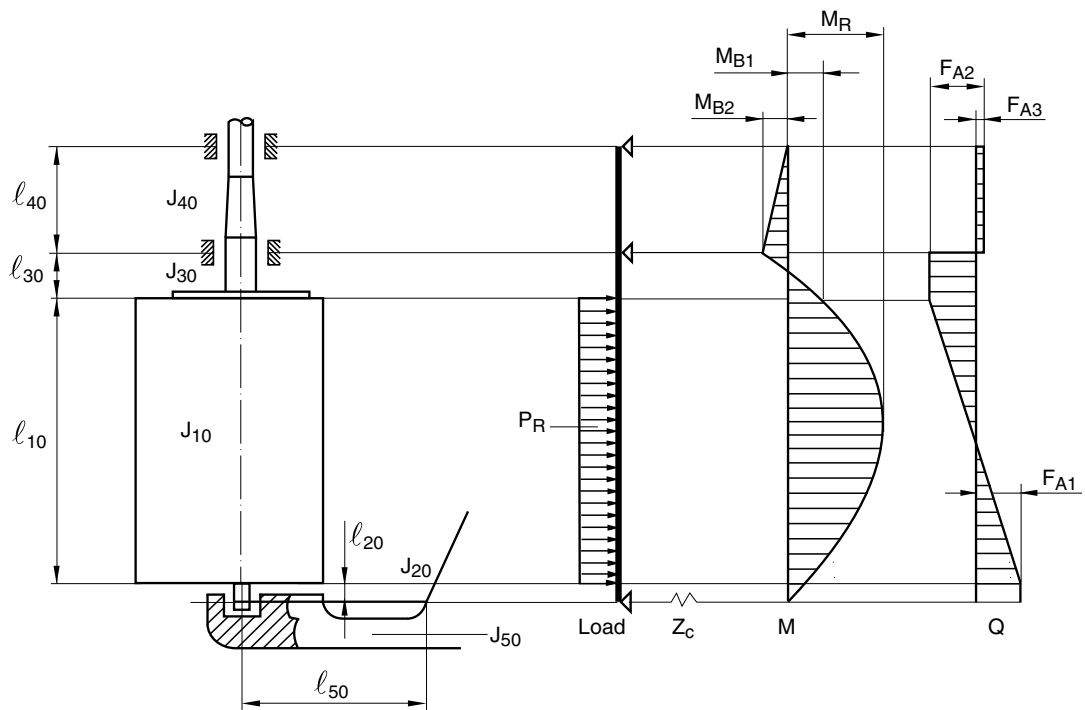
5.1.3 Spade rudder

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 (see also Fig 4):

$$p_{Rz} = p_{R1} + \left(\frac{p_{R2} - p_{R1}}{\ell_{10}} \right) z$$

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_{R1} : Force per unit length, in N/m, obtained for z equal to zero

p_{R2} : 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:

$$Q_R = C_R$$

5.2 Rudder stock bearing

5.2.1 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} : Force acting on the rudder stock bearing, in N, defined in Fig 3 and Fig 4

d_m : Actual inner diameter, in mm, of the rudder Stock bearings (contact diameter)

h_m : Bearing length, in mm (see [5.2.3])

$p_{F,ALL}$: Allowable bearing pressure, in N/mm², defined inTab 3.

Values greater than those given in Tab 3 may be accepted by the Society on the basis of specific tests.

5.2.2 An adequate lubrication of the bearing surface is to be ensured.

Figure 4 : Spade rudder
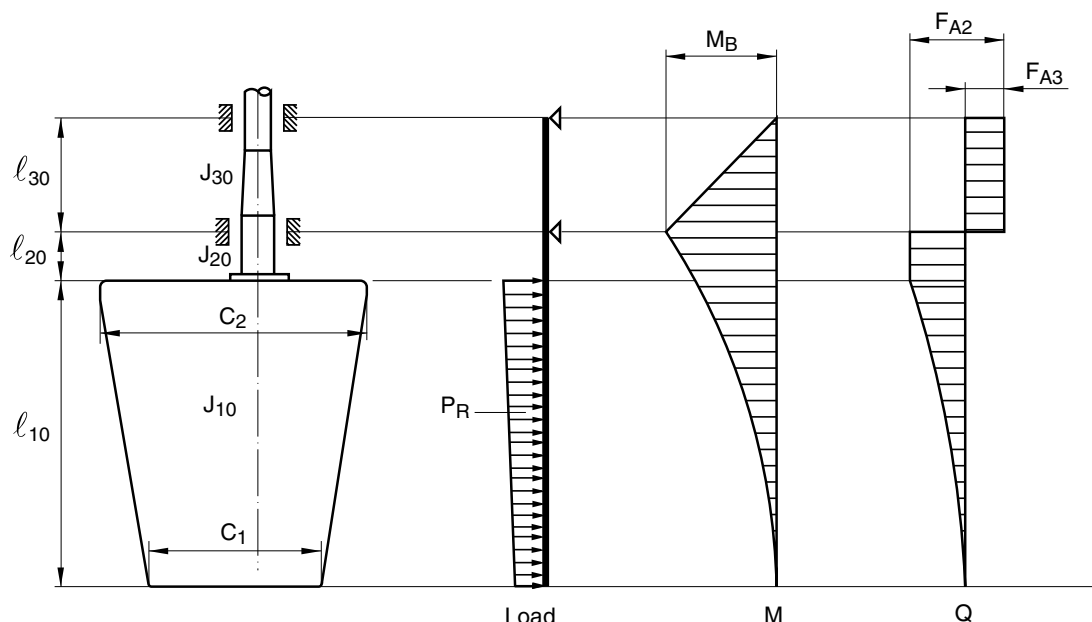
5.2.3 The length / diameter ratio of the bearing surface is to be not greater than 1,2.

5.2.4 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.

5.2.5 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.

5.3 Pintle bearings

5.3.1 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} : Force acting on the pintle, in N, calculated as specified in [5.1]

d_{AC} : Actual diameter, in mm, of the rudder pintles (contact diameter)

h_L : Bearing length, in mm (see [5.3.3])

$p_{F,ALL}$: Allowable bearing pressure, in N/mm², defined in Tab 3.

Values greater than those given in Tab 3 may be accepted by the Society on the basis of specific tests.

5.3.2 An adequate lubrication of the bearing surface is to be ensured.

5.3.3 The length / diameter ratio of the bearing surface is not to be less than 1 and not to be greater than 1,2.

Table 3 : 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 greater than 60 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.	

5.3.4 The manufacturing tolerance 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 tolerances 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 tolerance on support diameter is to be not less than 1,5 mm.

5.3.5 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 [5.2.5].

5.4 Pintles

5.4.1 Rudder pintles are to have a diameter not less than the value obtained, in mm, from the following formula:

$$d_A = \left(\frac{0,21V_{AV}}{0,54V_{AV}+3}\sqrt{F_{Ai}} + 30\right)\sqrt{k_1}$$

where:

d_A : corresponds to d_U value shown in Fig 2

F_{Ai} : Force, in N, acting on the pintle, calculated as specified in [5.1.1].

5.4.2 Provision is to be made for a suitable locking device to prevent the accidental loosening of pintles.

5.4.3 The pintles are to have a conical coupling, with a taper on diameter in compliance with [4.3.1].

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:

$d_E \geq d_M + 0,6\,d_A$

$t_N \geq 0,60\,d_G$

$d_N \geq \max(1,2\,d_0\,;\,1,5\,d_G)$

where:

d_A : Pintle diameter defined in [5.4.1]

d_E : External diameter, in mm, of the massive part of Fig 2, having the thickness t_S

d_M : Mean diameter, in mm, of the conical bore, as defined in [4.2.3]

t_S, d_G, t_N, d_N, d_0 : Geometrical parameters of the coupling, defined in Fig 2.

The above minimum dimensions of the locking nut are only given for guidance, the determination of adequate scantlings being left to the Designer.

5.4.4 The length of the pintle housing in the gudgeon, which corresponds to t_S in Fig 2, is to be not less than the value 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, calculated as specified in [5.1.1].

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 [5.4.1].

5.4.5 The required push-up pressure for pintle bearings, 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 [4.2.3]

t_i : Geometrical parameter of the coupling defined in Fig 2.

The push-up length is to be calculated according to [4.3.3] using required push-up pressure and pintle bearing properties.

6 Rudder blade scantlings

6.1 General

6.1.1 Application
The requirements in [6.1] to [6.5] apply to streamlined rudders and, when applicable, to rudder blades of single plate rudders.

6.1.2 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.

6.1.3 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 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.

6.2 Rudder blade plating

6.2.1 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:

$$t_F = 5,5s\beta\sqrt{k_0k\left(T+3,1y+\frac{C_R10^{-4}}{A}\right)} + t_C$$

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 $b_L/s > 2,5$

with:

b_L : Length, in m, of the longer side of the plate panel

s : Length, in m, of the shorter side of the plate panel

t_C : Corrosion addition:

- $t_C = 1,5$ mm for steel rudder
- $t_C = 1$ for aluminium alloy rudder

y : Coefficient to be taken as:

- $y = 0,099$ fof **IN**
- $y = n$ for **IN(x ≤ 2)**

6.2.2 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 [6.2.1], 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 [6.2.1], 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.

6.2.3 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.

6.2.4 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 [6.2.1]. 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 4.

6.2.5 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 4.

6.2.6 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.

Slot-welding is to be limited as far as possible. Slot-welding is not to be used in areas with large in-plane stresses transverse to the slots.

When slot welding is applied, the length of the slots is to be at least 75 mm with a breadth of 2 times the rudder plate thickness t_F, in mm. The distance between ends of slots is not to be greater than 125 mm. The slots are to be fillet welded around the edges and filled with a suitable compound, e.g. epoxy putty. Slots are not to be filled with weld.

6.2.7 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 [6.2.1].

The rudder nose plate thickness may be increased on a case by case basis to be considered by the Society.

6.3 Connections of rudder blade structure with solid parts in forged or cast steel

6.3.1 General

Solid parts in forged or cast steel which ensure the housing of the rudder stock or of the pintle are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

Table 4 : 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 supported by sole piece	$1,2\ t_F$	$1,6\ t_F$	$1,2\ t_F$	$1,4\ t_F$
Spade rudders	$1,4\ t_F$	$2,0\ t_F$	$1,3\ t_F$	$1,6\ t_F$
Note 1:				
t_F : Defined in [6.2.1].				

6.3.2 Minimum section modulus of the connection with the rudder stock housing

The section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed, which is made by vertical web plates and rudder plating, is to be not less than that obtained, in cm³, from the following formula:

$$w_S = c_S d_1^3 \left(\frac{H_E - H_X}{H_E}\right)^2 \frac{k_0 k}{k_1} 10^{-4}$$

where:

c_S : Coefficient, to be taken equal to:
- $c_S = 1,0$ if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate
- $c_S = 1,5$ if there is an opening in the considered cross-section of the rudder

d_1 : Rudder stock diameter, in mm, defined in [3.1.3]

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, for the rudder blade plating and the rudder stock, respectively.

6.3.3 Calculation of the actual section modulus of the connection with the rudder stock housing

The actual section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed is to be calculated with respect to the symmetrical axis of the rudder.

The breadth of the rudder plating to be considered for the calculation of this actual section modulus is to be not greater than that obtained, in m, from the following formula:

$$b = s_V + 2\frac{H_X}{m}$$

where:

s_V : Spacing, in m, between the two vertical webs (see Fig 5)

H_X : Distance defined in [6.3.2]

m : Coefficient to be taken, in general, equal to 3.

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate according to [6.1.3], they are to be deducted (see Fig 5).

6.3.4 Thickness of horizontal web plates

In the vicinity of the solid parts, the thickness of the horizontal web plates, as well as that of the rudder blade plating between these webs, is to be not less than the greater of the values obtained, in mm, from the following formulae:

$$t_H = 1,2 \, t_F$$

$$t_H = 0,045 \frac{d_s^2}{s_H}$$

where:

t_F : Thickness, in mm, defined in [6.2.1]

d_s : Diameter, in mm, to be taken equal to:
- d_1 for the solid part connected to the rudder stock
- d_A for the solid part connected to the pintle

d_1 : Rudder stock diameter, in mm, defined in [3.1.3]

d_A : Pintle diameter, in mm, defined in [5.4.1]

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 review.

6.3.5 Thickness of side plating and vertical web plates welded to the solid part

The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained, in mm, from Tab 4.

6.3.6 Solid part protrusions

The solid parts are to be provided with protrusions. Vertical and horizontal web plates of the rudder are to be butt welded to these protrusions.

These protrusions are not required when the web plate thickness is less than:

- 10 mm for vertical web plates welded to the solid part of the rudder stock coupling of spade rudders
- 20 mm for the other web plates.

Figure 5 : Cross-section of the connection between rudder blade structure and rudder stock housing
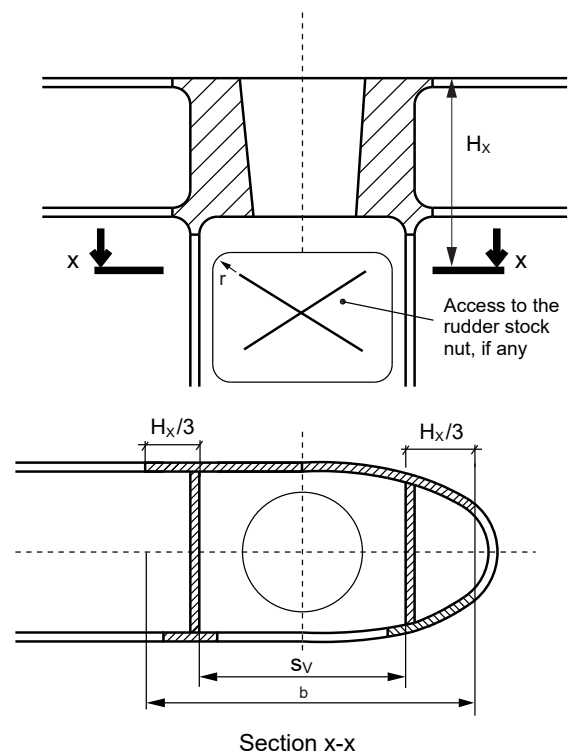
Section x-x

6.4 Connection of the rudder blade with the rudder stock by means of horizontal flanges

6.4.1 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 the requirements in [3.1.3], taking k_1 equal to 1.

6.4.2 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 [6.3.3].

6.4.3 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.

6.4.4 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 is to be not less than the values obtained, in mm, from Tab 4.

Figure 6 : Single plate rudder
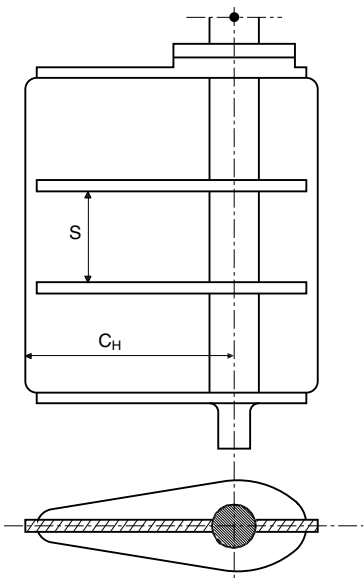
6.5 Single plate rudders

6.5.1 Mainpiece diameter

The mainpiece diameter is to be obtained from the formulae in [3.1.2] and [3.1.3].

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.

6.5.2 Blade thickness

The blade thickness is to be not less than the value obtained, in mm, from the following formula:

$$t_B = 0,81\,s\,V_{AV}\sqrt{k_0 k} + t_C$$

where:

s : Spacing of stiffening arms, in m, to be taken not greater than 1 m (see Fig 6).

t_C : Corrosion addition

- $t_C = 2,5$ mm for steel rudder
- $t_C = 1$ for aluminium alloy rudder

6.5.3 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:

$$Z_A = 0,15\ s\ C_H^2\ V_{AV}^2\ k_0 k$$

where:

C_H : Horizontal distance, in m, from the aft edge of the rudder to the centreline of the rudder stock (see Fig 6)

s : Defined in [6.5.2].

7 Solepiece scantlings

7.1 General

7.1.1 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 requirements of Pt C, Ch 1, Sec 11.

7.2 Scantlings of steel and aluminium alloy solepieces

7.2.1 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 through a direct calculation; where such a direct calculation is not carried out, this force may be taken equal to:

$$F_{A1} = \frac{C_R}{2}$$

x : Distance, in m, defined in Fig 7.

Figure 7 : Solepiece geometry
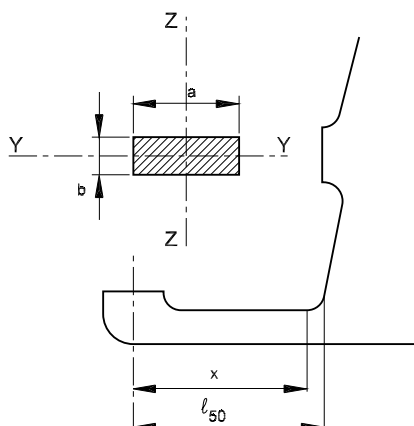
7.2.2 Strength checks

For the generic section of the solepiece within the length l_{50}, defined in Fig 7, it is to be checked that:

$$\sigma_B \leq \sigma_{B,ALL}$$

$$\tau \leq \tau_{ALL}$$

where:

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 at the section considered, in N·m, defined in [7.2.1]

F_{A1} : Force, in N, defined in [7.2.1]

W_Z : Section modulus, in cm³, around the vertical axis Z (see Fig 7)

A_S : Shear sectional area in Y direction, in mm²

$\sigma_{B,ALL}$: Allowable bending stress, in N/mm², equal to, depending on the solepiece material:

- For steel: $\sigma_{B,ALL} = 80 / k_1$ N/mm²
- For aluminium alloy: $\sigma_{B,ALL} = 35 / k_1$ N/mm²

τ_{ALL} : Allowable shear stress, in N/mm², equal to, depending on the solepiece material:

- For steel: $\tau_{ALL} = 48 / k_1$ N/mm²
- For aluminium alloy: $\tau_{ALL} = 20 / k_1$ N/mm²

Solepiece in composite materials are to be examined on a case-by-case basis by the Society taking into account safety factor criteria defined in Ch 2, Sec 6, [4] where the Rules safety factors are to be increased by a coefficient to be taken at least equal to:

- for the main stress safety factor: 1,9
- for the combined stress safety factor: 1,3

7.2.3 Minimum section modulus around the horizontal axis

The section modulus around the horizontal axis Y (see Fig 7) 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 Fig 7).

7.3 Scantlings of solepieces in composite materials

7.3.1 Solepieces in composite materials are to be examined on a case-by-case basis by the Society taking into account safety factor criteria defined in Ch 2, Sec 6, [4.2] where the Rules safety factors are to be increased by a coefficient to be taken at least equal to:

- for the main stress safety factor: 1,9
- for the combined stress safety factor: 1,3

8 Steering nozzles

8.1 General

8.1.1 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.

8.1.2 Nozzles normally consist of a double skin cylindrical structure stiffened by ring webs and other longitudinal webs placed perpendicular to the nozzle.

At least two ring webs are to be fitted, one of which is to be placed in way of the axis of rotation of the nozzle.

For nozzles with an inner diameter d_M exceeding 3 m, the number of ring webs is to be suitably increased.

8.1.3 The section modulus W_N, in cm3, 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:

$W_N = 0,29 k_0 k n_N\, d^2\, b\, V_{AV}^2$

where:

d : Inner diameter of nozzle, in m

b : Length of nozzle, in m

n_N : Coefficient taken equal to:

- 1,0 for steering nozzles

- 0,7 for fixed nozzles.

8.1.4 Care is to be taken in the manufacture of the nozzle to ensure the welded connection between plating and webs.

8.1.5 The internal part of the nozzle is to be adequately protected against corrosion.

8.2 Nozzle plating and internal diaphragms

8.2.1 The thickness of the inner plating of the nozzle is to be not less than the value obtained, in mm, from the following formula:

$t_F = (0,085\sqrt{Pd_M} + 9,65)\sqrt{k_0 k}$

where:

P, d_M : Defined in [8.1.1].

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.

8.2.2 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 [8.2.1] and, in any case, not less than 7 mm.

8.2.3 The thicknesses of ring webs and longitudinal webs are to be not less than $(t_F - 7)$ mm, where t_F is defined in [8.2.1], and, in any case, not less than 7 mm.

However, the thickness of the ring web, in way of the head-box 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.

8.3 Nozzle stock

8.3.1 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:

$S_{AV} = 43,7\,V_{AV}^2\,A_N$

S_{AD} : Force, in N, equal to:

$S_{AD} = 58,3\,V_{AD}^2\,A_N$

A_N : Area, in m², equal to:

$A_N = 1,35\,A_{1N} + A_{2N}$

A_{1N} : Area, in m², equal to:

$A_{1N} = L_M\,d_M$

A_{2N} : Area, in m², equal to:
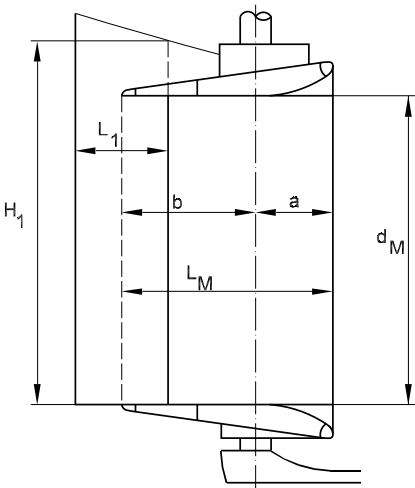
$A_{2N} = L_1\,H_1$

a, b, L_M, d_M, L_1, H_1 : Geometrical parameters of the nozzle, in m, defined in Fig 8.

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:

$d_{NT} = 0,75\,d_{NTF}$

Figure 8 : Geometrical parameters of the nozzle

8.4 Pintles

8.4.1 The diameter of the pintles is to be not less than the value obtained, in mm, from the following formula:

$$d_A = \left(\frac{0,19 V_{AV}}{0,54 V_{AV} + 3} \sqrt{S_{AV}} + 30 \right) \sqrt{k_1}$$

where:

S_{AV} :   Defined in [8.3.1].

8.4.2 The length/diameter ratio of the pintle is not to be less than 1,0 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:

$$p_F \leq p_{F,ALL}$$

where:

p_F :   Mean bearing pressure acting on the gudgeon, to be obtained in N/mm^2, from the following formula:

$$p_F = \frac{0,6 S'}{d'_A h'_A}$$

S' :   The greater of the values S_{AV} and S_{AD}, in N, defined in [8.3.1]

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 3.

8.5 Nozzle coupling

8.5.1 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 [8.3.1]

k_{1S} :   Material factor k_1 for the material used for the stock

k_{1B} :   Material factor k_1 for the material used for the bolts

e_M :   Mean distance, in mm, from the bolt axles 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 $d_{NTF} \leq 75$ 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 $(0,25\ d_{NT} \times 0,10\ d_{NT})$ mm^2, where d_{NT} is defined in [8.3.1], 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 $1,2\ d_B$.

8.5.2 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 :   Bolt diameter, in mm, defined in [8.5.1]

$k_{1B,}$:   Material factor k_1 for the material used for the bolts

k_{1F} :   Material factor k_1 for the material used for the coupling flange.

8.5.3 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:

$$\Delta_0 \leq \Delta_E \leq \Delta_1$$

where:

Δ_0 :   The greater of:

- $6,2 \dfrac{M_{TR} \eta \gamma}{c d_M t_i \mu_A \beta}$

- $16 \dfrac{M_{TR} \eta \gamma}{c t_i^2 \beta} \sqrt{\dfrac{d_{NTF}^6 - d_{NT}^6}{d_{NT}^6}}$

$$\Delta_1 = \frac{2\eta + 5}{1,8} \frac{\gamma d_0 R_{eH}}{10^6 c (1 + \rho_1)}$$

$$\rho_1 = \frac{80 \sqrt{d_{NTF}^6 - d_{NT}^6}}{R_{eH} d_M t_i^2 \left[1 - \left(\dfrac{d_0}{d_E} \right)^2 \right]}$$

d_{NTF}, d_{NT}:   Nozzle stock diameter, in mm, to be obtained from the formula in [8.3.1], considering $k_1 = 1$

η, c, β, d_M, d_E, μ_A, μ, γ : Defined in [4.2.3]

t_i, d_0 :   Defined in Fig 2

8.5.4 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

9 Azimuth propulsion system

9.1 General

9.1.1 Arrangement

The azimuth propulsion system is constituted by the following sub-systems (see Fig 9):

- 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.

9.1.2 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.

9.1.3 Operating conditions

The maximum angle at which the azimuth propulsion system can be oriented on each side when the vessel 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 review.

Figure 9 : Azimuth propulsion system
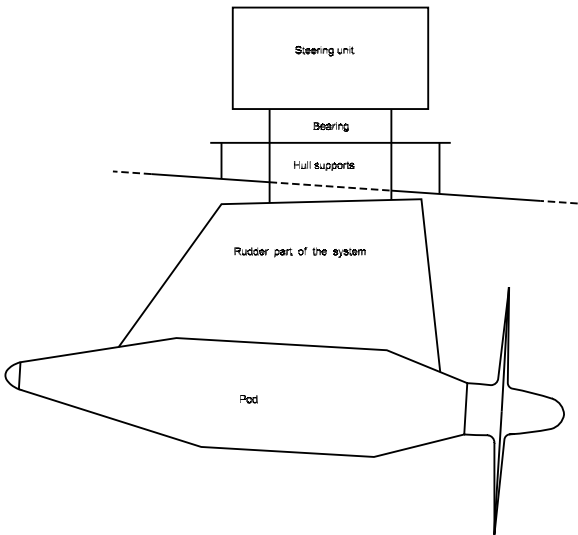
9.2 Arrangement

9.2.1 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 review. The scantlings of the supports and the maximum loads which act on the supports are to be specified in these drawings.

9.2.2 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.

9.3 Design loads

9.3.1 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 vessel 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.

9.4 Plating

9.4.1 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 [6.2.1], in which the term C_R/A is to be replaced by the lateral pressure calculated according to [9.3].

9.4.2 Plating of the pod

The thickness of plating of the pod is to be not less than that obtained, in mm, from the following formula:

$$t = s\sqrt{k_0 k p}$$

where:

s   : Stiffener spacing, in m

p   : Design lateral pressure, in kN/m^2, calculated according to [9.3].

9.4.3 Webs

The thickness of webs of the rudder part of the azimuth propulsion system is to be determined according to [6.2.4], where the lateral pressure is to be calculated according to [9.3].

9.5 Ordinary stiffeners

9.5.1 Ordinary stiffeners of the pod

The scantlings of ordinary stiffeners of the pod are to be not less than those obtained from the following formulae:

Net section modulus, in cm³:

$$w = \frac{p}{m(226/(k_0 k))} s l^2 10^3$$

Net shear sectional area, in cm²:

$$A_{sh} = 10 \frac{p}{226/(k_0 k)} s l$$

where:

s, p   : Parameters defined in [9.4.2]

ℓ : Unsupported span of stiffener, in m

m   : Boundary coefficient taken equal to 8.

9.6 Primary supporting members

9.6.1 Analysis criteria

The scantlings of primary supporting members of the azimuth propulsion system are to be obtained 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 [9.6.2].

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.

9.6.2 Loads

The following loads are to be considered 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 vessel 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 [9.1.3])
- maximum loads calculated for the crash stop of the vessel obtained through inversion of the propeller rotation
- maximum loads calculated for the crash stop of the vessel obtained through a 180° rotation of the pod.

9.6.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_E in primary supporting members, calculated, in N/mm², for the load cases defined in [9.6.2], is in compliance with the following formula:

$$\sigma_E \leq \sigma_{ALL}$$

where:

σ_{ALL} : Allowable stress, in N/mm², to be taken equal to 0,55 R_{eH}

9.7 Hull supports of the azimuth propulsion system

9.7.1 Analysis criteria

The scantlings of hull supports of the azimuth propulsion system are to be obtained through direct calculations, to be carried out in accordance with the requirements in [9.6.1].

9.7.2 Loads

The loads to be considered in the direct calculation of the hull supports of the azimuth propulsion system are those specified in [9.6.2].

9.7.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_E in hull supports, in N/mm², calculated for the load cases defined in [9.6.2], is in compliance with the following formula:

$$\sigma_E \leq \sigma_{ALL}$$

where:

σ_{ALL} : Allowable stress, in N/mm², equal to:

$$\sigma_{ALL} = 65 / (k_0 k)$$

Values of σ_E greater than σ_{ALL} may be accepted by the Society on a case-by-case basis, depending on the localisation of σ_E and on the type of direct calculation analysis.

SECTION 2 BULWARKS AND GUARD RAILS

Symbols

k : Material factor defined in:
- Ch 2, Sec 3, [2.3] for steel
- Ch 2, Sec 3, [3.5] for aluminium alloys

k_0 : Coefficient to be taken equal to:
- $k_0 = 1$ for steel
- $k_0 = 2{,}35$ for aluminium alloys

L : Rule length, in m, defined in Ch 1, Sec 2, [2.1]

t : Gross thickness, in mm.

1 General

1.1 Introduction

1.1.1 The requirements of this Section apply to the arrangement and scantling of bulwarks and guard rails provided at the boundaries of decks and work stations.

1.1.2 The outer edges of decks as well as work stations where persons might fall more than 1 m, shall be fitted with bulwarks or guard rails.

1.1.3 In case of non-propelled cargo carriers without accommodation, bulwarks of guardrails shall not be required where:

a) foot-guards have been fitted to the outer edges of the decks and side decks, and

b) hand rails have been fitted to the coamings

1.1.4 In case of vessels with flush or trunk decks, it shall not be required that guardrails be fitted directly on the outer edges of those decks and side decks where:

a) the passageways run over those decks, and

b) the passageways and work stations on those decks are surrounded by fixed guard rails

1.1.5 Requirements other than those set out in this Section may be called for by national or international authorities, specially for vessels assigned the range of navigation **IN(x ≤ 2)**, in order to allow the crew to move about under adequate safety conditions.

2 Bulwarks

2.1 General

2.1.1 The height of bulwarks is to be at least 1 m from the deck. This height may be reduced subject to the agreement of the Society where required by operational necessities.

2.1.2 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 m apart.

Bulwark stays 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.

2.1.3 Where bulwarks are cut completely, the scantlings of stays or brackets are to be increased with respect to those given in [2.2.2].

2.1.4 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 [3.1.4].

2.2 Scantlings

2.2.1 Plating thickness

The bulwark gross thickness, in mm, is not to be less than the values given in Tab 1.

Table 1 : Bulwark gross thickness, in mm

L, in m	Steel	Aluminium alloys
L ≤ 30 m	$t = 4k^{0,5}$	$t = 3(k_0 k)^{0,5}$
30 m < L ≤ 90 m	$t = 5k^{0,5}$	$t = 4(k_0 k)^{0,5}$
L > 90 m.	$t = 6k^{0,5}$	–

2.2.2 Scantlings of stays

The gross section modulus of stays in way of the lower part of the bulwark is to be not less than the value obtained, in cm^3, from the following formulae:

- for steel: $w = 40 \, k \, s \, (1 + 0{,}01 \, L_S) \, h_B^2$

- for aluminium alloys: $w = 32 \, k_0 \, k \, s \, (1 + 0{,}01 \, L_S) \, h_B^2$

where:

L_S : Length, in m, defined as: $L_S = \min (L ; 100)$

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.

3   Guard rails

3.1   Passenger areas

3.1.1 Guard rails are to be at least 1 m high and shall comprise a hand rail, intermediate rails and a foot-guard. This height may be reduced subject to the agreement of the Society where required by operational necessities.

3.1.2 The spacing between railing stanchions is not to be greater than 2 m.

3.1.3 The foot-guard is to rise at least 50 mm above the weather deck.

The distance between inner edge of foot-guard and inner edge of the stanchion is not be greater than 100 mm.

3.1.4 The opening below the lower course is not to be greater than 230 mm. The other courses are not to be more than 380 mm apart.

3.2   Working areas

3.2.1 Guard rails are to be at least 0,9 m high and shall comprise a hand rail, intermediate rails and a foot-guard.

3.2.2 The spacing between railing stanchions is not to be greater than 2 m.

3.2.3 The foot-guard is to rise at least 50 mm above the weather deck.

3.3   Scantlings

3.3.1 Guard rails shall maintain loads in such a way that deflection without permanent deformation is not to exceed 50 mm in the centre between two stanchions when a load of 500 N/m is acting on the railing.

3.3.2 Hand rails are to be of circular section 40 to 50 mm in diameter.

3.3.3 Adequate strength of guard rails shall be proved by means of a direct calculation submitted to the Society for review, or the design shall be in compliance with an appropriate design standard recognised by the Society.

SECTION 3   PROPELLER SHAFT BRACKETS

Symbols

A :   Sectional area, in cm^2, of the arm

A_S :   Shear sectional area, in cm^2, of the arm

d_P :   Propeller shaft diameter, in mm, measured inside the liner, if any

F_C :   Force, in kN, taken equal to:

$$F_C = \left(\frac{2\pi N}{60}\right)^2 R_P m$$

m :   Mass of a propeller blade, in t

N :   Number of revolutions per minute of the propeller

R_P :   Distance, in m, of the center of gravity of a blade in relation to the rotation axis of the propeller

R_y :   Minimum yield stress, in N/mm^2, of the material to be taken equal to:

-   $R_y = 235/k$ N/mm^2 for steel

-   $R_y = 100/k$ N/mm^2 for aluminium alloys

    unless otherwise specified

    with:

    k :   Material factor defined in:

       -   Ch 2, Sec 3, [2.3] for steel

       -   Ch 2, Sec 3, [3.5] for aluminium alloys

w_A :   Section modulus, in cm^3, of the arm at the level of the connection to the hull with respect to a transversal axis

w_B :   Section modulus, in cm^3, of the arm at the level of the connection to the hull with respect to a longitudinal axis

σ_{ALL} :   Allowable stress, in N/mm^2: $\sigma_{ALL} = 0{,}30\, R_y$

1 General

1.1

1.1.1 General

Propeller shafting is either enclosed in bossing or independent of the main hull and supported by shaft brackets.

1.2 Strength check

1.2.1 General

The strength check is to be carried out according to [2], [3], [4] or [5].

1.2.2 Vibration analysis

A vibration analysis according to Pt C, Ch 1, Sec 9 is recommended to be performed for single arm propeller shaft brackets.

2 Double arm propeller shaft brackets

2.1 General

2.1.1 Both arms of detached propeller brackets are to form an angle α to each other which differs from the angle included between propeller blades. Where 3- or 5-bladed propellers are fitted, it is recommended that the angle α should be approximately 90°. Where 4-bladed propellers are fitted, the angle α should be approximately 70° or 110°.

Where possible, the axes of the arms should intersect in the axis of the propeller shaft.

Exceptions to this will be considered by the Society on a case by case basis.

2.1.2 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.

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:

$$\sigma_F = \frac{M}{w_A}10^3$$

$$\sigma_N = 10F_C\frac{L\sin\beta}{A\ell\sin\alpha}$$

$$\tau = 10F_C\frac{L\cos\beta}{A_S\ell\sin\alpha}$$

2.1.3 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).

The thickness of the propeller shaft bossing is to be not less than $0{,}33\, d_P$.

Figure 1 : Angle β and length d₁
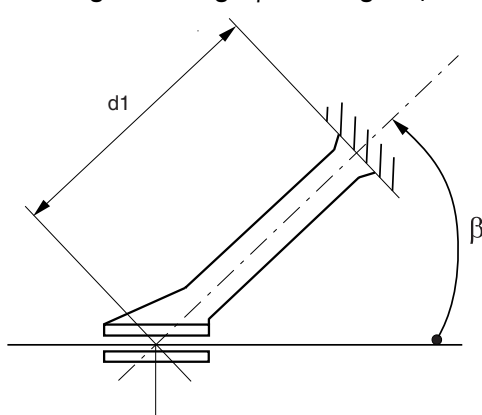
Figure 2 : Lengths L and ℓ
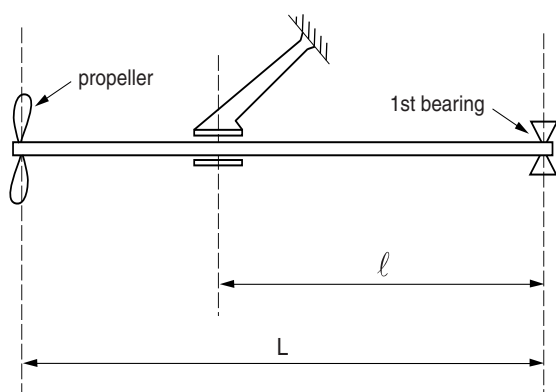
2.1.4 Bracket arm attachments

The bracket arms are to penetrate the hull plating and be connected to deep floors or girders of increased thickness. Moreover, in way of the attachments, the shell plating is to be increased in thickness by 50% or fitted with a doubling plate of same 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.

3 Single arm propeller shaft brackets

3.1 Scantlings

3.1.1 This type of propeller shaft bracket consists of one arm.

3.1.2 Scantlings of arms

The moment in case of a vertical single arm, in kN.m, is to be obtained from the following formula:

$$M = d_2 F_C \frac{L}{\ell}$$

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:

$$\sqrt{\sigma_F^2 + 3\tau^2} \leq \sigma_{ALL}$$

where:

$$\sigma_F = \frac{M}{w_B} 10^3$$

$$\tau = 10 F_C \frac{L}{A_S \ell}$$

3.1.3 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).

The thickness of the propeller shaft bossing is to be not less than 0,33 d_P.

3.1.4 Bracket arm attachments

The connection of bracket arms to the hull structure is to comply with [2.1.4].

4 Bossed propeller shaft brackets

4.1 General

4.1.1 Where bossed propeller shaft brackets are fitted, their scantlings are to be considered by the Society on a case by case basis.

4.1.2 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).

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.

4.1.3 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 vessel.

4.1.4 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.

5 Propeller shaft brackets in composite materials

5.1 General

5.1.1 For propeller shaft brackets built in composite materials, the scantling are to be checked by direct calculation, taking into account the checking criteria defined in Ch 2, Sec 6, [4.2] where the Rules safety factors are to be increased by a coefficient to be taken at least equal to:

• for the main stress safety factor: 1,8

• for the combined stress safety factor: 1,5.

SECTION 4 EQUIPMENT

Symbols

L_M : Maximum length of the hull, in m, excluding rudder and bowsprit

P : Required bow anchor mass, in kg

P_i : Increased required bow anchor mass, in kg

R : Minimum breaking load of anchor chain cable, in kN

R_{eH} : • for hull steel:

R_{eH} is the nominal yield point, in N/mm²

• for aluminium alloys:

R_{eH} is 0,2% proof stress, in N/mm²

R_S : Minimum breaking load of mooring cables, in kN

T : Scantling draught, in m, defined in Ch 1, Sec 2, [2.4].

1 General

1.1 General requirements

1.1.1 The requirements in this Section provide the equipment in anchors, chain cables and ropes for all ranges of navigation defined in Pt A, Ch 1, Sec 3, [12.2].

1.1.2 Vessels have to be equipped with anchors, chain cables and ropes complying with the applicable requirements of NR216 Materials and Welding.

1.1.3 The required equipment of anchors, chain cables, ropes and cables of the vessels trading on the inland waterways has to be determined according to [2] to [4].

The actual Regulations of the Local Authority have to be observed.

1.1.4 The Society, taking into account the conditions on the waterway concerned, may consent to a reduction in equipment for vessel intended for use only in a certain waterway system or area of inland water provided that a note of this waterway system or area of inland water is appended to the character of classification.

1.1.5 Barges to be carried aboard seagoing ships

Barges to be carried aboard seagoing ships are to be exempted from the anchor equipment requirements.

1.1.6 Multi-hull vessels

The breath B to be considered for the application of these Rules to multi-hull vessels is to be determined using the following formula:

$$B = \sum B_i$$

where B_i is the individual breadth of each hull.

2 Anchors

2.1 General

2.1.1 Anchors are to be of an approved type.

2.1.2 Cast iron anchors shall not be permitted.

2.1.3 The mass of the anchors shall stand out in relief in a durable manner.

2.1.4 Anchors having a mass in excess of 50 kg shall be equipped with windlasses.

2.2 Bow anchors

2.2.1 Cargo carriers

The total mass P of the bow anchors of cargo carriers shall be calculated by the following formula:

$P = k B T$

where:

• for non-propelled cargo carriers: $k = c$

• otherwise:

$$k = c\left(\frac{L_M}{8B}\right)^{0,5}$$

with:

c : Coefficient defined in Tab 1.

Table 1 : Coefficient c

Deadweight	Coefficient c
≤ 400 t	45
> 400 t ≤ 650 t	55
> 650 t ≤ 1000 t	65
> 1000 t	70

2.2.2 Passenger vessels and other vessels without deadweight measurement

Passenger vessels and vessels not intended for the carriage of goods, apart from pushers, shall be fitted with bow anchors whose total mass P is obtained from the following formula:

$P = k B T$

where:

k : Coefficient corresponding to [2.2.1] but where, in order to obtain the value of the empirical coefficient c, the maximum displacement, in m³, shall be taken instead of the deadweight tonnage.

2.2.3 Increased bow anchor mass

For passenger vessels and for vessels having a large windage area (container vessels), the bow anchor mass is to be increased as follows:

$$P_i = P + 4 A_f$$

where:

A_f : Transverse profile view (windage area) of the hull above waterline at the draught T, in m^2.

For calculating the area A_f, all superstructures, deckhouses and cargos (e.g. containers) having a breadth greater than B/4 are to be taken into account.

2.2.4 Range of navigation IN

For the range of navigation **IN**, where the current velocity is lower than 6 km/h, the anchor masses according to [2.2.1] to [2.2.3] may be reduced by 13%.

2.3 Stern anchors

2.3.1 Stern anchors are to be fitted in compliance with the requirements [2.3.3] to [2.3.6].

2.3.2 The requirement [2.3.1] may be waived by the Society depending on specified operating conditions regarding for instance current speed or vessel positioning.

2.3.3 Self-propelled vessels shall be fitted with stern anchors whose total weight is equal to 25% of the mass P calculated in accordance with [2.2].

2.3.4 Vessels whose maximum length L_M exceeds 86 m shall, however, be fitted with stern anchors whose total mass is equal to 50% of the mass P or P_i calculated in accordance with [2.2].

2.3.5 Pushers

Vessels intended to propel rigid convoys not more than 86 m in length shall be fitted with stern anchors whose total mass is equal to 25% of the maximum mass P calculated in accordance with [2.2] for the largest formation considered as a nautical unit.

Vessels intended to propel downstream rigid convoys that are longer than 86 m shall be fitted with stern anchors whose total mass equals 50% of the greatest mass P calculated in accordance with [2.2] for the largest formation considered as a nautical unit.

2.3.6 The following vessels are exempted from the stern anchor requirement:

- vessels for which the stern anchor mass will be less than 150 kg

- vessels intended to operate on reservoirs, lakes and,

- non-propelled cargo carriers.

2.4 High-holding-power anchors

2.4.1 The anchor masses established in accordance with [2.2] and [2.3] may be reduced for certain special anchors. The types of anchors given in Tab 2 have so far been recognised by the Society as "high-holding-power anchors".

Table 2 : Recognized types of anchors

Type of anchors	Mass reduction
HA - DU	30%
D'Hone Special	30%
Pool 1 (hollow)	35%
Pool 2 (solid)	40%
De Biesbosch - Danforth	50%
Vicinay - Danforth	50%
Vicinay AC 14	25%
Vicinay Type 1	45%
Vicinay Type 2	45%
Vicinay Type 3	40%
Stockes	35%
D'Hone - Danforth	50%
Schmitt high holding anchor	40%
SHI high holding anchor, type ST (standard)	30%
SHI high holding anchor, type FB (fully balanced)	30%
Klinsmann anchor	30%
HA-DU-POWER Anchor	50%

2.5 Number of anchors

2.5.1 The total mass P specified for bow anchors may be distributed among one or two anchors. It may be reduced by 15% where the vessel is equipped with only a single bow anchor and the mooring pipe is located amidships.

The required total weight of stern anchors for pushers and vessels whose maximum length exceeds 86 m may be distributed between one or two anchors.

The mass of the lightest anchor should be not less than 45% of that total mass.

3 Chain cables

3.1 General

3.1.1 Chains true to gauge size are to be used as anchor chain cables.

3.1.2 Short-link or stud-link chain cables may be used as anchor chain cables.

3.2 Minimum breaking loads

3.2.1 The minimum breaking load of chain cables shall be calculated by the formulae given in Tab 3.

For the breaking loads of short-link chains and stud-link chains, see Tab 4 and Tab 5, respectively.

3.2.2 Where the anchors have a mass greater than that required in [2.2], [2.3] and [2.5.1] the breaking load of the anchor chain cable shall be determined as a function of that highest anchor mass.

3.2.3 The attachments between anchor and chain shall withstand a tensile load 20% higher than the tensile strength of the corresponding chain.

3.3 Length of chain cables

3.3.1 Bow anchor chain cables

For the minimum length of bow anchor chain cables, see Tab 6.

3.3.2 Stern anchor chain cables

The length of stern anchor chain cables is not to be less than 40 m. However, where vessels need to stop facing downstream they are to be equipped with a stern anchor chain of not less than 60 m in length.

3.3.3 Steel wire ropes

In special cases, steel wire ropes may be permitted instead of anchor chain cables, for vessels intended to operate in stretches of fresh waters corresponding to **IN(1,2 ≤ x ≤ 2)**. The wire ropes are to have at least the same breaking strength as the required anchor chain cables, but shall be 20% longer.

A short length of chain cable is to be fitted between the wire rope and the anchor, having a length equal at least to the distance from the anchor in the stowed position to the winch.

Table 3 : Minimum breaking loads R of chain cables

Anchor mass (kg)	R (kN)
≤ 500	$R = 0,35 \, P'$
> 500 and ≤ 2000	$R = \left(0,35 - \dfrac{P' - 500}{15000}\right) P'$
> 2000	$R = 0,25 \, P'$
Note 1:	
P' : Theoretical mass of each anchor determined in accordance with [2.2] and [2.3].	

Table 4 : Breaking loads, in kN, for short-link chain cables

Chain diameter (mm)	Grade SL$_1$		Grade SL$_2$		Grade SL$_3$	
	Proof load	Breaking load	Proof load	Breaking load	Proof load	Breaking load
6,0	6,5	13	9	18	13	26
8,0	12,0	24	17	34	24	48
10,0	18,5	37	26	52	37	74
11,0	22,5	45	32	64	45	90
12,5	29,0	58	41	82	58	116
14,5	39,0	78	55	110	78	156
16,0	47,5	95	67	134	95	190
17,5	56,5	113	80	160	113	226
19,0	67,0	134	95	190	134	268
20,5	78,0	156	111	222	156	312
22,0	90,0	180	128	256	180	360
24,0	106	212	151	302	212	424
25,5	120	240	170	340	240	480
27,0	135	270	192	384	270	540
28,5	150	300	213	426	300	600
30,0	166	332	236	472	332	664
32,0	189	378	268	536	378	756
33,0	201	402	285	570	402	804
35,0	226	452	321	642	452	904
37,0	253	506	359	718	506	1012
38,0	267	534	379	758	534	1068
40,0	296	592	420	840	592	1184

Table 5 : Breaking loads, in kN for stud-link chain cables

Chain diameter (mm)	Grade K₁		Grade K₂		Grade K₃	
	Proof load	Breaking load	Proof load	Breaking load	Proof load	Breaking load
11	36	51	51	72	72	102
12,5	46	66	66	92	92	132
14	58	82	82	115	115	165
16	75	107	107	150	150	215
17,5	89	128	128	180	180	255
19	105	150	150	210	210	300
20,5	123	175	175	244	244	349
22	140	200	200	280	280	401
24	167	237	237	332	332	476
26	194	278	278	389	389	556
28	225	321	321	449	449	642
30	257	368	368	514	514	735
32	291	417	417	583	583	833
34	328	468	468	655	655	937
36	366	523	523	732	732	1050
38	406	581	581	812	812	1160
40	448	640	640	896	896	1280
42	492	703	703	985	985	1400
44	538	769	769	1080	1080	1540
46	585	837	837	1170	1170	1680
48	635	908	908	1270	1270	1810

Note 1: Grades K₁, K₂ and K₃ are equivalent to grades Q₁, Q₂ and Q₃, respectively.

Table 6 : Minimum length of bow anchor chain cables

L_M (m)	Minimum length of chain cables (m)	
	IN	**IN(x ≤ 2)**
$L_M < 30$	$\ell = 40$	$\ell = \max(40 ; L_M + 10)$
$30 \leq L_M \leq 50$	$\ell = L_M + 10$	
$L_M > 50$	$\ell = 60$	

4 Mooring and towing equipment

4.1 Ropes

4.1.1 General

Steel wire ropes as well as fibre ropes from natural or synthetic fibres or ropes consisting of steel wires and fibre strands may be used for all ropes and cables.

During loading and unloading of tankvessels carrying inflammable liquids, steel wire ropes only are to be used for mooring purposes.

4.1.2 Mooring cables

It is recommended at least mooring cables as defined in Tab 7 and Tab 8.

Table 7 : Mooring cables

Mooring cable	Minimum length of cable (m)
1st cable	$\ell' = \min(\ell_1 ; \ell_2)$ $\ell_1 = L_M + 20$ $\ell_2 = \ell_{max}$ **(1)**
2nd cable	$\ell'' = 2/3\ \ell'$
3rd cable **(2)**	$\ell'' = 1/3\ \ell'$

(1) $\ell_{max} = 100$ m
(2) This cable is not required on board of vessels whose L_M is less than 20 m.

Table 8 : Minimum breaking load R_S of mooring cables

$L_M \cdot B \cdot T$	R_S, in kN
≤ 1000 m³	$R_S = 60 + \dfrac{L_M B T}{10}$
> 1000 m³	$R_S = 150 + \dfrac{L_M B T}{100}$

4.1.3 Towing cables

Self-propelled vessels and pushers that are also intended to tow shall be equipped with an at least 100 m long towing cable whose tensile strength is not less than the value determined according to Ch 7, Sec 6, [4].

Tugs are to be equipped with a number of cables that are suitable for their operation. However, the most important cable shall be at least 100 m long and have a tensile strength, in kN, not less than one third of the total power, in kW, of the power plant(s).

4.2 Bollards

4.2.1 Every vessel has to be equipped with one double bollard each on the fore and aft body on port and starboard side. In between, depending on the vessel's size, one to three single bollards have to be arranged on either side of the vessel.

For larger vessels (as from L = 70 m) it is recommended to mount a triple bollard on the fore body and two double bollards on the aft body on port and starboard side.

4.2.2 The bollards have to be led through the deck and below be attached to a horizontal plate spaced at least one bollard diameter from the deck. Said plate being of the same thickness as the bollard wall has to be connected to the side wall and adjacent beam knees. Should this be impossible, the bollards have to be constrained in a bollard seat on deck.

4.3 Supporting hull structures associated with towing and mooring

4.3.1 General

The strength and arrangement of supporting hull structures associated with towing and mooring are to comply with the present sub-article.

On board 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 on board fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the mooring and towing forces acting upon the on board fittings, see Fig 1 for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be ensured.

Figure 1 : Reinforced members beneath onboard fittings
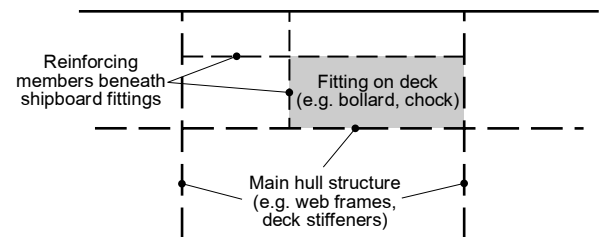
4.3.2 Information to be submitted

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 on board fitting:

a) location on the vessel

b) fitting type

c) safe working load

d) purpose (mooring, towing)

e) manner of applying towing and mooring lines (including line load, line angles, etc.).

4.3.3 Hull structure reinforcement

As a general rule, hull structure reinforcements in way of

mooring and towing equipment are to be examined by direct calculation, taking into account a tension in the mooring or towing line equal to the safe working load of the equipment and considering the following allowable stresses:

a) For strength assessment with beam theory or grillage analysis:

- normal stress: $\sigma \leq R_y$

- shear stress: $\tau \leq 0{,}6R_y$

b) For strength assessment with finite element analysis:

- $\sqrt{\sigma^2 + 3\tau^2} \leq R_Y$

where:

R_y : Minimum yield stress, in N/mm², of the material to be taken equal to:

- $R_y = 235/k$ N/mm² for steel

- $R_y = 100/k$ N/mm² for aluminium alloys

 unless otherwise specified

 with:

 k : Material factor defined in:

 - Ch 2, Sec 3, [2.3] for steel

 - Ch 2, Sec 3, [3.5] for aluminium alloys

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: When the mooring plan is not available, the equipment such as bitts and bollards (when the line may come and go from the same direction) are to be loaded up to twice their safe working loads.

4.3.4 Corrosion additions

The scantlings obtained by applying the allowable stresses as specified in [4.3.3] 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 2, Sec 5, [1] 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 on board fittings not selected from an recognised standard. This wear allowance is to be added to surfaces which are intended to regularly contact the line.

5 Hawse pipes and chain lockers

5.1 Arrangements

5.1.1 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.

5.1.2 The foreship of the vessels shall be built in such a way that the anchors do not stick out of the side shell.

5.1.3 All mooring units and accessories, such as riding and trip stoppers are to be securely fastened to the Surveyor's satisfaction.

5.1.4 Where two chains are used, the chain locker is to be divided into two compartments, each capable of housing the full length of one line.

5.2 Hawse pipe scantlings

5.2.1 The gross thickness of the hawse pipes is not to be less than:

- for $t_0 < 10$ mm:

  $t = \min (t_0 + 2 ; 10)$

- for $t_0 \geq 10$ mm:

  $t = t_0$

where:

t_0 : Gross thickness of adjacent shell plating, in mm.

SECTION 5   LIFTING APPLIANCES - HULL CONNECTIONS

1   General

1.1   Application

1.1.1 The present Section applies to the structural arrangement and strength of the vessel hull in way of the connections with the lifting appliances (cranes, derrick, bunker masts).

1.1.2 The fixed parts of lifting appliances and their connections to the vessel's structure are within the vessel classification scope, even when the certification of lifting appliances is not required.

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

1.1.4 It shall be possible to lower the crane boom or the derrick structure and to secure it to the vessel during the voyage.

2   Structural arrangement

2.1   General

2.1.1 The vessel structure is to be suitably reinforced in the area of lifting appliance attachments in order to avoid excessive local stresses or possible buckling of the deck plating.

2.1.2 When inserted plates are provided in deck, side shell or bulkheads in way of crane foundation, these inserts are to have well radiused corners and are to be edge-prepared prior to welding.

3   Hull strength check

3.1   Load transmitted by the lifting appliances

3.1.1 The forces and moments transmitted by the lifting appliances to the vessel's structures, during both lifting service and navigation, are to be submitted to the Society.

3.1.2 For a lifting appliance having a safe working load F less than 50 kN, and when its deadweights are unknown, the bending moment M, in kNm, induced by the pedestal to the hull is not to be taken less than:

$$M = 2,2 F x_0$$

where:

x_0 :   Maximum jib radius of the crane, in m.

3.1.3 For cranes having a safe working load greater than 50 kN, the bending moment and forces induced by the crane pedestal to the hull are to be as defined in NR526 Rules for the Certification of Lifting Appliances on board Ships and Offshore Units.

3.2   Strength criteria for steel and aluminium structures

3.2.1 Local reinforcements and hull structure surrounding the lifting appliance pedestal are to be checked by direct calculation according to the following:

$$\sqrt{\sigma^2 + 3\tau^2} \leq 0,63 R_Y$$

where:

σ :   Normal stress, in N/mm², calculated considering the bending moments and the tensile and compressive forces

τ :   Shear stress, in N/mm², calculated considering the torsional moment and the shear forces

R_y :   Minimum yield stress, in N/mm², of the material to be taken equal to:

- $R_y = 235/k$ N/mm² for steel
- $R_y = 100/k$ N/mm² for aluminium alloys

unless otherwise specified

with:

k   :   Material factor defined in:
- Ch 2, Sec 3, [2.3] for steel
- Ch 2, Sec 3, [3.5] for aluminium alloys

3.2.2   Corrosion additions

The scantlings obtained by applying the allowable stresses as specified in [3.2.1] are gross scantlings including corrosion additions.

The net scantlings for the surrounding hull structure is to be obtained according to the process defined in Ch 2, Sec 5, [1].

3.3   Strength criteria for structures in composite materials

3.3.1 Local reinforcements and hull structure surrounding the crane pedestal are to be checked by direct calculations, taking into account the following permissible stresses:

$SF_{CRANE} = 1,7 SF$

$SF_{CSCRANE} = 1,7 SF_{CS}$

where:

SF   :   Rules safety factor applicable to maximum stress defined in Ch 2, Sec 6, [4.3.3]

SF_{CS} :   Rules safety factor applicable to combined stress defined in Ch 2, Sec 6, [4.3.3].

SECTION 6 — VESSEL COUPLING

1 General

1.1 Application

1.1.1 The requirements of this Section apply to coupling arrangements and scantling of vessels assigned the range of navigation **IN**.

The coupling of vessels assigned range of a navigation **IN(x ≤ 2)** will be examined by the Society on a case by case basis.

1.1.2 Pushed barges and pushers/self-propelled vessels intended to push other vessels are to comply with [2].

Towed units and tugs/self-propelled vessels intended to tow other vessels are to comply with [3].

The requirements under [4] are given as recommendations.

2 Pushing arrangements

2.1 Hull strengthening

2.1.1 The bow of the pusher and the stern of the barge are to be reinforced in order to withstand the connection forces (see [2.4.4]).

The structural reinforcements are to be continued in aft and fore directions in order to transmit the connection forces to the hull structure of pusher and barge.

2.1.2 Pushers

Pushers are to be arranged with a pushing device, having a width not smaller than two thirds of its breadth.

2.2 Pushing transoms

2.2.1 Pushing transoms, at the stem of the pushing vessel and the stern of the barge, are to be arranged with boxes securely attached to the vessel structure by means of horizontal and vertical web plates.

Attention is to be paid that this box is not supported by elements thinner and/or a less rigid structure.

2.3 Other structures

2.3.1 Pusher fore part

The pusher fore structure is to be aligned with the barge aft structure in way of the notch or the dock bottom.

2.3.2 Barge aft part

The barge aft structure is to be aligned with the pusher fore structure in way of the notch or the dock bottom.

2.4 Coupling devices

2.4.1 Every coupling system shall guarantee the rigid coupling of all the craft in a convoy, i.e. under foreseen operating conditions the coupling device shall prevent longitudinal or transversal movement between the vessels, so that the assembly can be seen as a nautical unit.

2.4.2 The forces arising from foreseen operating conditions shall be properly absorbed and safely transmitted into the vessel's structure by the coupling system and its components.

2.4.3 The coupling devices are to be fixed on deck, which is to be locally reinforced. The dimensioning of longitudinal coupling components is to be performed on the basis of coupling forces defined by the designer.

Where the value of coupling forces is not available, it is not to be taken less than those derived from [2.4.4].

2.4.4 Coupling forces

The coupling devices of convoys and formations of vessels shall be dimensioned so as to guarantee sufficient safety levels. This condition is deemed to be fulfilled if the coupling forces determined according to (1), (2) and (3) are assumed to be the tensile strength for the dimensioning of the longitudinal coupling components.

Coupling forces, in kN, between units forming a rigid pushed convoy may be obtained using the following formulae:

- Coupling points between pusher and pushed vessel:

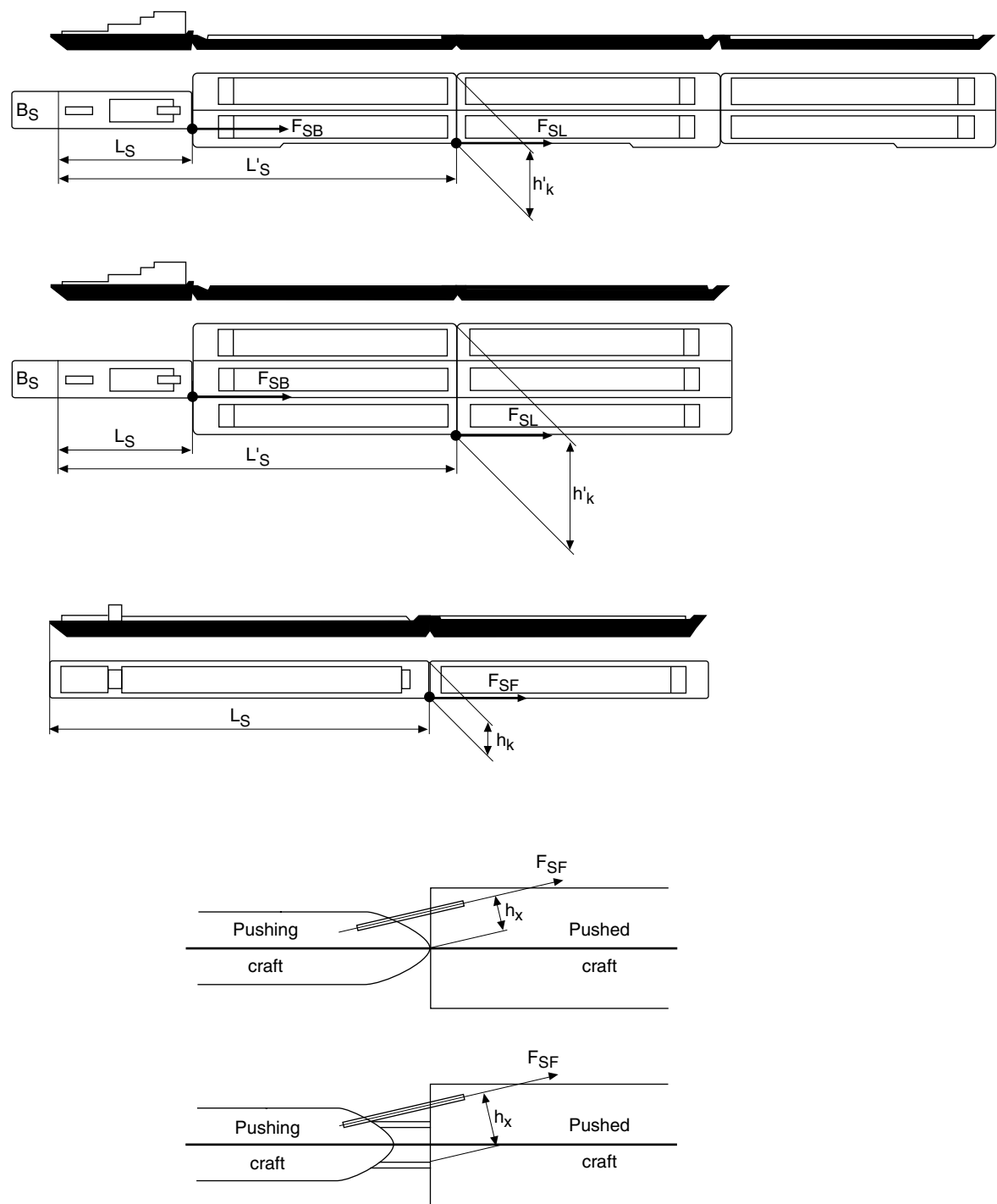$$F_{SB} = \frac{T_F P_B L_S}{B_S} 10^{-3} \qquad (1)$$

- Coupling points between pushing motor vessel and pushed vessel:

$$F_{SF} = \frac{T_F P_B L_S}{h_K} 10^{-3} \qquad (2)$$

- Coupling points between pushed vessels:

$$F_{SL} = \frac{T_F P_B L^1_S}{h^1_K} 10^{-3} \qquad (3)$$

Figure 1 : Vessel coupling arrangement

where (see also Fig 1):

F_{SB}, F_{SF}, F_{SL} : Coupling force, in kN, of the longitudinal connection

P_B : Installed propulsion power, in kW, of the pusher or pushing vessel

L_S : Distance, in m, from the stern of the pusher or pushing vessel to the coupling point

L^1_S : Distance, in m, from the stern of the pushing vessel to the coupling point between the first pushed vessel and the vessel coupled ahead of it

h_K, h^1_K : Respective lever arm, in m, of the longitudinal connection

B_S : Breadth, in m, of the pusher or pushing vessel.

T_F : Empirical factor for the conversion of installed power to thrust including adequate safety factor

- T_F = 270 kN/kW, for coupling points between pusher and pushed vessel

- T_F = 80 kN/kW, for coupling points between pushing motor vessel and pushed vessel or coupling points between pushed vessels.

A value of 1200 kN is deemed to be sufficient for the maximum coupling force for a pushing craft at the coupling point between the first pushed craft and the craft coupled ahead of it, even if formula (3) hereabove produces a higher value.

For the coupling points of all other longitudinal connections between pushed craft, the dimensioning of the coupling devices shall be based on the coupling force determined according to formula (3) hereabove.

2.4.5 For the longitudinal coupling of individual craft, at least two coupling points shall be used. Each coupling point shall be dimensioned for the coupling force determined according to [2.4.4]. If rigid coupling components are used, a single coupling point may be authorised if that point ensures secure connection of the craft.

2.4.6 Bollards

Sufficient numbers of bollards or equivalent devices shall be available and be capable of absorbing the coupling forces arising.

A safety coefficient not less than 4, considering the breaking load, is to be obtained when the bollards are subjected to the forces exerted by the cables.

Bollards supporting the cables of a convoy, are never to be applied simultaneously for mooring purposes.

The diameter of the bollards is to be not less than 15 times the diameter of the cable.

Bollards fitted on the pusher are to be at adequate distance of the bollards fitted on the pushed vessel, namely at a distance not less than 3 m.

3 Towing arrangements

3.1 General

3.1.1 Barges are to be fitted with suitable arrangements for towing, with scantlings under the responsibility of the designer.

The Society may, at the specific request of the interested parties, check the above arrangements and the associated hull strengthening; to this end, the maximum pull for which the arrangements are to be checked is to be specified on the plans.

4 Cables

4.1 General

4.1.1 The tensile strength of the cables shall be selected according to the foreseen number of windings. There shall be no more than three windings at the coupling point. Cables shall be selected according to their intended use.

4.1.2 The cables are to be joined at their end or equipped with a sleeve.

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Part B
Hull Design and Construction

</div>

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Chapter 8
CONSTRUCTION AND TESTING

</div>

SECTION 1   GENERAL

1   Application

1.1   Scope

1.1.1 The present Chapter contains the requirements concerning construction, protection and testing of hull structures made of materials covered by these Rules.

1.2   Connections of structures

1.2.1   Steel hulls
The preparation, execution and inspection of welded connections in steel hull structures are to comply with Ch 8, Sec 2.

1.2.2   Aluminium alloy hulls
The preparation, execution and inspection of welded connections in aluminium alloy hull structures are defined in NR561 Aluminium Ships.

The conditions for heterogeneous assembly between steel and aluminium alloy structures are also to be as defined in NR561 Aluminium Ships.

1.2.3   Direct calculation of fillet welds
As an alternative to the determination of the necessary fillet weld throat thicknesses according to [1.2.1] and [1.2.2], a direct calculation may be performed in accordance with Ch 2, Sec 8, [3], e.g. in order to optimize the weld thicknesses in relation to the loads.

1.2.4   Hulls made of composite material or plywood
The scantling of joint assembly for vessels built in composite material or plywood are to be as defined in NR546 Composite Ships.

1.3   Protection of hull metallic structure

1.3.1 The requirements for the protection of hull metallic structure are given in Ch 8, Sec 1.

1.4   Testing

1.4.1   Metallic hulls
The testing conditions for tanks, watertight and weathertight structures for vessels built in steel and aluminium alloy are given in Ch 8, Sec 4.

1.4.2   Hulls made of composite material or plywood
The testing conditions for tanks, watertight and weathertight structures for vessels built in composite material or plywood are defined in NR546 Composite Ships.

SECTION 2   WELDING AND WELD CONNECTIONS - STEEL HULL STRUCTURES

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the preparation, execution and inspection of welded connections in steel hull structures.

1.2 General requirements

1.2.1 The general requirements relevant to fabrication by welding and qualification of welding procedures are given in the relevant chapters of NR216 Materials and Welding, Chapter 5.

1.2.2 Weld connections are to be executed according to the reviewed plans. A detail not specifically represented in the plans is, if any, to comply with the applicable requirements.

1.2.3 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 reviewed/approved plans.

1.2.4 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.

1.3 Base material

1.3.1 The requirements of this Section apply for the welding of hull structural steels of the types considered in NR216 Materials and Welding or other types accepted as equivalent by the Society.

1.3.2 The service temperature is intended to be the ambient temperature, unless otherwise stated.

1.4 Welding consumables and procedures

1.4.1 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.

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
AH40	2Y40	2Y40
DH40	3Y40	

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.

1.4.2 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 and H10 shall be used for welding hull steel forgings and castings of respectively ordinary strength level and higher strength level.

The condition and remarks of welding consumables manufactures have to be observed.

1.5 Personnel and equipment

1.5.1 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.

1.5.2 Automatic welding operators

Personnel manning automatic welding machines and equipment are to be competent and sufficiently trained.

1.5.3 Organisation

The internal organisation of the Building Yard, is to be such as to ensure compliance with the requirements in [1.5.1] and [1.5.2] and to provide for assistance and inspection of welding personnel, as necessary, by means of a suitable number of competent supervisors.

1.5.4 NDE operators

Non-destructive tests are to be carried out by qualified personnel, certified by the Society, or by recognised bodies in compliance with appropriate standards.

The qualifications are to be appropriate to the specific applications.

1.5.5 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.

1.6 Documentation to be submitted

1.6.1 The structural plans to be submitted for review/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.

1.6.2 A plan showing the location of the various steel types is to be submitted at least for outer shell, deck and bulkhead structures.

1.7 Design

1.7.1 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.

1.7.2 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.

1.7.3 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 are to be submitted.

1.7.4 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.

1.7.5 Local clustering of welds, minimum spacing, socket weldments

The local clustering of welds and short distances between welds are to be avoided.

- Adjacent butt welds should be separated from each other by a distance of at least:

  50 mm + 4 t

- Fillet welds should be separated from each other and from butt welds by a distance of at least:

  30 mm + 2 t,

where t is the plate thickness, in mm.

The width of replaced or inserted plates (strips) should, however, be at least 300 mm or ten times the plate thickness, whichever is the greater.

Reinforcing plates, welding flanges, mountings and similar components socket welded into plating should be of the following minimum size:

$D = 120 + 3 (t - 10)$, without being less than 120 mm.

The corners of angular socket weldments are to be rounded to a radius of at least 50 mm unless the longitudinal butt welds are extended beyond the transverse butt weld as shown in Fig 1. The socket welding sequence shall then comprise firstly the welding of the transverse seams (1) following by cleaning of the ends of these and then the welding of the longitudinal seams (2).

The socket welding of components with radiused corners should proceed in accordance with the relevant welding sequence description.

Figure 1 : Corners of socket weldments

(1), (2) = welding sequence
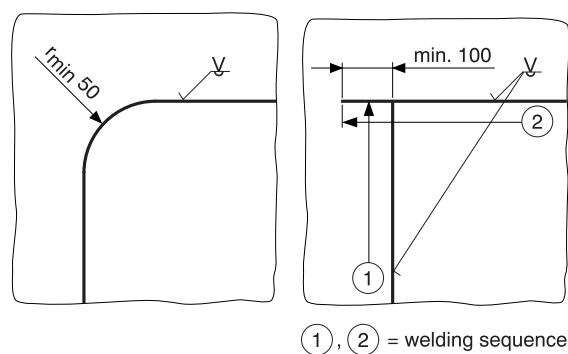
2 Type of connections and preparation

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 z equal to or greater than (see Fig 2):

- 3 mm   if $t_1 \leq 10$ mm

- 4 mm   if $t_1 > 10$ 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.

The transition between different component dimensions shall be smooth and gradual.

When the difference in thickness is less than the above values, it may be accommodated in the weld transition between plates.

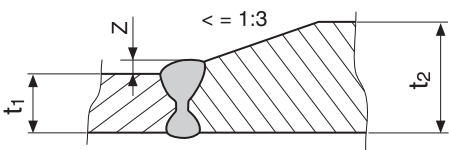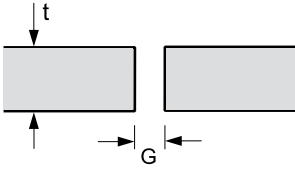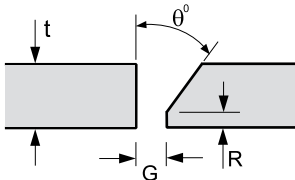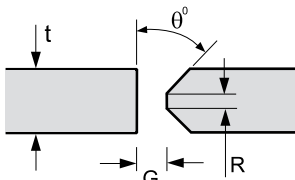**Figure 2 : Transition between different component dimensions**
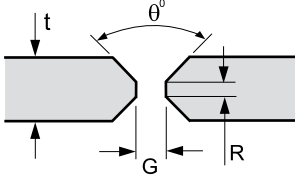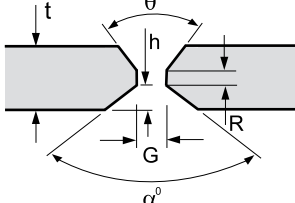
Table 2 : Typical butt weld plate edge preparation (manual welding) - See Note 1

Detail	Standard
Square butt	$t \leq 5$ mm $G = 3$ mm
Single bevel butt	$t > 5$ mm $G \leq 3$ mm $R \leq 3$ mm $50° \leq \theta \leq 70°$
Double bevel butt	$t > 19$ mm $G \leq 3$ mm $R \leq 3$ mm $50° \leq \theta \leq 70°$
Double vee butt, uniform bevels	$G \leq 3$ mm $R \leq 3$ mm $50° \leq \theta \leq 70°$
Double vee butt, non-uniform bevels	$G \leq 3$ mm $R \leq 3$ mm $6 \leq h \leq t/3$ mm $\theta = 50°$ $\alpha = 90°$
Note 1: Different plate edge preparation may be accepted or approved by the Society on the basis of an appropriate welding procedure specification.	

2.2.3 Butt welding edge preparation, root gap

Typical butt weld plate edge preparation for manual welding is specified in Tab 2 and Tab 3.

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 full penetration of the weld on its backing and an adequate connection to the stiffener as required.

See Fig 3.

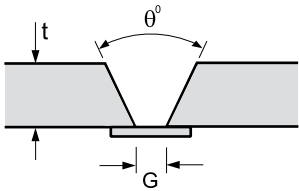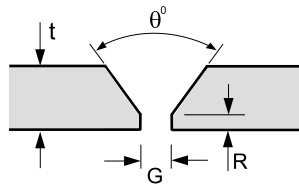**Figure 3 : Butt welding on permanent backing**
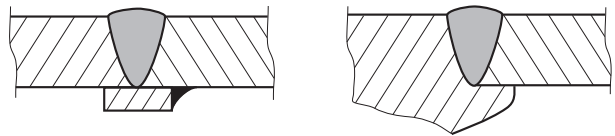
2.2.5 Section, bulbs and flat bars

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.

Table 3 : Typical butt weld plate edge preparation (manual welding) - See Note 1

Detail	Standard
Single vee butt, one side welding with backing strip (temporary or permanent)	$3 \le G \le 9$ mm $30° \le \theta \le 45°$
Single vee butt	$G \le 3$ mm $50° \le \theta \le 70°$ $R \le 3$ mm

Note 1: Different plate edge preparation may be accepted or approved by the Society on the basis of an appropriate welding procedure specification.

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.

Table 4 : 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

Hull area	Connection			w_F (1)	φ (2) (3)			p₁, in mm (see [2.3.6]) (3)
	of	to			CH	SC	ST	
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
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				
Fore peak (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 cm² (7)	0,25	1,8	1,8		CH/SC 130
			A ≥ 65 cm² (7)	See Tab 5				
After peak (6)	internal structures	each other		0,20				
	side ordinary stiffeners	side plating		0,20				
	floors	bottom and inner bottom plating		0,20				

Hull area	Connection			w_F (1)	φ (2) (3)			p_1, in mm (see [2.3.6]) (3)
	of	to			CH	SC	ST	
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
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 7, Sec 1, [6.3] or Ch 7, Sec 1, [6.4]				
		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 $w_F ≥ 0,35$, 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.

Table 5 : 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
	of	to			CH	SC	ST	(see [2.3.6]) (3)
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 ≥ 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.

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 75 mm

- for connections of stiffeners subject to wheeled loads

- where intermittent welding is not allowed, according to [2.3.4].

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

In water, fuel and cargo tanks, in the bottom area of fuel oil tanks and of spaces where condensed or sprayed water may accumulate and in hollow components (e.g. rudders) threat-ened by corrosion, only continuous or intermittent scallop welding shall be used.

Where the plating is liable to be subjected to locally concentrated loads (e.g. due to grounding or impacts when berthing) intermittent welding with scallops should not be used.

The spacing p and the length d, in mm, of an intermittent weld, shown in:

- Fig 4 for chain welding

- Fig 5 for scallop welding

- Fig 6 for staggered welding,

are to be such that:

$p / d ≤ φ$

where the coefficient φ is defined in Tab 4 and Tab 5 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 external pressure, tank pressure or concentrated loads.
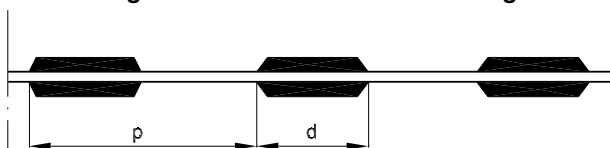
In addition, the following limitations are to be complied with:

* chain welding (see Fig 4):

  $d \geq 75$ mm

  $p - d \leq 200$ mm

Figure 4 : Intermittent chain welding

* scallop welding (see Fig 5):

  $d \geq 75$ mm

  $p - d \leq 25$ t   and $p - d \leq 150$ mm,

  where t is the lesser thickness of parts to be welded

  $v \leq 0,25$ b, without being greater than 75 mm

Figure 5 : Intermittent scallop welding
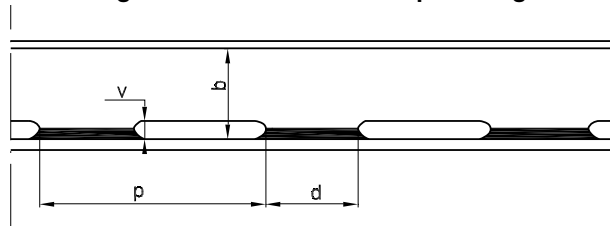
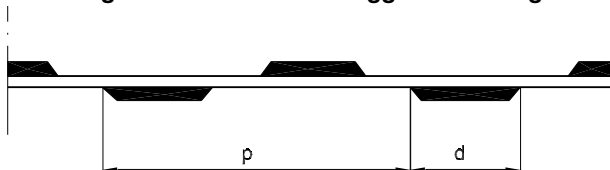* staggered welding (see Fig 6):

  $d \geq 75$ mm

  $p - 2 \, d \leq 300$ mm

  $p \leq 2 \, d$ for connections subjected to high alternate stresses.

Figure 6 : Intermittent staggered welding

2.3.5 Throat thickness of fillet weld T connections

Fillet welds shall normally be made on both sides, and exceptions to this rule (as in the case of closed box girders and predominant shear stresses parallel to the weld) are subject to approval in each individual case.

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 4 for the various hull structural connections; for connections of primary supporting members belonging to single skin structures and not mentioned in Tab 4, w_F is defined in Tab 5

t : Actual gross thickness, in mm, of the structural element which constitutes the web of the T connection

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.

Unless otherwise agreed (e.g. for the fully mechanised welding of smaller plate thicknesses in appropriate clamping jigs), the minimum fillet weld throat thickness shall be the greater of:

* $t_{T-min} = \sqrt{\dfrac{t_1 + t_2}{3}}$

and:

* 3,0 mm   for $t_1 \leq 6$ mm

  3,5 mm   for $t_1 > 6$ mm,

where:

t_1, t_2 : Thicknesses of connected plates with $t_1 < t_2$.

In the case of automatic or semi-automatic deep penetration weld, the throat thickness may be reduced according to [2.3.9]. Prior to start fabrication welding with deep penetration a production test has to be conducted to ensure the relevant weld quality. The kind of tests and the test scope has to be agreed with the Society.

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 6 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 4. The values of p_1 in Tab 4 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 4, 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 4, by:

* 10 mm for chain or scallop welding

* 20 mm for staggered welding.

Table 6 : 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

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 7 for continuous welding

- Fig 8 for intermittent scallop welding.

Figure 7 : Continuous fillet welding between cut-outs
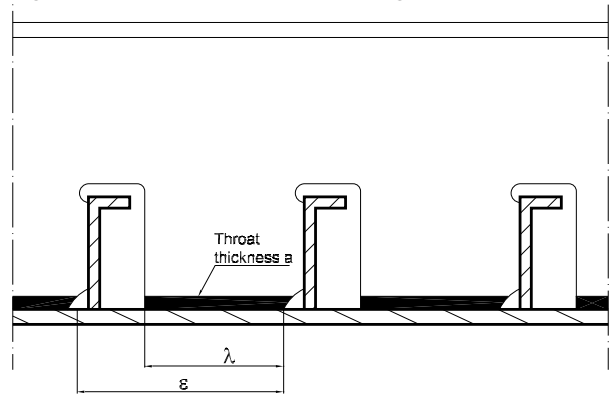
2.3.8 Throat thickness of welds connecting ordinary stiffeners with primary supporting members

The throat thickness of fillet welds connecting ordinary stiffeners and collar plates, if any, to the web of primary supporting members is to be not less than 0,35 t_W, where t_W is the web gross thickness, in mm.

Figure 8 : Intermittent scallop fillet welding between cut-outs
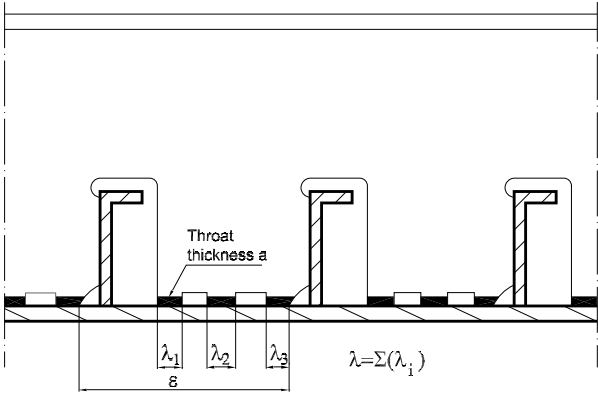
2.3.9 Throat thickness of deep penetration fillet welding

When fillet welding is carried out with automatic welding processes, the throat thickness required in [2.3.5] may be reduced up to 15%, depending on the penetration of the weld process. The evidence of the weld penetration is subject to a welding procedure test which has to be approved by the Society. 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.

Typical edge preparations are indicated in:

- for partial penetration welds: Fig 9 and Fig 10, 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 11 and Fig 12, 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.

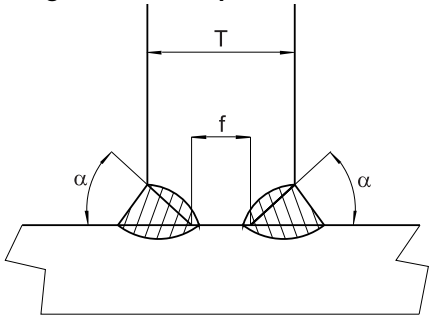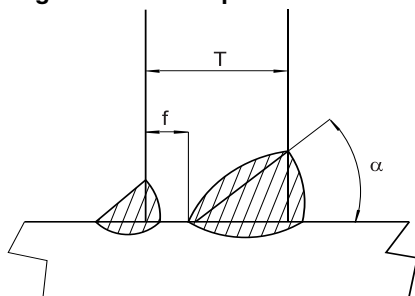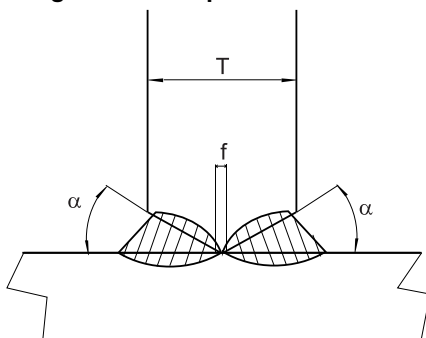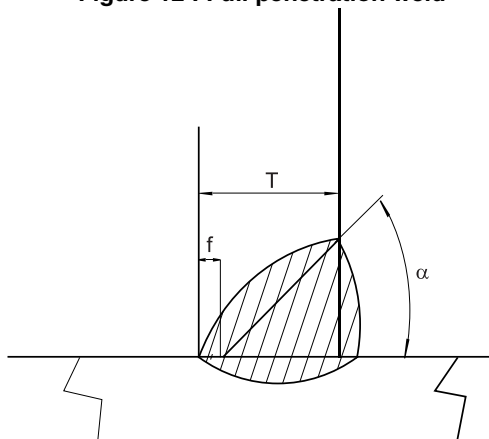**Figure 9 : Partial penetration weld**

Figure 10 : Partial penetration weld

Figure 11 : Full penetration weld

Figure 12 : 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.

Additional provisions may be required by the Society on a case by case basis.

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 Tab 7.

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 2, Sec 4, [3.1].

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 Tab 7.

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.
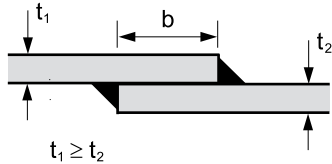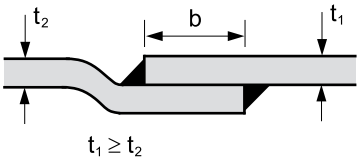
2.7 Plug welding
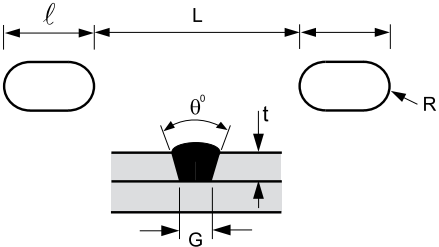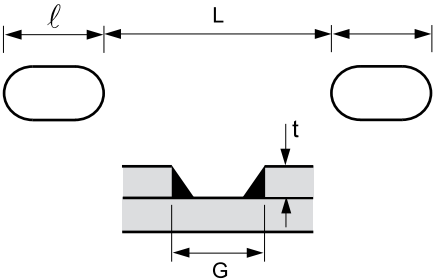
2.7.1 Plug welding may be adopted only when accepted by the Society on a case by case basis, according to specifically defined criteria. Typical details are given in Tab 7.

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.

Table 7 : Typical lap joint, plug and slot welding (manual welding)

Detail	Standard	Remark
Fillet weld in lap joint $b = 2 t_2 + 25$ mm (diagram) $t_1 \geq t_2$	$b = 2 t_2 + 25$ mm	location of lap joint to be approved by the Society
Fillet weld in joggled lap joint (diagram) $t_1 \geq t_2$	$b \geq 2 t_2 + 25$ mm	
Plug welding (diagram)	• $t \leq 12$ 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 (diagram)	• $t \leq 12$ 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	

3.2 Bilge keel connection

3.2.1 The intermediate flat, through which the bilge keel is connected to the shell according to Pt D, Ch 2, Sec 12, [2.1], 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:

$$t_T = \frac{\eta F}{n_W \ell_W \tau} 10^3$$

where:

F : Maximum force transmitted by the strut, in kN

η : Safety factor, to be taken equal to 2

n_W : 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/mm².

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/mm², 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.

3.8 Welds at the ends of structural members

3.8.1 As shown in Fig 13, the web at the end of intermittently welded girders or stiffeners is to be continuously welded to the plating or the flange plate, as applicable, over a distance at least equal to the depth h of the girder or stiffener, subject to a maximum of 300 mm and minimum of 75 mm.

Figure 13 : Welds at the ends of girders and stiffeners
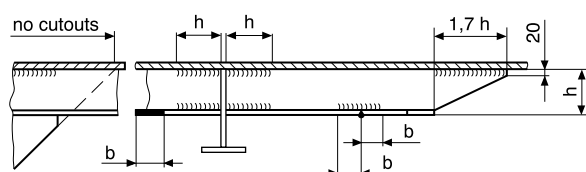
3.8.2 The areas of bracket plates should be continuously welded over a distance at least equal to the length of the bracket plate. Scallops are to be located only beyond a line imagined as an extension of the free edge of the bracket plate.

3.8.3 Wherever possible, the free ends of stiffeners shall abut against the transverse plating or the webs of sections and girders so as to avoid stress concentrations in the plating. Failing this, the ends of the stiffeners shall be cut off obliquely and shall be continuously welded over a distance of at least 1,7 h, subject to a maximum of 300 mm.

3.8.4 Where butt joints occur in flange plates, the flange shall be continuously welded to the web on both sides of the joint over a distance at least equal to the width of the flange.

3.9 Joints between section ends and plates

3.9.1 Welded joints uniting section ends and plates (e.g. at lower ends of frames) may be made in the same plane or lapped.

Where no design calculations have been carried out or stipulated for the welded connections, the joints may be made analogously to those shown in Fig 14.

If the thickness t_1 of the section web is greater than the thickness t of the plate to be connected, the length of the joint d must be increased in the ratio t_1 / t.

Figure 14 : Joints between section ends and plates
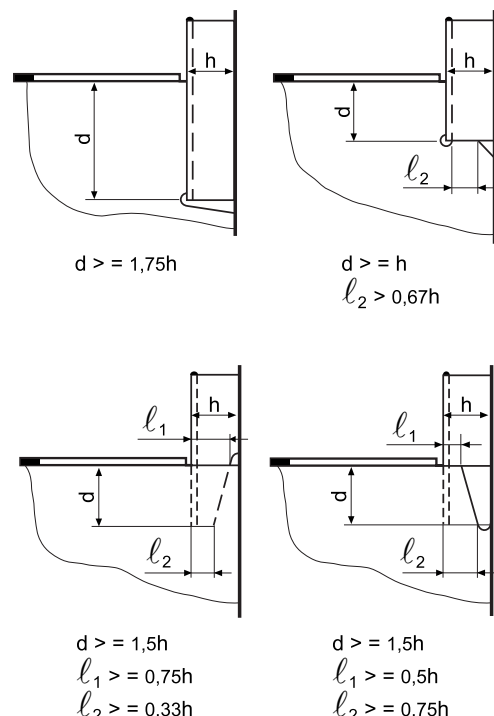
3.9.2 Where the joint lies in the plane of the plate, it may conveniently take the form of a single-bevel butt weld with fillet. Where the joint between the plate and the section end overlaps, the fillet weld must be continuous on both sides and must meet at the ends. The necessary a dimension is to be calculated in accordance with Ch 2, Sec 8, [3.7] but need not exceed 0,6 t. The fillet weld throat thickness shall not be less than the minimum specified in [2.3.5].

3.10 Welded shaft bracket joints

3.10.1 Unless cast in one piece and provided with integrally cast welding flanges (see Fig 15), strut barrel and struts are to be connected to each other and to the shell plating in the manner shown in Fig 16.

3.10.2 In the case of single-strut shaft brackets no welding may be performed on the arm at or close to the position of constraint. Such components must be provided with integrally forged or cast welding flanges in the manner shown in Fig 15.

3.11 Rudder coupling flanges

3.11.1 Unless forged or cast steel flanges with integrally forged or cast welding flanges are used, horizontal rudder coupling flanges are to be joined to the rudder body by plates of graduated thickness and full penetration single or double-bevel welds as prescribed in [2.4] (see Fig 17).

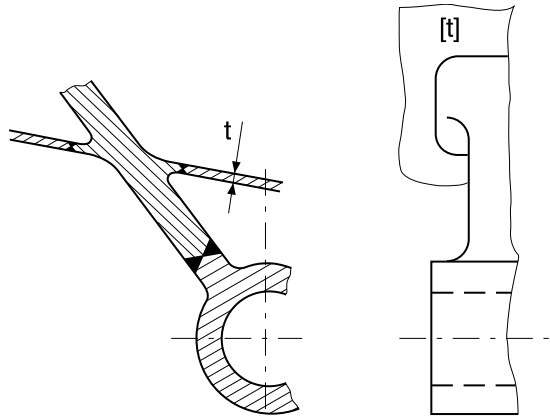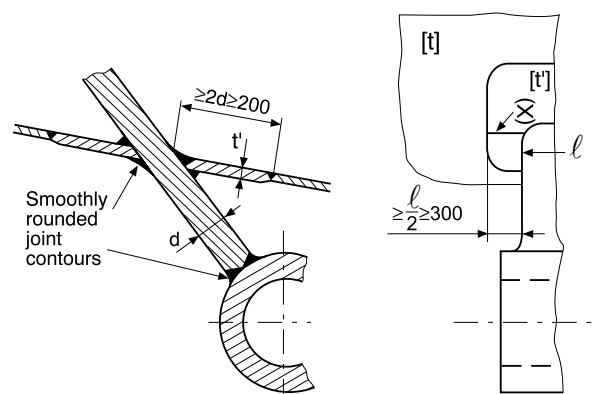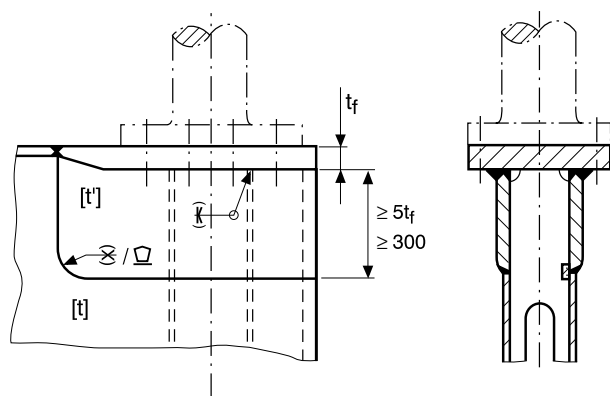**Figure 15 : Shaft bracket with integrally cast welding flanges**

Figure 16 : Shaft bracket without integrally cast welding flanges

t   : Shell plating thickness
$t' = d/3 + 5$ mm, where $d < 50$ mm
$t' = 3\, d^{0,5}$ mm, where $d \geq 50$ mm.

Figure 17 : Horizontal rudder coupling flanges

t   : Rudder plating thickness, in mm
t_f : Actual flange thickness, in mm
$t' = 1,25\, t$

3.11.2 Allowance shall be made for the reduced strength of the coupling flange in the thickness direction (see Note 1). It is recommended that a material with guaranteed properties in the thickness direction (Z grade) should be used for this purpose. In case of doubt, proof by calculation of the adequacy of the welded connection shall be produced.

Note 1: Special characteristics peculiar to the material such as the (lower) strength values of rolled material in the thickness direction or the softening of cold hardened aluminium as a result of welding are factors which have to be taken into account when designing and dimensioning welded joints.

3.12 Welded joints between rudder stock and rudder body

3.12.1 Where rudder stocks are welded into the rudder body, a thickened collar of the type shown in Fig 18 must be provided at the upper mounting (top edge of rudder body). The welded joint between the collar and the top rib is to take the form of a full penetration single or double-bevel weld in accordance with [2.4].

The transitions from the weld to the collar are to be free from notches. The collar radii shall be kept free from welds in every case.

Figure 18 : Rudder stock welded to rudder body
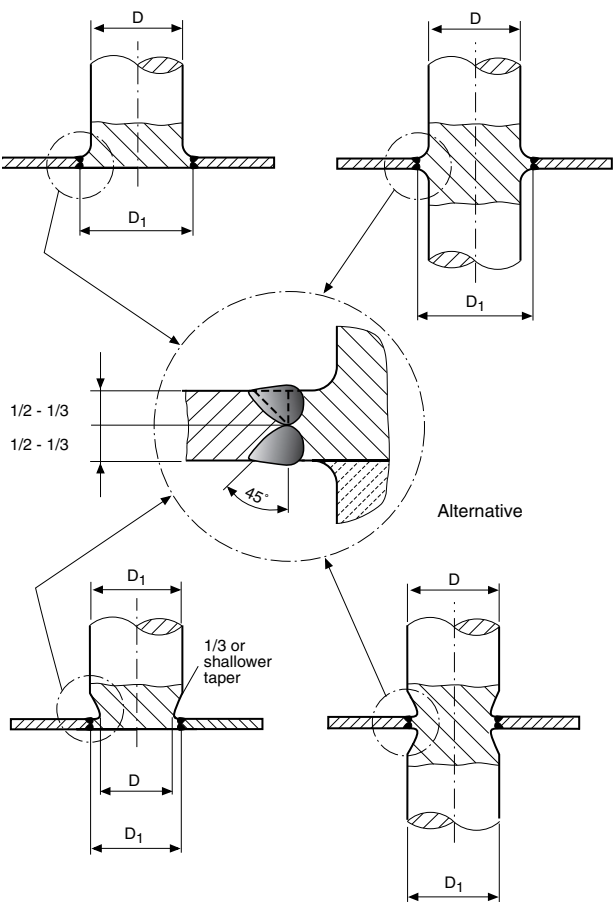
$D_1 = 1,1\, D$ without being less than $D + 20$ mm

$D_{1\,min} = D + 10$ mm (applies only to alternative solution),

where D is the rudder stock diameter, in mm.

3.13 Deck subjected to wheeled loads

3.13.1 Double continuous fillet welding is to be adopted for the connections of ordinary stiffeners with deck plating.

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.

Welding may only be performed on materials whose identity and weld ability under the given fabricating conditions can be unequivocally established by reference to markings, certificates, etc. Only welding consumables and auxiliary materials tested and approved according to the Society's Rules and of a quality grade standards recognized by the Society appropriate to the base material to be welded may be used.

4.2 Welding operations

4.2.1 Weather protection

The area in which welding work is performed (particularly outside) is to be sheltered from wind, damp and cold. Where gas-shielded arc welding is carried out, special attention is to be paid to ensuring adequate protection against draughts. When working in the open under unfavourable weather conditions it is advisable to dry welding edges by heating.

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.

Seam edges (groove faces) prepared by thermal cutting shall be finished by machining (e.g. grinding) if a detrimental effect on the welded joint as a result of the cutting operation cannot be ruled out. Welding edges of steel castings and forgings shall always be ground as a minimum requirement; roll scale or casting skin is to be removed.

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.

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.

When preparing and assembling components, care shall be taken to ensure compliance with the weld shapes and root openings (air gaps) specified in the manufacturing documents. With single and double bevel butt welds in particular, care shall be taken to make an adequate root opening to achieve sufficient root penetration. Moisture or dirt shall be carefully removed before welding.

4.2.5 Gap in fillet weld T connections

In fillet weld T connections, a gap g, as shown in Fig 19, may not be greater than 2 mm. In the case of a gap greater than 2 mm, the throat thickness shall be increased accordingly, or a single or double-bevel weld shall be made, subject to the consent of the Surveyor. Inserts and wires may not be used as fillers.

Figure 19 : Gap in fillet weld T connections
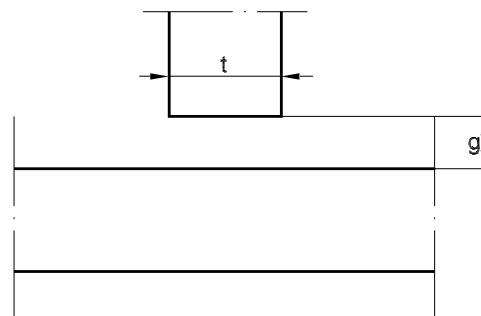
4.2.6 Plate misalignment in butt connections

The misalignment m, measured as shown in Fig 20, between plates with the same gross thickness t is to be less than 0,15 t, without being greater than 3 mm.

4.2.7 Misalignment in cruciform connections

The misalignment m in cruciform connections, measured on the median lines as shown in Fig 21, is to be less than:

- t /2, in general, where t is the gross thickness of the thinner abutting plate for steel grade A, B and D

- t /3, where t is the gross thickness of the thinner abutting plate for steel grade AH32 to DH40.

The Society may require lower misalignment to be adopted for cruciform connections subjected to high stresses.
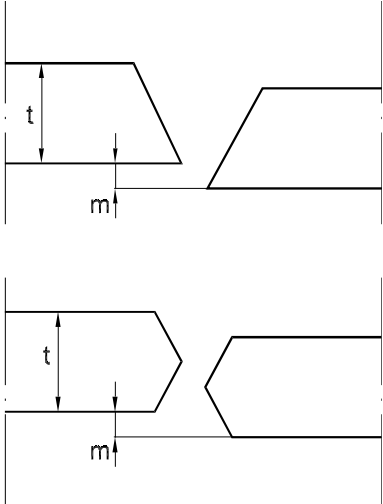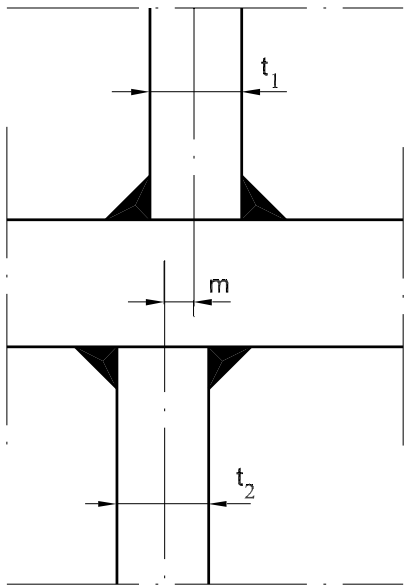
Figure 20 : Plate misalignment in butt connections

Figure 21 : Misalignment in cruciform connections

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.

Further specifications may be required by the Society on a case by case basis.

4.2.9 Preheating and interpass temperatures, welding in cold conditions

The need for and degree of preheating is determined by various factors, such as chemical composition, plate thickness, two or three-dimensional heat dissipation, ambient and work piece temperatures, or heat input during welding.

At low (subzero) temperatures, suitable measures shall be taken to ensure the satisfactory quality of the welds. Such measures include the shielding of components, large area preliminary warming and preheating, especially when welding with a relatively low heat input, e.g. when laying down thin fillet welds or welding thick-walled components. Wherever possible, no welding should be performed at temperatures below −10°C.

Normal-strength hull structural steels do not normally require preheating. In the case of corresponding thick-walled steel castings and forgings, gentle preheating to approximately 80 - 120°C is advisable. The necessary pre-heating temperatures of other materials (e.g. thick-walled higher tensile steels) have to comply with the applicable Society's Rules for Materials and Welding.

Suitable preheating, to be maintained during welding, and slow cooling may be required by the Society on a case by case basis.

The preheating and interpass temperatures are to be shown in the welding procedures which have to be approved by the Society.

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 vessel 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 vessel launching and with the vessel afloat.

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.

Further specifications may be required by the Society on a case by case basis.

Welding may be performed at the cold formed sections and adjacent areas of hull structural steels and comparable structural steels provided that the minimum bending radius is not less than those specified in Tab 8.

Table 8 : Minimum bending radius of welding of cold formed sections

Plate thickness t (mm)	Minimum inner bending radius r
up to 4	1,0 t
up to 8	1,5 t
up to 12	2,0 t
up to 24	3,0 t
over 24	5,0 t

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 Building Yard suitable to check compliance with the applicable requirements, reviewed/approved plans and standards.

6.1.2 The Building yard is to make available to the Surveyor a list of the manual welders and welding operators and their respective qualifications.

The Building yard's internal organisation is responsible for ensuring that welders and operators are not employed under improper conditions or beyond the limits of their respective qualifications and that welding procedures are adopted within the approved limits and under the appropriate operating conditions.

6.1.3 The Building yard is responsible for ensuring that the operating conditions, welding procedures and work schedule are in accordance with the applicable requirements, reviewed/approved plans and recognised good welding practice.

6.1.4 The Building yard 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 In case of non-destructive testing carried out by an independent company from the manufacturer or shipyard, such company has to comply with the requirements set out in NR669 "Recognition of non-destructive testing suppliers".

6.2.3 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.

6.2.4 The NDE acceptance criteria defined by the Building yard are to be submitted to the Society and should comply with a recognized standard which has been accepted by the Society.

6.2.5 All finished welds are to be subjected to visual testing by the Building yard's qualified personnel.

6.2.6 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.

6.2.7 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.

6.2.8 The Society may accept radiographic testing to be replaced by ultrasonic testing.

6.2.9 The Shipbuilder's NDE plan describing the extent, type and location of NDE is to be submitted to the Society for acceptance.

6.2.10 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.

6.2.11 Ultrasonic and magnetic particle testing may also be required by the Surveyor in specific cases to check the base material.

6.3 Radiographic inspection

6.3.1 A radiographic inspection 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. This inspection 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 Building Yard 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 Building Yard is to carry out random non-destructive testing of the welds (radiographic or ultrasonic inspection) 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 vessel 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 vessels 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, a radiographic inspection is to be taken, 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.

6.3.4 Outwards the midship area, a programme of radiographic inspection at random is to be set up by the Building Yard 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, masts
- 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 Building Yard is to determine the length of the defective part, then a set of inspection 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 Building Yard, the film showing the initial defect is to be submitted to the Surveyor together with the film taken after repair of the joint.

SECTION 3 PROTECTION OF HULL METALLIC STRUCTURES

Symbols

t   :   Thickness, in mm.

1 Protection by coating

1.1 General

1.1.1 It is the responsibility of the Building Yard and the Owner to choose the coating and have it applied in accordance with the manufacturer's requirements.

1.1.2 Information and recommendations aiming to fulfilling the requirements of this Section are developed in NI607 Guidelines for Corrosion Protection Applicable to Inland Navigation Vessels.

1.2 Structures to be protected

1.2.1 All areas endangered by corrosion are to be protected by a suitable corrosion protective coating.

1.2.2 All brackish 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.

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

1.2.4 Narrow spaces are generally to be filled by an efficient protective product, particularly at the ends of the vessel 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 Suitable protection measures shall take place, where the danger of galvanic corrosion exists.

2.1.2 Non-stainless steel is to be electrically insulated from stainless steel or from aluminium alloys.

2.1.3 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 Cathodic protection of tanks

3.1 General

3.1.1 Ballast water tanks or other internal spaces endangered by corrosion due to brackish or harbour water may be provided with cathodic protection.

Cathodic protection may be fitted in addition to the required corrosion protective coating, if any.

3.1.2 Uncoated stainless steels are not to be protected cathodically if they are suitable for withstanding the corrosion stress.

Coated stainless steels must be cathodically protected in the submerged zone.

3.1.3 Where fitted, cathodic protection shall comply with the manufacturer's instructions / recommendations.

4 Protection of bottom by ceiling

4.1 General

4.1.1 In single bottom vessels, ceiling is to be laid on the floors from side to side up to the upper bilge.

4.1.2 In double bottom vessels, 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 Pt D, Ch 1, Sec 2, [3.7.4] or Pt D, Ch 1, Sec 2, [4.6.4].

4.2 Arrangement

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

4.2.2 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.

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

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

4.2.5 In single bottom vessels, 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 vessels.

4.3 Scantling

4.3.1 The thickness of ceiling boards, in mm, is to be at least equal to the smaller of the following values:

- vessels intended to carry ore or concentrated loads, and not fitted with a double bottom:
  - $t = 50$
  - $t = 0,45 \, s \, (L + 160)$
- other vessels:
  - $t = 25$
  - $t = 0,3 \, s \, (L + 160)$

with:

s   :   Floor spacing, in m.

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

Under cargo hatchways, the thickness of ceiling is to be increased by 15 mm.

4.3.2 Where a side ceiling is provided, it is to be secured every 4 frame spacings to the side frames by an appropriate system. Its thickness may be taken equal to 0,7 times that of the bottom ceiling, without being less than 20 mm.

The batten spacing is not, as a rule, to exceed 0,2 m.

5 Protection of decks by wood sheathing

5.1 Deck not entirely plated

5.1.1 The wood used for sheathing is to be of good quality dry teak or pine, without sapwood or knots. The sheathing thickness, in mm, is not to be less than:

- teak: $t = (L + 55) / 3 \geq 40$
- pine: $t = (L + 100) / 3$

5.1.2 The width of the planks is not to exceed twice their thickness. Their butts are to be adequately shifted so that, if two butts occur in the same frame spacing, they are separated by at least three planks.

Planks are to be secured to every other frame by means of 12 mm bolts. On small vessels, galvanized steel screws are permitted.

5.1.3 Wooden decks are to be carefully caulked, to the satisfaction of the Surveyor.

5.2 Wood sheathed plate deck

5.2.1 As far as practicable, plate decks above passenger or crew cabins are to be sheathed with wood planks.

5.2.2 The plank thickness, in mm, is not to be less than 40 nor than:

- teak: $t = (L + 40) / 3$
- pine: $t = (L + 85) / 3$

SECTION 4   TESTING - METALLIC HULLS

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 vessels. These procedures may also be applied to verify the weathertightness of structures and onboard outfitting.

The tightness of all tanks and watertight boundaries of vessels during new construction and vessels relevant to major conversions or major repairs is to be confirmed by these test procedures prior to the delivery of the vessels.

Note 1: Major repair means a repair affecting structural integrity.

1.1.2 Testing procedures are to be carried out in accordance with the requirements [1.4.1] to [1.9.1].

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 **(3)** 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 vessel is afloat, provided the results of a leak test are confirmed to be satisfactory before the vessel 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 vessel, 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

d) tanks which do not form part of the watertight subdivision of the vessel, 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 **(3)** 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 inTab 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 river/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 appropriate safe precautions.

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.

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		leak and structural **(1)**	See Ch 3, Sec 4, Tab 15	
2	Double bottom voids		leak	See [1.6.4] to [1.6.6], as applicable	
3	Double side tanks		leak and structural **(1)**	See Ch 3, Sec 4, Tab 15	
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 **(1)**	The greater of: • top of the overflow • 1,0 m above top of tank **(2)**	
6	Cargo oil tanks		leak and structural **(1)**	See Ch 3, Sec 4, Tab 15	
7	Peak tanks		leak and structural **(1)**	See Ch 3, Sec 4, Tab 15	After peak to be tested after installation of stern tube
8	a)	Fore peak spaces with equipment	leak	See [1.6.3] to [1.6.6], as applicable	
	b)	Fore peak voids	leak	See [1.6.4] 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
9	Cofferdams		leak	See [1.6.4] to [1.6.6], as applicable	
10	a)	Watertight bulkheads	leak **(6)**	See [1.6.3] to [1.6.6], as applicable **(5)**	
	b)	Superstructure end bulkheads	leak	See [1.6.3] to [1.6.6], as applicable	
11	Watertight doors below freeboard or bulkhead deck		leak **(4) (5)**	See [1.6.3] to [1.6.6], as applicable	
12	Double plate rudder blades		leak	See [1.6.4] to [1.6.6], as applicable	
13	Shaft tunnels clear of deep tanks		leak **(3)**	See [1.6.3] to [1.6.6], as applicable	
14	Shell doors		leak **(3)**	See [1.6.3] to [1.6.6], as applicable	
15	Weathertight hatch covers and closing appliances		leak **(3) (5)**	See [1.6.3] to [1.6.6], as applicable	Hatch covers closed by tarpaulins and battens excluded
16	Chain lockers		leak and structural	Head of water up to top of chain pipe	
17	Ballast ducts		leak and structural **(1)**	The greater of: • ballast pump maximum pressure • setting of any pressure relief valve	
18	Fuel oil tanks		leak and structural **(1)**	See Ch 3, Sec 4, Tab 15	

(1) See [1.4.2], item b).
(2) The top of a tank is the deck forming the top of the tank, excluding any hatchways.
(3) Hose test may be also considered as a medium of the leak test. See [1.3.2].
(4) 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.
(5) 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. For watertight bulkheads (item 10 a)), alternatives to the hose test may be used only where the hose test is not practicable.
(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.

Table 3 : Additional test requirements for special service vessels/tanks

Item	Type of vessel/tank	Structure to be tested	Type of test	Test head or pressure	Remarks
1	Liquefied gas carriers	Integral tanks	leak and structural	See Ch 3, Sec 4, Tab 15	
		Independent pressure tanks	structural	See Pt C, Ch 1, Sec 3, [7.3]	
		Independent gravity tanks	See applicable NR467, Pt D, Ch 9, Sec 4	See applicable NR467, Pt D, Ch 9, Sec 4	
		Hull structure supporting membrane or semi-membrane tanks			
2	Edible liquid tanks	Independent tanks	leak and structural **(1)**	The greater of: • top of the overflow • 1,0 m above top of tank **(2)**	
3	Chemical carriers	Integral or independent cargo tanks	leak and structural **(1)**	See Ch 3, Sec 4, Tab 15	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], item b).					
(2) Top of tank is deck forming the top of the tank excluding any hatchways.					

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.

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 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 NDE show no significant defects.						